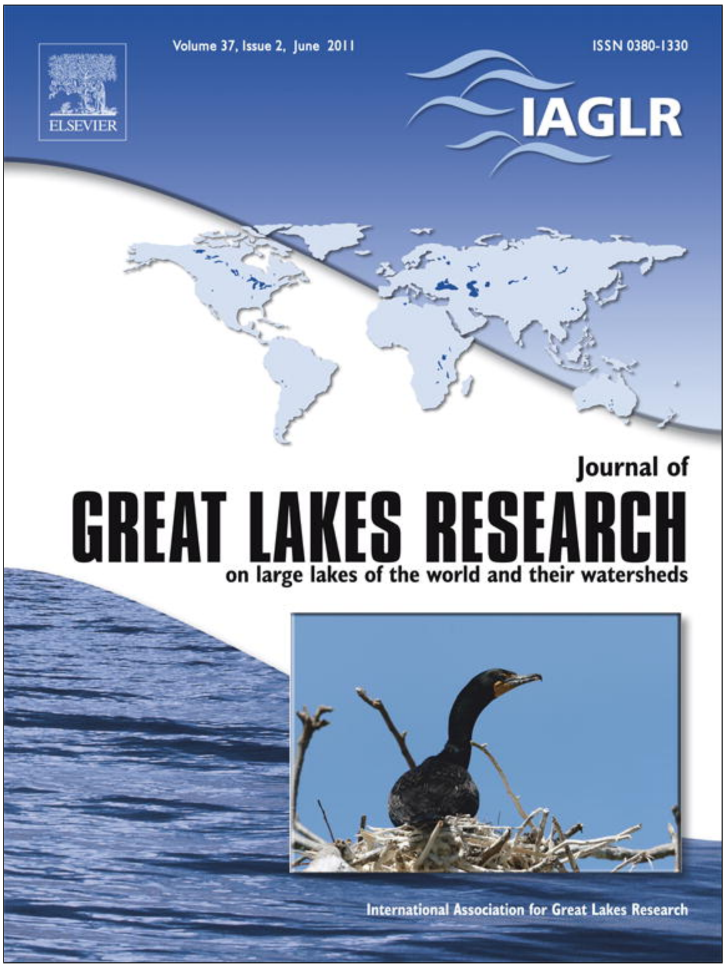
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Blending science and public policies for remediation of a degraded ecosystem: Jackfish Bay, north shore of Lake Superior, Ontario, Canada

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ABSTRACT

The Jackfish Bay Remedial Action Plan is the first of Lake Superior's Areas of Concern (AOCs) to consider recognition as an Area in Recovery (AiR). As a result of a high degree of complexity and uncertainty, ecosystem recovery in Jackfish Bay has been determined using a combination of regulatory policies and scientific evidence and extensive public and expert-based decision making. As a result, the conceptualization of the AiR status in Jackfish Bay has been developed with the adaptive management and the ecosystem approach, which provide the basic principles of assessing, monitoring, and managing the Area of Concern. To determine the status of beneficial use impairments caused by effluent from the Terrace Bay Pulp Inc., three public advisory committees—an academic panel of experts, a government technical review committee, and the Jackfish Bay Public Area in Recovery Review Committee (PARRC)—reviewed relevant scientific data and documents, including peer-reviewed publications, to assess changes in pollution levels in Jackfish Bay and improvements to aquatic, biotic, and benthic environments of the bay. The public decision-making process concluded with recommendations by the PARRC to develop a systematic monitoring program so that the ecosystem recovery process in the bay could be assessed on a continued basis, leading to its eventual delisting as an AOC. The entire process provides an example of blending science and public policies for remediation of a degraded ecosystem on the Great Lakes.

Introduction

Science and policy are often poles apart in their goals: the former aiming at 'verifiable objective facts,' the latter searching for competing options (Hannigan, 1995; Pielke, 2007). Yet, both of them converge at the 'boundary work' of regulatory science, which differs from conventional research science in its greater emphasis on knowledge synthesis than on the creation of new knowledge (Jasonoff, 1990; Guston, 2001; Doremus, 2007). The knowledge derived from the scientific understanding of the ecosystem, for example, is the basis for formulating sound environmental management policies. The process is essentially symbiotic. The scientists serving in an advisory capacity must acquire insight into other aspects of the problem under consideration in order to provide decision makers with the most essential information (Bolin, 1994; Poff et al., 2003). The regulatory agencies, on the other hand, seek scientific input into their decisions as a means of legitimization, which amounts to a negotiated and constructed model of scientific knowledge.

