

Community-based monitoring and the science of water quality

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Abstract Reductions in funding for hydrological monitoring by government agencies, the recognition of the need to involve communities and stakeholders in the planning and delivery of sustainability, increasing mistrust of the government's care of the environment and the continued rise in environmental consciousness are all factors which have led to the proliferation of community based monitoring (CBM) initiatives. CBM is a process in which concerned citizens, government agencies, industry, academia, community groups and local institutions collaborate to monitor, track, and respond to issues of common community concern. The UNEP has stated that public participation is an essential component of sustainability, and it has been argued that the integration of community-based monitoring into resource management is one of the most significant developments in this area since the environmental movement itself. The Predictions in Ungauged Basins (PUB) Science Plan, among other purposes, intends to "actively promote capacity building activities in the development of appropriate scientific knowledge and technology to areas and communities where it is needed". This paper draws on the expertise and experience of working on CBM initiatives through Environment Canada's Ecological Monitoring and Assessment Network (EMAN) as well as the Community-Based Environmental Monitoring Network in Nova Scotia. Examples are drawn from Nova Scotia, where community watershed groups have undertaken water quality monitoring activities in more than 10 of Nova Scotia's watersheds. Since the early 1990s they have gathered in excess of 55 monitoring-years of water quality data at over 200 sampling sites. CBM initiatives, in close collaboration with government and academia, following standardized monitoring protocols with careful quality assurance and quality control programmes, have the ability to address otherwise uncertain changes as a result of land-use alterations and climate change. Science alone is not well equipped to model and understand future changes and scientists are even less equipped to reach decision-makers. The community serves a role and a purpose here.

Key words community; environment; monitoring; public participation; volunteers; sustainability; watersheds; water quality

INTRODUCTION

Public participation has become an increasingly important part of environmental management, with the United Nations Environment Programme stressing public participation as an essential component of sustainability (Au *et al.*, 2000). Ecological monitoring is an important component of sustainable development. Unfortunately, the reality in many areas of Canada is that, due to government budget cuts, there are large gaps in monitoring activities. Community groups have been encouraged, and have

attempted, to fill this gap. Reductions in funding for hydrological monitoring by government agencies, the recognition of the need to involve communities and stakeholders in the planning and delivery of sustainability, increasing mistrust of the government's care of the environment and the continued rise in environmental consciousness are all factors which have led to the proliferation of community-based monitoring (CBM) initiatives.

With the recognition that into the 21st century, changes in climate, land use and population, among other factors, will affect freshwater quality, there is a need for the valuable information and data that can be collected by citizens and community organizations. The IAHS has designated 2003–2012 to be the decade on Predictions in Ungauged Basins (PUB). According to the PUB Science Plan, one goal intends to “*actively promote capacity building activities in the development of appropriate scientific knowledge and technology to areas and communities where is it needed*”. (PUB, 2003, p.4). An ungauged basin is “*...one with inadequate records (in terms of both data quantity and quality) of hydrological observations to enable computation of hydrological variables of interest (both water quantity and quality) at the appropriate spatial and temporal scales, and to the accuracy acceptable for practical applications*” (PUB, 2003 p.5). According to the World Water Assessment Project (a United Nations initiative), an “*acceptance of the need for a more people oriented and integrated approach to water management and development has gradually evolved*” (WWAP, 2006). Among the specific programme objectives, one intends to “*Develop mechanisms for the transfer of knowledge and expertise to national governments, decision makers at all levels from local to international, user organizations, academic institutions and the general public,... in order to facilitate and improve freshwater assessment*” (WWAP, 2006). This evolution of the concept of citizen engagement and community participation has made significant progress. Many challenges remain, but the significance of the participation of stewardship groups in data collection, particularly in ungauged basins, will be exemplified throughout this paper.

