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SUSTAINABILITY AND IMPINGEMENT: A NEW MULTI-DISCIPLINARY APPROACH[1]

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Abstract: This paper advances a new and different approach for understanding sustainable development in theory and practice. It recognizes that sustainable development is a function of socio-economic, ecological and governance systems. But it advances the central proposition that these systems can successfully co-exist without negative interdependencies or what we prefer to call "impingements" as the former term has a strict meaning within the discipline of economics. Evidence from the Great Lakes of North America provides the context for isolating successful (non-impinging) and unsuccessful policy cases. Propositions are advanced for building an analytic theory based on impingement. We thus differ from much current academic work that seeks to integrate all three systems as a way to operationalize sustainable development.

It has now been more than two decades since the Bruntland Commission produced its influential treatise on sustainable development. Its influence has been felt in both academic and practical developments in both developing and more developed worlds (Sustainability, Science, Practice and Policy, ejournal, ubi. org). Google Scholar lists more than one million scholarly citations, notwithstanding that the concept was devised well before 1987 (Sadler, Manning, Dendy, 1995; Google Scholar, 2010). This is a remarkable impact.

The influence of sustainable development as a concept in part stems from its implications that prudent economic development can be compatible with environmental stewardship. By inference, governmental processes might find the balance. Governance was thus a third sector of influences that could balance those of economics and of environmental science.

Over time, studies of sustainable development expanded their agendas to develop broader concepts, propositions and evidence in a quest to integrate economic science with environmental science. A continuous example is the study of "ecological footprints" that ostensibly integrates socio-economic behaviours with ecology (Wacknegal and Rees, 1996, was the seminal study).

A second way in which sustainable development studies have grown is in the efforts to build inclusive theories or frameworks that would marry sustainable development with other social and life science approaches. These include "limits to growth" theories, "natural capital" theories, "co-evolution" of living systems theories, "adaptive management" and "resilience" theories, and last but not least, "polycentric

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governance" theories. Useful recent reviews include Sabatier, Focht, Lubell, Trachtenberg, Vedlitz, Matlock (eds.) (2005); Berkes, Colding and Folke (eds.) (2003); Ostrom (2007 and 2009); Young, Berkhout, Gallopin, Janssen, Ostrom and Van der Leew (2006).

This paper offers a comparable method by placing sustainable development within a theoretical approach. It draws upon works that aim to integrate socio-economic, ecological and governance systems. Its central proposition is that sustainable development is a function of compatible socio-economic, ecological and governance systems. By compatible we do not mean that all three systems are necessarily integrated or synchronised. Rather we pose a less demanding question. Do these three systems coexist without (substantial) negative impacts or negative interdependencies? Alternatively are there elements in socio-economic systems or ecosystems or governance systems that pose threats to either or both of the other two systems in any resource situation or context? Readers will note that we take governance systems as active users and/or takers and/or sustainers, and not as managers, stewards or regulators of socio-economic systems and ecosystems. They play these last roles but their former roles are what interest our evaluations. In other words, we do not use a stricter criterion of sustainable development that any of the three systems can and do positively help the others to flourish. We set that criterion aside for future studies.

The paper proceeds as follows. The next section discusses the methodological approach. In part, it stresses the importance of situational circumstances in developing differently comprised ecosystems, socio-economic and governance systems. We then describe the large situation of the Great Lakes of North America, the world's largest fresh waters, and describe the three systems as they exist today in this context. We then look at the impingement of any one of our systems on the other two. Finally, we review our studies and develop a number of propositions that can form the basis of an overarching analytical theory for understanding sustainable development and its limits and directions.

■ METHODOLOGY

Context matters. This is a conclusion of most environmental studies of the last several decades (Honadle, 1999). It is a maxim fundamental to ecosystem science, but sometimes exogenous to social science propositions. An example of the importance of context is the more recent recognition of the theory and practice of indigenous knowledge of resource populations and their variability across different situations (Berkes, Colding, Folke, 2003). Another is the recognition of particular community governance systems of resource commons, as the bases for successful resolution of any tragedy of the commons (Ostrom, 1990, 2008). We will describe the Great Lakes as a context as well as its primary ecosystems, socio-economic and governance systems.

The body of the work consists of six case studies, three where the three systems do not impinge upon the sustainable development of the region and three where impingement constrains or even threatens the resilience of one of more of the other systems. The cases are deliberately selected to illustrate the impingements or non-impingements that happen in our context. Thus ecosystems are first a dependent variable potentially impinged upon by one or both of the other two systems, and then each of these other systems are treated as dependent variables subject to impingement or non-impingement from the others.