This blending of science and policy is essential in the remediation of degraded ecosystems within the Great Lakes Water Quality Agreement's Remedial Action Plan program (RAP) (Hartig et al., 1998; McCone et al., 2006). The RAP requires a comprehensive management that first includes an ecosystem approach to focus on those variables and their interactions that cause the greatest variation in system behavior and are amenable to modification through management intervention (Krantzberg, 2003). Secondly, an adaptive management approach is used to address the high degree of uncertainty involved in managing changes in complex ecosystems (Mitchell, 2010). The implementation of an adaptive ecosystem approach, therefore, integrates the linkages among institutional, administrative, and scientific ways of managing the most interactive components of the ecosystem (Slocombe, 1998; Pahl-Wostl, 2007).

The RAP process in Jackfish Bay provides an example of adaptive ecosystem management, since remediation of the BUIs in the Jackfish Bay Area of Concern (AOC) has been undertaken in successive stages, has involved a range of government and non-government stakeholders in determining the status of impairment, and involves a high degree of complexity and uncertainty in the assessment of ecosystem recovery.

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Using the case study of Jackfish Bay on the north shore of Lake Superior, the objectives of this article are three-fold:

- To describe how inputs from scientific and public advisory committees were blended with regulatory policies for remediation of the Jackfish Bay Area of Concern;
- To summarize the current status of recovery of its impaired ecosystem and the rationale for the designation of the Jackfish Bay AOC as an Area in Recovery; and
- To provide recommendations for monitoring further progress towards recovery, eventually leading to the delisting of Jackfish Bay as an AOC.

Nature of impairment in the Jackfish Bay Area of Concern

The Jackfish Bay AOC is located on the north shore of Lake Superior, approximately 250 km northeast of Thunder Bay, and is adjacent to the town of Terrace Bay (Fig. 1). With an area of 6.4 km^2, the bay has two inner arms, namely Moberly Bay on the west and Tunnel Bay on the east. The Blackbird Creek, with a drainage area of 62 km^2, flows into Moberly Bay. There are two small lakes on the Blackbird Creek basin: Lake A and Lake C (also called Moberly Lake), with original surface areas of 19 ha and 29 ha, respectively. The pollution problem in this AOC can be traced back to the operations of a pulp and paper mill in Terrace Bay, which was initially owned and operated by Kimberly Clark of Canada Ltd. and subsequently taken over by Terrace Bay Pulp Inc. The mill is located approximately 2 km upstream of Blackbird Creek, but its effluents are routed through a canal into the creek, eventually discharging into Moberly Bay. The effluents pass through Lakes A and C, which were initially maintained as shallow detention basins, but accumulation of solids has nearly filled in both lakes. The areas of impairment extend from a 14 km reach of Blackbird Creek and its drainage basin to the entire bay and its adjacent areas (Stewart et al., 2010).