COMMUNITY-BASED MONITORING

Within this paper, community-based monitoring (CBM) is understood to mean “*a process where concerned citizens, government agencies, industry, academia, community groups and local institutions collaborate to monitor, track and respond to issues of common community concern*” (Whitelaw *et al.*, 2003, p.410). CBM seeks to give the community the lead in both collecting data and in using the information generated to promote informed decision-making. It thus promotes sustainability at a community and at a wider level. Community-based monitoring can provide a number of benefits and opportunities, for both government and the community (Whitelaw *et al.*, 2003). CBM can benefit government through the extension of their monitoring networks, cost savings, promotion of public participation to achieve government goals, and providing an early warning system of ecological changes. Non-governmental organisations and communities can benefit from CBM through the engagement of individuals in local environmental issues, the development of social capital and the opportunity to have input into the management of natural resources. It has been argued that the integration of community-based monitoring into resource management is one of the most significant developments in this area since the environmental movement itself (Kenney, 1999).

Community-based monitoring initiatives emerged in Nova Scotia, much like they did in other parts of Canada. This rise can in part be attributed to an increasing mistrust of the government's care of the environment (Au *et al.*, 2000), coupled with the continued rise in environmental consciousness (Chicoine, 1996). In the absence of conservation authorities and government agencies mandated with the monitoring and protection of watersheds, there are numerous stewardship groups undertaking baseline monitoring activities. Stewardship groups are active in more than 10 of Nova Scotia's watersheds and since the early 1990s have gathered in excess of 55 monitoring-years of water quality data at over 200 sampling sites. CBM in Nova Scotia, as in many parts of the country, is undertaken in lakes, streams and rivers, estuaries, and nearshore marine settings. These watershed groups are active in monitoring a range of water quality parameters (Conrad, 2006a) including:

- biological (e.g. benthic invertebrates, faecal coliform bacteria);
- physical (e.g. total suspended solids, temperature); and
- chemical (e.g. dissolved oxygen, nitrates and pH).

The extent to which these stewardship groups are capable of linking their monitoring initiatives to the relevant decision-makers or those involved in watershed *management*, however, is extremely limited (Sharpe & Conrad, 2006).

It can be argued that many groups that have benefited from Environment Canada's Atlantic Coastal Action Plan have had a greater degree of success with influencing decision-makers and yet the specific examples of influence in Nova Scotia are more uncommon than not.

This scenario is not unique to Nova Scotia. The majority of CBM groups tend to focus on monitoring *tasks* as opposed to undertaking analyses of what the *processes* to meaningfully integrate their tasks into the decision-making structure might be. In this context, a task would be a particular monitoring protocol (e.g. terrestrial, aquatic or marine) or a problem that is being addressed (e.g. sedimentation), while the process would be how the relevant groups and individuals work together in the effort to protect, enhance, preserve or restore some environmental component. For collaboration to be effective, there should not be over-emphasis on tasks and avoidance of process, which has been the traditional tendency in CBM. It has been advocated that since task and process are linked in this way, that progress of both should be measured (Allen, 2005). This is currently not the case in Nova Scotia, nor in many parts of the country where CBM activities are being undertaken.

There are numerous resources available to groups in Canada (e.g. Ecological Monitoring and Assessment Network (EMAN), and the Community-Based Environmental Monitoring Network (CBEMN)), however quality assurance and quality control are an on-going concern for all those involved. Funding remains a chronic issue for many groups wishing to undertake monitoring work. There is simply not enough funding available for the magnitude of CBM that is being undertaken.