FIGURE 1: POLICY CASES, POTENTIALLY IMPACTED SYSTEMS

SYSTEM	POSITIVE	NEGATIVE
Ecosystems	Sea Lamprey	Areas of Concern
Socio-Economic	Beaches	Waste Water regulations
Governance	Water Quality Agreement 1972	National Boundaries

The methodology is essentially inductive in form, generalizing from detailed case studies. But our conclusion presents a number of testable propositions that can be integrated into an analytical theory of impingement.

■ CASE ONE: THE SEA LAMPREY PROGRAM

The sea lamprey is a parasitic-invasive specie that was introduced into the Great Lakes environment probably from ballast water of freighters and perhaps through migration up shipping canals from the Atlantic Ocean (GLFC, 2005). It had a fast and immediate impact on all species of large Great Lakes fish like trout, salmon, whitefish, chubs, walleye, catfish and even sturgeon. They contributed significantly to the collapse of these fish species that were the mainstay of a vibrant Great Lakes commercial fishery. For example, it is estimated that 15 million pounds of lake trout were harvested annually in Lakes Huron and Superior before the lampricide program began. By the early 1960's, the catch was only 300,000 pounds. (Applegate, 1961, 3). The ecosystem was not only in exploitative distress but the pace of change jeopardized any reorganizational response.

The governance system responded in part by establishing a Great Lakes Fishery Commission in 1955 by joint Acts of the Canadian and U.S. Governments. The Sea Lamprey Control Program uses a combination of techniques such as immigration barriers, sterile-male releases, trapping, and more controversial TFM Lampricide (3-trifluoromethyl-4-nitrophenol). Implementation is a joint effort between Fisheries and Oceans Canada, the U.S. Fish and Wildlife Service and the U.S. Army Corps of Engineers. Studies commissioned by the Great Lakes Fishery Commission and independent researchers suggest that TRM is not persistent, is detoxified and poses no threat to wildlife (Hansan and Manian, 1978, 6; Hubert, 2003, 461). Questions still remain about the long run exposure of macro-invertebrates in streams and also of crops sprayed with irrigation water contaminated with TRM (<10mg/L of water) (Gilderhus, 1990, 3; Hudson, 1979, 4; Lieffers, 1990, 1). The program made modest improvements of fish stocks (Francis, 1979).

The G.L.F.C. has felt that the program has successfully arrested the invasion, and permitted the fisheries ecosystem to reorganize. In that sense, the governance system readapted itself to help restore the ecosystem. The socio-economic system in the form of the sports fishery successfully lobbied for introduction and continued program longevity.

At least for significant periods of recent history, there appears to be synchronicity between the ecosystems and the socio-economic systems and, potentially, the governance system too. It has taken until 2008 for the Canadian and U.S. governments to require salt-water flushing of seagoing vessels entering the St. Lawrence. There is thus prima facia evidence that the governance system has moved toward effectiveness in its impacts on the ecosystems in question.

■ CASE TWO: LOOSE COUPLINGS AND AREAS OF CONCERN

Figure 2 depicted hypothetical relationships (coupling) between different clusters of users in an multiple use context some of which are subject to coupling relationships with regulatory bodies. The latter are usually governmental agencies devoted to inducing or commanding user groups to change their practices. Sometimes too there are multiple regulators of the same cluster, as in the previous example of ballast water regulations for ocean going vessels.

Besides a loosely coupled governance system, socio-economic systems are often not well integrated across such a large geographical space, despite common visions for resolving negative interdependencies between uses. The traditional way is to rely on common law, and courts still use the principle of navigable servitude to grant priority to shipping over other uses (Sproule-Jones, 1993). Some of the states and provinces attempt to prioritize sectoral uses, often giving top priority to that of clean potable water for domestic purposes (Percy,

1998) but these efforts rely on regulations for enforcement rather than negotiations between parties to any dispute. In these circumstances, one would expect little in the way of common behaviours of socio-economic systems and governance systems in relation to their impacts on ecosystems.

In 1985, the International Joint Commission approved and promoted localized efforts to coordinate multiple users as stakeholders to remediate identified deficiencies in the local bays, harbours or river mouths. These efforts were to be termed Remedial Action Plans (RAP's) which were to be developed for the local "pollution hotspots" or Areas of Concern (AOC's). 14 deficiencies (or "impaired beneficial uses") were identified, and each AOC could have anywhere between 3 and 14 of the problems. Appendix B provides a map of the AOC's in the Great Lakes, and Appendix C lists the impaired uses for each AOC. It is perhaps important to note that 6 of the impaired uses directly impact ecological health and reproduction, and one is expressly that of improved fish and wildlife habitat.

In the 20 plus years since RAP's were developed under the auspices of state/provincial environmental regulators, and with the help of their federal counterparts, only three AOC's have been delisted. Some progress has been made toward re-establishing fish and wildlife habitat (Jackson, 2006) but many of the indicators of ecological health and reproduction imply mixed, uncertain or even deteriorating status (Solec, 2005).