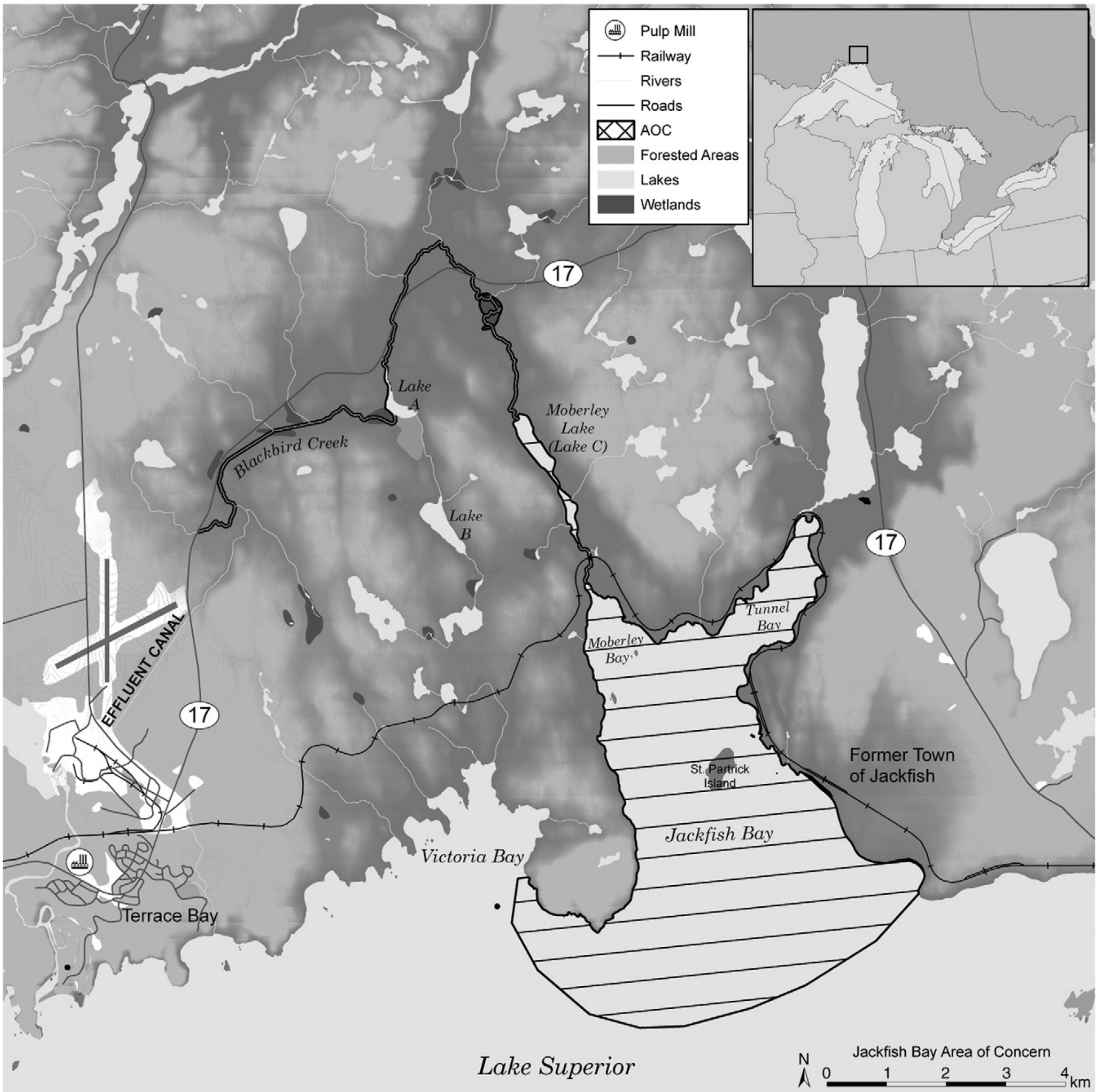

Fig. 1. Map showing the Jackfish Bay Area of Concern (Source: Garnett, 2011; adapted from Environment Canada).

Since its construction in 1947 and until 1999 when pulp and paper mills were required to switch from elemental chlorine bleaching to chlorine dioxide bleaching to reduce dioxins and furans from mill effluents (CEPA, 1999), operations of the Terrace Bay pulp mill were based on a chemical treatment method using, among other chemicals, sodium hydroxide and sodium sulfide for converting wood chips into pulp and paper (Stewart et al., 2010). During this period of operation, the resulting effluents from the original kraft process were responsible for polluting the bay extensively, affecting most of its leading water quality parameters such as turbidity, biological oxygen demand (BOD), pH levels (acidity/alkalinity), chloroform, phosphorous, dioxin, and furan (Jackfish Bay RAP Team, 1998). Ecological impairments of the bay and its adjacent areas included elevated levels of body burdens in fish and wildlife (e.g., dioxin, furan, mercury, PCBs, etc.) and degradation of its aesthetic and benthic (underwater) environments (Jackfish Bay RAP Team, 1998).

Toxicity tests following the introduction of the RAP program in the Jackfish Bay AOC in 1988 indicated nearly 100% fish mortality in surface waters up to 1.5 km from the creek discharge (Jackfish Bay RAP Team, 1991). Commercial and recreational uses of the bay, including fishing, boating and diving had been severely restricted. As a part of pollution abatement, in 1989, the pulp mill installed a secondary treatment system to reduce its toxic effluents. Although the secondary treatment was effective for reducing BOD and suspended solids significantly, Blackbird Creek had still been receiving substantial amounts of other pollutants, including persistent chlorinated organic compounds (Jackfish Bay RAP Team, 1991).

The benthic environment of the Jackfish Bay AOC had been severely impacted by the mill effluent between 1969 and 1987. This was evident from both sediments and benthic organisms. In the early stages of the Jackfish Bay Remedial Action Plan, sediments in Moberly Lake were found to be acutely toxic to benthic fauna (Jackfish Bay RAP Team, 1991). There was a corresponding increase in the density of pollution-tolerant species (e.g., tubificids) and a decrease in pollution intolerant species (e.g., *Pontoporea hoyi*). Opposum shrimp (*Mysis relicta*) and mussels (*Elliptio complanata*) from Moberly Bay had a dioxin and furan congener pattern similar to that of the mill effluent and showed body burdens of dioxins and furans in concentrations approximating those contained in the mill effluent (Sherman et al., 1990).