Given the importance of informed environmental stewards, the ability to have access to environmental monitoring methods and technology is critical. While the scientific literature indicates that community watershed groups have the ability to generate data of adequate accuracy and precision, this can only be achieved with sufficient resources, through the use of standardised protocols, and use of Quality Assurance/Quality Control (QA/QC) procedures. There are a diversity of mandates

among CBM initiatives, including education, the establishment of states of the environment, determining background levels against which future impacts can be compared, and habitat restoration. Citizens can gather monitoring information to produce long-term data sets that help them understand environmental change and possibly lead to influencing local planning and decision-making (Pollock & Whitelaw, 2005). Regardless of the specific mandate, they all tend to have the hope that their efforts will be utilized to assist in local decision making. Further proliferation of volunteer monitoring groups will undoubtedly influence environmental protection, stewardship and rehabilitation in North America (Savan *et al.*, 2003). Constraints to CBM include data fragmentation, loss of interest by volunteers, inconsistent funding, data inaccuracy due to lack of standardized methods, quality control and participant objectivity (Stokes *et al.*, 1990; Sharpe & Conrad, 2006). Community-based ecological monitoring programmes are on the rise (Spellerberg, 2005) and with this expansion, there is a greater likelihood that they will generate data that will be used as a basis for decision-making. It is incumbent upon those with ecological monitoring expertise, to share their knowledge with the widest community possible, in order to address inevitable education and training implications. The fact remains that CBM initiatives have the capacity to add to our understanding of both gauged and ungauged basins.

One of the common criticisms levelled at community-based watershed groups is the quality of the water quality data gathered by their staff and volunteers. Natural resource administrators have a responsibility to question the accuracy and validity of all data that are used in decisions on how a resource will be managed. An examination of the literature indicates that, on the whole, water quality data gathered by community groups can be comparable to that gathered by professionals (Fore *et al.*, 2001; Engel & Voshell, 2002; Nicholson *et al.*, 2002). This has been shown to be the case for both biological and chemical water parameters. An important caveat to this conclusion is that community groups must use validated protocols, and have adequate resources for equipment and the regular training of volunteers and staff. A second, but equally important issue is the value that community-based efforts can add to broader watershed monitoring programmes. In the USA, insufficient monitoring data exist on two-thirds of the country's water bodies (Savage, 2002). This lack of monitoring data hampers attempts to assess the status of these water bodies and limits management of the resource. It is highly unlikely that government programmes, even with significant cash infusions, would have the capacity to adequately monitor all watersheds in sufficient detail to allow informed management decisions to be made. Nicholson *et al.* (2002, p.199) states that volunteer data "*adds to the database on water quality in areas that are not measured by professionals, with reasonable accuracy*". The authors go on to conclude that the increased spatial and temporal scales of watershed monitoring provided by volunteers can only improve the scientific understanding of the watershed.

ANALYSIS OF COMMUNITY BASED WATERSHED MONITORING IN NOVA SCOTIA

There are a number of community groups in Nova Scotia which have successfully developed long-term monitoring records, including the Sackville Rivers Association (SRA) and Clean Annapolis River Project (CARP).

The SRA is a volunteer, non-profit organisation that was organised in 1988, with the objectives:

- (a) to restore and preserve the Sackville River watershed's natural habitat for the enhancement of adjacent communities and properties; and
- (b) to heighten people's awareness and concern for the cleanliness of urban and rural watersheds.

The SRA has evolved from working strictly on restoration and educational issues towards comprehensive environmental monitoring. The association has undertaken many monitoring activities in response to frustration with the lack of detailed information regarding the physical health of their watershed. Activities are carried out independently or in partnership with government agencies (such as the Department of Fisheries and Oceans and Environment Canada) or universities. Examples include monitoring benthic macroinvertebrates, sediment and water quality, in conjunction with their restoration and educational initiatives. In the absence of detailed and long-term data, it can be frustratingly difficult to quantify the successes of the organization. Has the physical condition of the watershed that they are mandated with protecting continued to decline? Have their efforts been successful? Have they made a difference? These are the questions that the organization would like to answer through their monitoring efforts.

The Clean Annapolis River Project (CARP) operates the Annapolis River Guardians, a volunteer-based water quality-monitoring programme on Nova Scotia's Annapolis River. The programme, which has been active since 1992, has involved more than 90 volunteers in the collection and analysis of over 3500 water samples. Through its administration by a community-based organisation and the use of volunteers, the cost of the programme has been kept to a minimum, allowing it to conduct annual monitoring on the river, now in its fifteenth consecutive session.