The socio-economic system and the governance system are not synchronized themselves and, as implied, not synchronized with the ecological system. Two important pieces of evidence are worth noting. First, in a survey of stakeholder committees designing goals and priorities for each AOC, most included federal, state/provincial, and municipal representatives, plus representatives of industry, farming groups, environmental groups, universities and "citizens at large". Of the major users, recreational, shipping and human health groups were frequently not included and Aboriginals were only included in 1 of the 43 AOC's (Sproule-Jones, 2002, 96).

Secondly, in an examination of the participants involved in formulating Lake Wide Management Plans for the Great Lakes, every management steering committee was composed of representatives of regulatory agencies, and user interests were either ignored or reduced to commentary on governmental draft reports. The governance system is dislocated from the socio-economic system and its connections with the ecological system are sporadic and "untuned".

■ CASE THREE: BEACHES AND ACCESS

Most of the human settlements in the Great Lakes Basin are either on the coasts of the Great Lakes and their tributaries or within half a day's drive. Citizens have traditionally used this physical accessibility for body contact recreation in the form of bathing, surfing and pleasure boating (on both closed and open waters) (Berton, 1996, 160-64). Unfortunately, many beaches were closed from the turn of the 20th century due to pathogenic pollution. By 1985, some 24 of the 43 AOC's had some or all of the beaches closed. What is remarkable, however, is that over 75% of beaches in Canadian shores remain open throughout the year and over 65% of American beaches are similarly open (Solec, 2005, 161-62). This suggests that many coastal ecosystems continue to provide carrying capacities for human recreation. It also suggests that pathogenic pollution is a product of localized pollution, typically from combined sewers and sanitary sewer overflows after storm events and, less frequently, malfunctioning sewer systems and poor livestock management practices in rural areas.

Hamilton Harbour provides an exemplary case (Sproule-Jones, 1993, 133-152). Between 1920 and 1970 some 20% of the coastal shores were infilled and sold as industrial properties. Only 7% of the shoreline was open space as of 1985. Combined sewers regularly overflowed, and the three sewage treatment plants exercised only primary treatment until 1978. As a result, beaches were closed to swimming after 1930. The waters were largely anaerobic for many summer months. Due to selective interventions associated with the

Remedial Action Plan, beaches were re-opened for swimming in 1998 and sailing, canoeing, kayaking and pleasure boating involving anywhere between 175,000 and 350,000 citizens in any one year are now apparent. Access to the waters were increased to 25% of the coastline. The site was restored for recreational use even as it prospered as the largest shipping port in the Basin. Work continues to upgrade sewage treatment and prevent combined sewage water overflows and remove Canada geese from the beaches (that were temporarily closed in the early 2000's due to geese droppings).

In sum, there is evidence that governance interventions can be effective, mesh with socio-economic activities at least on localized bases, and timed with the reorganization of multiple ecosystems.

■ CASE FOUR: MISPLACED REGULATIONS

We have already noted how the bays, harbours and river mouths that are sites for most human settlements on the Great Lakes display indicators of ecosystem deterioration and impaired water quality. Social and industrial activities have generated residuals and, while many ecosystems retain some levels of reorganization especially in open waters, the governance system seems partly ineffective in synchronizing its work with adaptive ecosystems and socio-economic waste disposal. Indeed, one careful study of over 600 industrial point sources of waste water disposal of toxic pollutants estimates that over 50% of the toxins (by weight) are still discharged into the lakes even under active regulatory regimes at the state/provincial and federal levels (Thomas, 2003, 310-48). One consequence is that certain population groups receive more persistent exposure to toxic chemicals through the consumption of contaminated fish. These groups include anglers, particularly the urban poor, commercial fishers, charter boat crews, pregnant women, aboriginals and Asian immigrants all of whom consume larger amounts of fish (IJC, 2000, 18).

Why has the governance system lacked effectiveness in establishing and implementing regulations on water pollution produced by society? Typically, an agency of the state/provincial governments issues discharge permits that reflect current opinions on effluent standards, and (especially in the U.S. States) with the aid of an active Environmental Protection Agency at the federal level.

There may be conditions attached to an authorization to use the lakes, bays, and rivers for the disposal of liquid industrial effluent, but there may be no reciprocal duty to or from other users. In contrast, riparians may have claims on waste dischargers, but these can be attenuated by the conditions of use that may be authorized for in a discharge. The Ontario Environmental Protection Act, for example, removes the common law damage claims that riparians may have with respect to pollution caused by municipal waste water treatment plants. We can have many thousands of users of the Great Lakes for one or more of the uses we have depicted, but many of the users are not made legally interdependent (i.e., they are not made claim holders) with regard to the "technical" interdependencies they may create.