Methodology

The objectives of the study were to describe how inputs from scientific and public advisory committees were blended with regulatory policies for remediation of the Jackfish Bay Area of Concern; to summarize the current status of recovery of its impaired ecosystem and the rationale for the designation of the Jackfish Bay AOC as an Area in Recovery; and to provide recommendations for monitoring further progress towards recovery, eventually leading to the delisting of Jackfish Bay as an AOC. As a result, the methodology had to account for the complexity and uncertainty involved in understanding ecosystem change and the reality that large data gaps existed for most beneficial use impairments (BUIs). These objectives were achieved through the development of a negotiated model of scientific knowledge that sought input from a broad spectrum of stakeholders through scientific and public advisory committees (Hartig and Vallentyne, 1989; Hartig, 1990; Hartig et al., 1998; Mason, 2002).

The public advisory committee was selected first by contacting the existing members of the original committee in addition to inviting community stakeholders and the general public who represent the public and private sectors. The committee included representatives of the Terrace Bay Pulp Mill ($n=3$) municipal councilors ($n=2$), municipal planners ($n=2$), the tourism and education sector ($n=1$), and the general public ($n=3$). Representatives were selected by their respective organizations, or in the case of the public, were recruited or invited through media or open house. For public unable to commit to a year-long process, additional opportunities for broad public input were provided through a citizen-based advisory group (i.e., the Lake Superior Binational Forum) in the form of ongoing information updates on the internet and through the local media. A two-day forum for information dissemination and public discussion about ecosystem recovery was also provided to the general public in Terrace Bay.

Scientific/technical expertise was provided in two separate committees. An academic technical committee ($n=8$) was composed of local researchers or researchers with specific field experience in the area (aquatic entomology, sedimentology, molecular biology, aquatic toxicology, wetlands ecology, and fish ecology). A government technical team was composed of the current scientists/managers involved in beneficial use impairment (BUI) data collection and monitoring for the Jackfish Bay RAP ($n=12$). Following extensive literature reviews and government interviews to collect available data, BUI templates were developed to describe the nature of the impairment, an interpretation of monitoring data to date, options for future monitoring, and an interpretation of the status of each BUI. The development of the templates was coordinated by the RAP team, composed of an academic with expertise in environmental management, and program representatives from each of the government agencies involved in administering the RAP (Ontario Ministry of Environment and Ministry of Natural Resources, Environment Canada). These templates were first provided to the government technical committee to ensure that all available data was represented and interpreted by those who collected the data.

A decision-maker's workshop was a platform for government representatives to work in teams according to each BUI. Each team reviewed and interpreted the data in relation to delisting criteria and provided recommendations to better understand the status of BUIs through monitoring. The academic technical committee was then able to peer review the templates to provide a neutral interpretation of the certainty of the data and to provide additional recommendations based on the academic literature. Template development between the government representatives and the public advisory group then occurred through four iterations to initiate social learning and to select the data that best represented the collective understanding of ecosystem recovery. The BUI templates were compiled into a technical report that further allowed for discussion and three additional iterations of review by each committee (Stewart et al., 2010). These iterations ensured that additional information could be added to the review process as it was developed, and knowledge transfer between all advisory groups could be enhanced from the collective discovery of new information.

Results

Table 1 provides the status and delisting criteria for the seven beneficial use impairments that were monitored in the past decade in Jackfish Bay (Stewart et al., 2010). Delisting criteria were developed through collaborative workshops between the Jackfish Bay RAP team and the public advisory committee. These delisting criteria reflect a desire by managers, scientists, and the public to see the Jackfish Bay ecosystem reflect the same conditions that exist in regions of Lake Superior unaffected by impairments. Data collected by the Ontario Ministry of Environment showed that fish consumption restrictions and body burdens of fish in Jackfish Bay were less severe than reference conditions (Ministry of the Environment, 2009). However, data gaps restricted a statistical comparison of these BUIs in Jackfish Bay and its reference site location. The BUI was listed as requiring further assessment. A similar level of complexity and uncertainty was involved in determining the status of degraded fish populations and fish habitat. Lake trout populations have improved in western Lake Superior, and the 2001 provincial netting data demonstrated that trout populations were high in Jackfish Bay (Chong, 2004). There was also a decrease in the number of reproductive alterations observed in

Table 1
Status of beneficial use impairments in the Jackfish Bay Area of Concern.