Community-based monitoring programmes, like those administered by government or other organisations, face on-going challenges to ensure accuracy and validity of their monitoring data. A key question is whether community groups can put in place systems to avoid data quality problems and, when they do occur, allow the problems to be identified and rectified quickly. For example, during the summer of 2003, several of the water samplers used by the Annapolis River Guardians became contaminated with a bacterial species. This type of contamination was unprecedented over the then 11-year history of the programme. Through a subsequent investigation, and with the assistance of microbiologists at Acadia University and Environment Canada, the contaminated equipment was identified and taken out of service. In consultation with provincial and federal environmental officials, a new sampling protocol was developed that will hopefully avoid a repeat of this incident.

While the scientific literature indicates that community watershed groups have the ability to generate data of adequate accuracy and precision, this can only be achieved with sufficient resources, through the use of standardised protocols, and use of Quality Assurance/Quality Control (QA/QC) procedures. Community watershed groups must ensure that QA/QC procedures are incorporated into the study design of every monitoring programme. For this to occur, groups need guidance, training, and support to put the necessary procedures in place. As a result of the 2003 equipment event described above, CARP is currently developing a Quality Assurance Project Plan for

its water quality monitoring programs, based on a template used by community groups in the USA (US EPA, 2004).

The introduction of a standardised benthic invertebrate monitoring protocol to the Atlantic provinces is an important success for Environment Canada's *Ecological Monitoring and Assessment Network* (EMAN). Benthic invertebrate monitoring in lakes and streams can provide important information in terms of assessing both water quality and ecosystem health. Prior to the introduction of the CABIN (Canadian Aquatic Biomonitoring Network) protocol, benthic invertebrate monitoring was used infrequently and with a variety of methodologies (Reynoldson *et al.*, 1999; Bailey *et al.*, 2003). CABIN provides a scientifically robust, accessible, and standardised approach for community watershed groups to monitor the abundance and diversity of benthic invertebrate communities. The CABIN protocol has been used by 10 groups in Nova Scotia since its introduction in 2002, with a total of 37 samples being collected. As the method makes use of the Reference Condition Approach with the data being held in a central database, the results from different watersheds can be compared.

Beyond consistent field procedures, which standardised protocols will provide, community groups require assistance with the management and sharing of data once it is collected. Data management in this respect entails both "in-house" procedures for inputting, archiving and retrieval of field data, and mechanisms to allow the data collected by one or more groups to be compared and analysed. If in-house procedures are inadequate, there is the risk that field data may be corrupted or lost, particularly with staff turnover. Having the ability to aggregate water quality data from more than one group or watershed has the potential to significantly increase the value of the monitoring effort, and allow trends to be tracked over much wider spatial scales.

ENVIRONMENTAL EDUCATION: THE ROLE OF THE COMMUNITY-BASED ENVIRONMENTAL MONITORING NETWORK

There is a significant role that academia and government can play in CBM, in the context of community-based research. Community-based research (CBR) is "...a partnership of students, faculty and community members who collaboratively engage in research with the purpose of solving a pressing community problem or effecting social change" (Strand *et al.*, 2003). As opposed to traditional academic research, CBR finds research questions in the needs of the community. It is characterized as being collaborative (academic researchers; professors and students and community members), it validates multiple sources of knowledge, promotes the use of multiple methods of discovery and dissemination of the knowledge produced, and its goal is often social action and social change (Strand *et al.*, 2003). CBR projects usually link citizens' groups with university experts, permitting collaborative research that is both credible and relevant, while drawing on valuable local knowledge (Mackinson, 2001; Savan *et al.*, 2003). CBR "...can provide a good model for launching and maintaining projects, especially when quality assurance and quality control are fundamental to success" (Savan *et al.*, 2003). Community-based research has a strong tradition in the health field, but more recently, there have been significant applications in environmental sustainability work (i.e. Savan & Sider, 2003).