Beneficial use impairments	Status stage 1 1991	Status stage 2 1998	Status AiR 2010	Delisting criteria
Fish consumption	RFA	Impaired	RFA	Not impaired when the fish consumption advisories in the AOC are no more restrictive than at an appropriate reference site on Lake Superior.
Body burdens of fish	Impaired	Impaired	RFA	Not impaired when a statistical analysis can demonstrate that fish body burdens in Jackfish Bay do not differ significantly from those in the open water reference area.
Degradation of fish populations	Impaired	Impaired	Impaired	Not impaired when monitoring data shows that the fish community at a population level does not differ significantly from a suitable Lake Superior reference site.
Fish tumors and other deformities	Impaired	Impaired	Not impaired	Not impaired when the fish tumor rates/deformities in Jackfish Bay do not statistically exceed rates in suitable reference sites in Lake Superior.
Loss of fish habitat	Impaired	Impaired	Impaired	Not impaired when the amount and quality of physical, chemical, and biological habitat required to achieve Lake Superior fish community objectives has been established.
Dynamics of benthic populations	Impaired	Impaired	Impaired	Not impaired when acute and chronic toxicity of sediment, and composition and densities of benthic communities are statistically indistinguishable from suitable reference sites.
Body burdens of benthic populations	Impaired	Impaired	Impaired	Not impaired when invertebrate tissue concentrations are below either (a) levels associated with adverse impacts or (b) invertebrate tissue concentrations at reference sites.

(RFA, requires further assessment; AiR, Area in Recovery).

Jackfish Bay (Bowron, 2008). However, data on the health of other fish species was limited, and as a result, this BUI remains listed as impaired. The BUIs pertaining to benthic populations and body burdens were clearly the strongest data and methodology for comparing an individual BUI against the delisting criteria. Both of these BUIs were still impaired according to the delisting criteria; however, the data revealed to the committees that the impairment has decreased in severity since the beginning of the RAP, ending a long period of incremental degradation that was documented since 1975. Only the fish tumors BUI had sufficient data to conclude that a decrease in fish tumors had occurred in Jackfish Bay.

This overview was provided to demonstrate why the committees were forced to adapt decision making and incorporate a high degree of uncertainty when comparing impairments to specific delisting criteria. The committees ultimately chose a broader ecosystem approach to determine if Jackfish Bay is in a state of recovery. The committees agreed that visible and measurable signs of ecosystem recovery had occurred pertaining to water quality, benthic health, and fish health. These improvements could be correlated with the time line of regulatory improvements that had occurred since the initiation of the RAP and provided a rationale for determining that Jackfish Bay was experiencing recovery.

Water quality

The effluents discharged into the Jackfish Bay AOC from the Terrace Bay mill and the elimination or reduction of dioxins and furans constituted the primary RAP strategy for remediation of the degraded ecosystem (Jackfish Bay RAP Team, 1998). This was achieved with the Ontario discharge limits for dioxins and furans that were established in the early 1990s at average rates of 1.5–2.5 kg of adsorbable organic halogens (AOX) per ton of pulp, which were comparable to those of Sweden and other European countries (Murray, 1992). Specific discharge limits for AOX and other parameters were set by the Municipal/Industrial Strategy for Abatement (MISA) for each of the kraft pulp mills in Ontario, using Ontario Regulation 760/93: Effluent Monitoring and Effluent Limits—Pulp and Paper Sector (MISA, 2008). The monthly average limits for AOX from the Terrace Bay pulp mill effluent were set at about 0.8 kg AOX per ton of pulp with an approved pulp production of 1372 metric ton per day (MISA, 2008). The ability to produce elemental chlorine-free pulp has significantly reduced toxicity of the mill's effluents. This is evident from the 2008 data on actual discharge rates for the parameters listed in Table 2. The AOX (phase 3) substances have been effectively eliminated. Among other substances, chloroform, toluene, and phenol have been reduced by 97–100% below their monthly average upper limits. Phosphorus has been reduced by 79%, whereas suspended solids and BOD have been reduced by 44% and 28%, respectively. Thus, by the end of 2009 the Terrace Bay mill effluent loads have not only met the MISA upper limits for all of the parameters listed in Table 2 but have exceeded the required reductions by significant margins.

The mill's effluents also met the limits for all other parameters with the exception of color, alkalinity, and conductivity, which experienced no change, and total nitrogen which experienced a decline in quality. A distinct brown color was a particular problem in Moberly Lake (Burniston, Environment Canada, personal communication, May 2010). Dissolved oxygen levels were high in certain spots of Blackbird Creek, such as immediately below the outfall of the mill effluents. However, other sites in the Blackbird Creek system and in Jackfish Bay met the MISA reduction limits. A key recommendation for monitoring water quality in the future is the selection of ecologically relevant control sites. Tunnel Bay seems to be such a site, but this site has not been used in the past as it lies within the boundaries of the AOC. However, this site is sufficiently separated from Moberly Bay by a protruding land mass and, consequently, it receives less than 1% of the total mill effluents. Further, its depth and vegetation composition are typical of the shoreline beyond the AOC and may provide the most suitable reference in comparison to reference sites that have been used outside of the AOC.

Benthic health

The baseline data from sediment core samples by Sherman and McMillan (1988), Sherman et al. (1990), and Jardine (1990) indicated that the maximum concentration of dioxins and furans occurred in Moberly Bay, immediately below the effluent outfall from the pulp mill, but the concentrations in other parts of the bay decreased

Table 2
Decline in concentrations of selected parameters from the Terrace Bay pulp mill effluents, 1986–2008.

Source: MISA (Municipal/Industrial Strategy for Abatement), 2008. The Municipal/Industrial Strategy for Abatement. Ontario Ministry of the Environment, Toronto, ON for upper limits; actual values (2008) collected by the RAP team from MOEE and the Terrace Bay pulp mill.

Parameter	Monthly average upper limit (kg/day)	Actual value (2008) (kg/day)	Percent decline (1986–2008)
BOD	6960	5000	28
Phosphorus	233	50	79
Suspended solids	10,800	6000	44
Chloroform	2.58	0	100
Toluene	0.295	0.01	97
Phenol	0.567	0.018	97
AOX phase 3	1100	Close to 0	100

significantly. This spatial pattern of organochlorine contamination of bay sediments is delineated by a water-sediment plume from the mouth of Blackbird Creek, which flows along the western side of the bay. The plume is deflected in that direction by the prevailing east–west circulation of water in the bay. Consequently, the plume is diluted from about 5:1 within 500 m of the mouth of Blackbird Creek to about 20:1 at a distance of 3.5 km into Jackfish Bay, reaching a dilution level of 200:1 outside the bay (Farara, 2007). A follow-up survey conducted about a decade after the first survey indicated persistence of a similar spatial pattern of organochlorine contamination of bay sediments (Sibley et al., 2000). Mean concentrations of other organic contaminants in bay sediments followed a similar spatial pattern of deposition. Concentrations of grease and oil were highest in Moberly Bay (7600 mg/L) and decreased substantially in Jackfish Bay (1600 mg/L) and Tunnel Bay (600 mg/L) (Milani and Grapentine, 2007).

Following the installation of the secondary treatment at the mill (1989), both density and diversity of benthic organisms have improved (Beak Consultants, 1988). Most of the samples from other parts of the bay, including Tunnel Bay, were representative of mesotrophic and oligotrophic ecosystems with minimum degradation of benthos. Despite such improvement in the overall benthic ecosystem of Jackfish Bay, the most recent assessment indicated that the levels of dioxins and furans in some of the sediment samples from Moberly Bay continued to exceed the no-effect level of the Provincial Sediment Quality Guidelines (PSQG) and continue to be listed as impaired (Milani and Grapentine, 2007). Benthic impairment was evident in 2003 and 2008 (Milani and Grapentine, 2007; Milani, 2009), most notably in Moberly Bay, with the presence of pollution-tolerant benthic communities and sediment toxicity.

The recent history related to effluent from the Terrace Bay mill has created differences in habitat. The communities at the Tunnel Bay and Moberly Bay locations may differ greatly from each other because of the organic enrichment and deposition of contaminants in Moberly Bay by mill effluent which creates significant differences. Even if all effluent stopped, there are still historical sources of contaminants in the AOC that should be investigated. For example, the historic contamination of Blackbird Creek sediments could be mobilized from high flows during heavy rains or spring runoff and should be the focus of continued study and monitoring.

Fish health

Because of the diversity of fish species in and around the Jackfish Bay AOC, the stage 1 method of calculating biotic indices of sample species caught in Moberly Bay vs. Tunnel Bay was not replicated, and data collection during the RAP was not sufficient to assess fish populations. Fish tumors and other deformities, however, appeared to have decreased. White suckers were collected in Jackfish Bay in 2006 using electrofishing, gill nets, and trap and hoop nets. Neoplasms were rare and there was a smaller percentage of fish with neoplasm than at the beginning of the RAP. Liver neoplasms declined over 7% in Jackfish Bay and were not different from the incidence rate of neoplasms in other reference site locations (Baumann, Ohio State University, May 2010). The fish consumption restrictions published in the Ministry of the Environment's 2009 Guide to Eating Sport Fish further show that Jackfish advisories are less stringent than advisories in the open water reference site. However, the advisories for Jackfish Bay are based on the latest measurements while data from the reference were collected 5 years earlier. Although limited samples pertaining to body burdens of fish exist, mercury levels and PCB concentrations in lake trout and whitefish appear to have declined in Jackfish Bay since the establishment of the RAP.