In 1999–2000, the author became a member of a local watershed group (the Sackville Rivers Association) and was amazed by the level of involvement and spectrum of environmental activities that this organization was involved in. As an academic, the author was perceived as someone with an “in”, with access to knowledge and expertise. As monitoring efforts got underway and a programme was being developed within this organization, it became quite evident that there were many stewardship organizations in the province of Nova Scotia and in the Maritime provinces in general, that would benefit from access to a variety of researchers in a University setting. It was also noted that stewardship groups would benefit from a formalized “network”, where they could seek advice from one another on their environmental monitoring activities.

The Community-Based Environmental Monitoring Network (CBEMN) was established to further existing relationships with community groups and foster new ones. This Network, housed within the Department of Geography at the Saint Mary’s University campus, serves as a location that members of the community can contact when they have a question about:

- How to monitor/measure the environmental quality of the ecosystems in their community (based on Environment Canada’s *Ecological Monitoring and Assessment* (EMAN) protocols.
- How to “access” scientific and social scientific data related to the environment.
- How to use these data and utilize technology as a tool to further their understanding of their communities.

The CBEMN serves as a source of information through direct contact with our office and through a mechanism for knowledge transfer across groups. In addition to the web site (<http://www.envnetwork.smu.ca>), newsletters are produced and training workshops are held. The Network takes a holistic and interdisciplinary ecosystem approach, advancing monitoring protocols that are aquatic, marine and terrestrial in scope.

The CBEMN is mutually beneficial to the University as well as the stewardship community. While helping the University to fulfil a component of the mandate of its Academic Plan, students have the opportunity to have applied, experiential learning. Many students express an interest in learning while working on “real-world” problems. Since the creation of the CBEMN, students have worked on course work placements, through the Environmental Studies programme, assisted stewardship groups in monitoring, through courses in the Geography Department and been employed through co-op work placements, through the Government of Nova Scotia’s “Nova Scotia Youth Conservation Corps” programme, and the Federal Government’s Science Horizon’s internship programme. The environmental stewardship community is therefore able to access students and have work projects completed at no cost to their organization. As well, a large number of groups are able to take advantage of monitoring protocols, as well as our monitoring “toolkit”. To date, over 100 groups from across the country have requested and received our monitoring toolkit.

One of the most widely utilized resources provided by the CBEMN is the “Equipment Bank”. A wide variety of monitoring equipment is housed and maintained at the University and is loaned to groups at no expense to them. The benefits of this include the ability for groups to conduct monitoring with sophisticated equipment that they might otherwise not be able to afford, they are trained in the proper use of the

equipment by students and staff at the CBEMN and they do not have to worry about annual maintenance, proper storage and calibration.

EXAMPLES OF CBM: EXPERIENCES FROM THE CBEMN

There is no precise count of how many stewardship and/or CBM groups are currently operating in Nova Scotia, but it is believed that the number is close to fifty. Most of the CBM groups in the Province engage in some sort of watershed monitoring, testing for variables such as pH, temperature, dissolved oxygen, salinity, macroinvertebrates, and various bacteria, while fewer undertake terrestrial or wildlife monitoring. Oddly, there are few marine monitoring programmes being undertaken in the Province, even though most CBM groups are based on or near the coast. This is a function of the fact that Nova Scotia's Department of the Environment is not specifically mandated with protection of non-drinking watersheds, and therefore communities have assumed, by default, the concern and burden of understanding the state of their freshwater systems. Groups that are linked with the CBEMN have primarily been concerned with, and therefore engaged in, freshwater monitoring. Their work is either baseline or in response to a perceived impact; with very little results and in-put in terms of integrating into the decision-making structure.