Recently, more innovative methods of assessing fish health have been used by Bowron (2008), who has measured plasma steroid concentrations as an indicator of egg production (fecundity) in females and gonadal development and secondary sex characteristics in males. Long-term studies on target fish species in Jackfish Bay show that exposure to mill effluent causes reproduction alteration (e.g., delayed sexual maturity, reduced gonad size); however, there has been a gradual improvement in these conditions since the mid-1990s following installation of secondary treatment and changes in the pulping process at the Terrace Bay mill. Such reproduction studies have potentials for complementing traditional toxicology studies. Such experimental studies may be too expensive for routine monitoring in the AOC, but they provide a relatively rapid assessment of the fish health.

Discussion

The case study reflected the recent literature in the research on Great Lakes Areas of Concern that emphasizes the impossibility of delisting BUIs based on inconsistent and sometimes non-existent monitoring data and the need to compare BUI data to specific delisting criteria (Coronado et al., 2006; Pitelka-Opfer et al., 2006). As a result, RAP partners have only been able to provide qualitative descriptions about ecosystem restoration and the relationship between BUIs and their respective delisting targets (George and Boyd, 2007). However, this did not deter the Jackfish Bay RAP partners from moving towards a decision to define the status of Jackfish Bay and develop monitoring actions that combine science and policy techniques through a meaningful review of the process (Krantzberg, 2004). The ability for committees to deviate from pre-determined goals set by the RAP and focus the existing data on more realistic policy goals of determining if ecosystem recovery is occurring demonstrates the adaptive flexibility required when attempting to define the limits to restoration (Ehrenfeld, 2000).

The committees agreed that existing data collected in Jackfish Bay showed signs of recovery. This consensus was reached through the integration of a precautionary and a risk-based approach to decision making (Graham, 2008) that relied on degrees of scientific certainty (i.e., high medium and low) to validate the signs of recovery in relation to regulatory improvements (water quality, benthic health, and fish health). High certainty was ascribed to evidence drawn from primary sources of data that supported the delisting of a BUI. For example, a number of studies confirmed that the incidences of fish tumors and other deformities in white suckers caught in Jackfish Bay have declined below reference conditions since the establishment of the RAP. Medium certainty was ascribed from evidence drawn from ecosystem improvements that correlate with the implementation of regulatory improvements at the beginning of the RAP. Water quality parameters had improved since the implementation of the Municipal/Industrial Strategy for Abatement and this was indicative of sufficient remediation action. Low certainty was ascribed to evidence from data that showed signs of improvement but required further assessment to understand if improvements occurred in relation to regulatory changes. The current fish consumption restrictions were comparable to reference sites outside of the Jackfish Bay AOC. However, further data and analyses are needed to correlate dioxin and furan concentrations in fish tissue with dioxin and furans originating from the operation of the Terrace Bay pulp mill. Likewise, signs of improvement in benthic health have been detected, but the benthos still exhibit acute and chronic toxicity and high invertebrate tissue concentrations.

The methodological approach of integrating scientific and regulatory information through an iterative process of advisory group consultations reflected an adaptive approach to decision making. The approach provided a rationale for changing the status of the Jackfish Bay AOC to an Area in Recovery based on an interpretation of both qualitative and quantitative assessments of ecosystem recovery. The iterative phases of the advisory group meetings and interactions through the use of BUI templates allowed for social learning to inform a process of consensus building. New information that emerged during the consultation process was immediately incorporated into the decision-making process, and new research was collected at the request of committees to provide the information needed to form a consensus (Folke et al., 2005).

This research was successful at developing consensus among committees with varying degrees of ascribed and non-ascribed knowledge (Mason, 2002). It allowed the committees to agree on recommendations to improve data collection and decision making through a negotiated understanding of Area in Recovery status:

- Establish long term funding and program commitment to monitoring BUIs;
- Reduce the data gaps and standardize data collection to better reflect the status of beneficial use impairments in relation to delisting criteria;
- Add to existing baselines to effectively assess the level of natural recovery over time;
- Understand ecosystem recovery during periods of mill operation vs. mill closure; and
- Examine the severity of historic contamination in Blackbird Creek, which is highly understudied.