Even though CBM is a relatively new phenomenon, there are still groups that have been involved in the monitoring of their environment for many years. The many groups that make up the landscape of CBM in Nova Scotia carry with them many different experiences and attitudes when it comes to CBM. It is difficult to gauge the success and effectiveness of such groups, especially when it comes to linkages to environmental management and decision-making (Conrad, 2006b). Regardless, one of the most acknowledged outcomes of community-based environmental monitoring programmes is environmental education (Spellerberg, 2005).

There is a wide variety of types of monitoring that groups can undertake, from simple Nature Watch programmes, through to more complex and long-term monitoring of their ecosystems and watersheds. Some groups are involved in a variety of types of monitoring and at a variety of scales. For those groups who are not provided with core funding from a government agency, it is particularly important that they have access to educational resources. Many groups that approach the CBEMN express an interest in doing multiple types of monitoring. Sometimes they have a very specific purpose in mind (i.e. they feel that a river in their community is polluted and want to verify this or not; they want to know if a species in their lake is native or an invasive) and sometimes they do not (i.e. they want to get an understanding of the "state of their environment").

Citizens in general are interested in learning more about their local environments on a variety of scales (Fig. 1). The literature indicates this to also be the case elsewhere in Canada (Pollock & Whitelaw, 2005).

The importance of environmental stewards and volunteers filling in gaps of knowledge about our ecosystems should not be ignored.

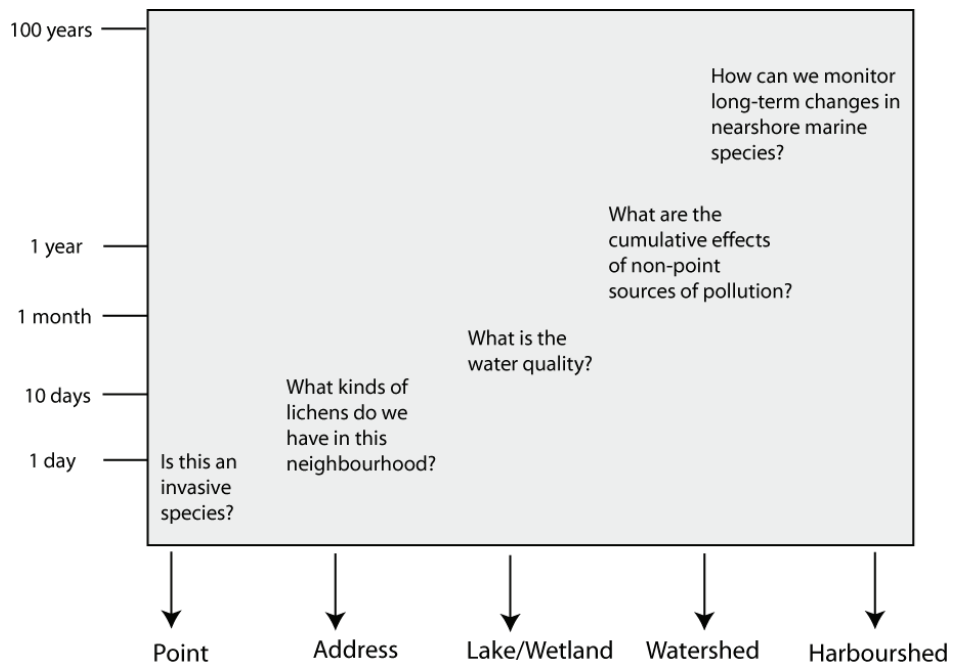


Fig. 1 The scale and duration of a spectrum of monitoring questions posed by community-based environmental organizations.

DISCUSSION AND CONCLUSIONS

CBM groups have the potential to make a substantial contribution to the effective understanding and management of water resources, if they are given the appropriate support and opportunities. A limited number of groups have been successful in establishing a long-term monitoring record. Upon examination, these groups share a number of common features, including:

- management by a steering committee composed of members from the community, academia, government agencies, and the private sector;
- adequate long-term funding;
- access to scientific expertise in data collection and interpretation procedures;
- a strong programme to communicate the results of monitoring activities to both the community and to those volunteers actually collecting the data; and
- engagement of politicians and decision makers by the volunteers (as opposed to employees being paid to run the programme).

There are other similar initiatives in Canada to the CBEMN. The Citizens Environment Watch (CEW) in Ontario is one example. While the CEW has established partnerships with many organizations to promote volunteer monitoring, the relationship with the University of Toronto is most central to their operations (Savan *et al.*, 2003). This author also notes that as useful and beneficial as linkages between the environmental stewardship community and academia may be, there are a number of notable caveats.

Associations with university experts can undermine citizen confidence in their own ability to produce credible results, and academic focus on peer-reviewed publications might influence the goals and focus of the monitoring work. Therefore

some degree of autonomy is critical. The CBEMN does not drive the agenda of monitoring efforts. Groups approach us with their questions and we provide assistance and guidance. It is important to note, as the foundation of community-based research implies, that we are not researching *on* members of the community, but rather provide research assistance *for* communities. It is important for groups to feel in control of the purpose and methodologies of the work being undertaken, for ownership of the monitoring. In many cases, groups request that the CBEMN conduct an extensive programme of monitoring, but we emphasize the need for volunteers from within the community to be fully interested and engaged and to direct the purpose and goals of the programme in order for it to be a useful and successful initiative. Caveats aside, making strong linkages between dedicated university researchers with community members can result in meaningful and useful research results for everyone involved.

No matter how much monitoring we do, we will not change anything if we can not deliver the results to inform choices, decisions, and policies. Science alone is not well equipped to model and understand future changes and scientists are even less equipped to reach decision-makers. The community serves a role and a purpose here.

Information which is timely, integrated and non-confrontational is required to support adaptive management (Vaughan, 2005). More opportunities to participate in integrated watershed and resources management are no doubt required (Sharpe & Conrad, 2006) and in order for this to occur, adequate resourcing of ecological monitoring is a necessary first step. Financial and material resources need to be provided to community-based groups, via an established mechanism to provide core support for CBM. There is a need to characterize the information that a spectrum of decision-makers would use and design CBM to deliver it (Vaughn, 2005). We need to improve communication and publicize examples, strategies and opportunities to enhance participation in integrated watershed management, where community groups are a meaningful partner in the process.

An adaptive management strategy will not provide the ultimate solution here but has the potential to serve as a useful guide in terms of providing a structured process of learning by doing. Most management plans contain at least passing reference to the need for an adaptive approach and it is therefore a structure which is increasingly being acknowledged by government. Business as usual is no longer an option for sustaining and restoring ecosystems. "*We need to shamelessly publicize the outcomes of our commitment to the adaptive management strategy*" (Walters, 1997).

There is a strong need for further research on political and educational strategies to assist CBM in influencing decision-making. There is a need for creative thinking about how to make management experimentation an irresistible opportunity, rather than a threat (Walters, 1997). The challenge remains to discover and define an approach whereby decision-making and sustainable actions are well balanced (Vasseur, 2005) and the appropriate level of public participation is involved.

Community Based Monitoring information intended to inform decision making should be targeted and relevant to problems, accessible and understandable, usable and timely. To be effective, the delivery and communication of CBM information should suggest a course of action, allow decision-makers to weigh consequences, and make those involved feel they are in control of the problem (Pollock *et al.*, 2003). Without

doubt, the engagement of politicians and decision-makers is required and in order for this to unfold, it is likely that broader public interest, engagement and ultimately pressure may be a necessity.

We should exploit models (e.g. the US National Estuarine Program) which have at least in part been successful elsewhere, and propose models to local and regional governments based on these cases. For CBM to ultimately be more meaningful, we need to work better from within and make decision-makers better aware of what is being collected and why it is useful, and foremost why we need to act on the results to ensure sustainability. Whichever model is ultimately adopted, there needs to be government support, including both financial resources and meaningful management opportunities.

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