The public committee agreed that it was important for monitoring results to provide an understanding of the rate of recovery and how it is affected by mill upgrades to effluent quality vs. prolonged periods of mill shutdown when effluent does not enter Blackbird Creek. Blackbird Creek was highly understudied and there is a need to better characterize the effects of historic contaminants and the potential for them to affect the Jackfish Bay ecosystem. Addressing other sources of contamination is critical to ensure that an ecosystem-based approach is applied to the study of ecosystem recovery. This could be achieved by applying the Canada Ontario Agreement's sediment management decision-making framework to the Blackbird Creek system. Since Blackbird Creek has been viewed as an effluent canal in the past, this recommendation would see the adoption of the ecosystem approach to ensure that the natural and anthropogenic influences on the Blackbird Creek system are assessed and considered in relation to recovery of Jackfish Bay.

The nature of these recommendations reflects adaptive management because they go beyond a trial and error approach to managing and monitoring through experimentation and casual observation. The recommendations incorporate a comparative assessment of policy outcomes and regulation improvements in relation to the traditional scientific data (Arvai et al., 2006). By linking science and policy in this way, the contributions of adaptive management include knowledge transfer over knowledge creation, social learning about complexity and uncertainty, and an enhanced decision-making capacity of policy makers who are faced with high levels of complexity and uncertainty (Ludwig, 2001). As a result, policy makers must learn to fail and learn from their failures (Gunderson and Holling, 2002) to provide a clear focus on effective actions for ecosystem recovery.

It was important to the Public Area in Recovery Review Committee that the use of the term Jackfish Bay Area in Recovery was reflective of a shift to active management in Jackfish Bay and a renewed perspective on what 'monitoring on an ongoing basis' truly meant. However, the key limitations throughout the research related to the lack of understanding by all participants of exactly what the Area in Recovery status would mean to the health of Jackfish Bay in comparison to the previous status as an Area of Concern and the process of government involvement over the long term. The Remedial Action Plan could advance from the development of a clear set of guidelines and benchmarks for determining an Area in Recovery and provide the corresponding rationale and resources for a renewed phase of management to begin. Details and timelines of monitoring efforts during Area in Recovery status should be outlined to avoid long durations of inactivity and to provide the community with a long-term involvement strategy. Ongoing community participation and education would result to better understand the process and techniques used to monitor ecosystem changes and determine ecosystem status.

Summary

The first objective of the research was to describe how inputs from scientific and public advisory committees were blended with regulatory policies for remediation of the Jackfish Bay Area of Concern. Consensus was developed through a series of iterative templates that were used in a progression of individual and combined advisory group workshops. Academic, government, and public advisory groups reviewed and compared scientific data and regulatory information and agreed that signs of recovery are evident since the designation of the Jackfish Bay AOC. The second objective was to summarize the current status of recovery of its impaired ecosystem and the rationale for the designation of Jackfish Bay as an Area in Recovery. There was a general lack of clear and consistent evidence to support a complete assessment of the status of all BUIs against their respective delisting criteria; however, there was evidence related to larger ecosystem variables, such as water quality, benthic health, and fish health, that the committees adopted to support the designation of the Jackfish Bay Area in Recovery. The final objective was to provide recommendations for monitoring further progress towards recovery, eventually leading to the delisting of Jackfish Bay as an AOC. It was clear that ongoing monitoring and scientific study will be required to determine the level of recovery that has occurred, the impact of mill operations and lakewide and nonpoint pollution effects on recovery, and if the beneficial use impairments that define the Jackfish Bay AOC have met their individual delisting targets.

The Advisory groups concluded that since the Jackfish Bay AOC could be among one of the first Great Lakes AOCs to receive recovery status, it may be viewed by others as a model for designation of recovery status across the Great Lakes. As such, it was decided that standards should be high and leadership in management was paramount. Advisory group members also agreed that the recovery process should be an active one, rather than a passive one as it had been in the past. This could be achieved by ensuring a committed and robust monitoring program that adapts to a continuum based on phases of recovery, research, and remediation attention to the Blackbird Creek system and on community participation during the lifetime of the AiR status. These recommendations reflect an ecosystem approach to the RAP by focusing on variables that may cause the greatest variation in system behavior but can be modified through management intervention.

An ecosystem approach and an adaptive management approach were successful in allowing the committees to make progressive decisions in the face of scientific uncertainty. On the one hand, public and scientific committee members had to learn about other aspects of the impairments in order to select the most essential information for a decision to be made. On the other hand, management agencies gained a socially constructed and negotiated model of scientific knowledge that supported the goals of the remedial action plan process.

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