In cases like these, it is the responsibility of the government agencies that issue the license to police for violations. Uses are not self-formed but, rather, are governed by those with the power to create and remove claims. Obviously, policing is more difficult across sovereign jurisdictions like nation states or states and provinces.

If this analysis is correct, then authorized users (or squatters) have privileges that do not require them to take other users into account (unless so specified in the conditions of authorized use). They can, of course, voluntarily agree to a correlative duty. In these circumstances, it will depend on the values of the person and on the social norms of the community whether voluntary self-regulations occurs. In large group situations, we know that social norms tend to dissipate and that free riding can occur (Olson, 1965).

In the large multiple-use legal system that has evolved on the Great Lakes, reciprocal duties on users are either not specified in their conditions of use or they are specified and then policed (somewhat) by government agencies. In these circumstances, there is little incentive on users to take other users into account. Unreasonable regulation provides a commons of a different ilk.

This is a long and somewhat sad conclusion on the ineffectiveness of governance systems to support and sustain socio-economic systems (and protect from waste disposals) across a large multiple use water resource basin. We now look at how the socio economic and ecological systems impact the governance systems themselves.

■ CASE FIVE: THE G.L.W.Q.A (1972)

The Great Lakes Water Quality Agreement between Canada and the United States was a seminal moment in the regulation and removal of waste disposal (phosphorus pollution in this case) and the restoration of alternative uses like fishing and contact sports in the lower Great Lakes. It was the culmination of years of investigation by and pressure from scientists, public administrators and citizens at large. It presaged further and later governmental responses to ecosystems deteriorations and their restorations.

As early as 1912, the Canadian and U.S. governments asked the IJC to examine the general extent of pollution in the Great Lakes and to make specific recommendations for connecting channels. The IJC recommended sewage treatment and water purification to control human waste disposal. Limited responses led to degraded water quality conditions in the lower lakes. By 1953, the bottom waters of Lake Erie showed the first signs of anoxia. By the late 1960's, the lake was often characterized as "dead" (Colborn, 1990, 95). The lake was subject to "cultural eutrophication" whereby phosphorous (as a nutrient) was an algae bloom in this the smallest of the five lakes and one with low levels of dissolved oxygen in summer months.

The IJC was a focal point for advancing the case for governmental responses. As early as 1960 it began a series of scientific reviews that emphasized nutrient loadings as the primary cause of eutrophication. Reports produced in 1965 and 1969 further advanced the case (Munton, 1980; 155; Muldoon, 1980). Ministerial meetings between 1970 and 1972 finally produced the first GLWQA. The environmental movement in the two North American countries both advanced and grew strength from the burgeoning pressures on two national governance systems. Ecosystems and socio-economic systems appeared to be finally synchronized with governmental systems in this particular "problem-issue" for the Great Lakes.

The practical consequence of the agreement was the reduction of phosphorus loadings through improved sewage treatment. Targets and objectives were attained by 1991, and chlorophyll a (an indicator of nuisance algae growth) was at acceptable levels by the early 1990's.

■ CASE SIX: SOVEREIGN BOUNDARIES

The previous case of the GLWA of 1972 also showed that international boundaries can complicate and delay efforts by informed publics to solve cooperative issues (like lake wide eutrophication shared by two or more countries).

Boundaries can also provide an incentive to defect from consensual horizontal arrangements. For instance, every instance (except one, the St. Marys Ripar) of a Remedial Action Plan in polluted hot spots shared by Canada and the United States on the Great Lakes led to defection by one of the parties. Consequently, two parallel RAP's were devised for each site with protocols that assumed an impermeable barrier down the middle of the shared river or watershed! Even the RAP established for the Menominee River between Michigan and Wisconsin broke down and had to be replaced by two parallel and different RAP's with a "mythical barrier" in midstream (Sproule-Jones, 2002, 79, 90-103).

The institutional arrangements for water quality management on the Great Lakes are even more bizarre, focusing as they do on diversions, pipelines, and bulk water removals. Three separate legal systems exist for the waters of the single basin. First, small scale diversions are regulated by their riparian governments, the eight states and two provinces. Some of the riparians rely exclusively on the common law regime (such as

Pennsylvania); others use a statutory permitting system (such as Minnesota and Ontario). The definition of small scale is ambiguously vague, a matter to be determined by domestic courts. Second, some large scale diversions from international boundary waters are subject to the International Boundary Waters Treaty which gives each of the Canadian Prime Minister, the U.S. President and the International Joint Commission a veto over diversions. Thirdly, there are diversions from Lake Michigan which is considered solely as U.S. domestic lake. The actors here include the U.S. Supreme Court which sets a cap on the size of the major outflow (the Chicago Canal) and has blocked state efforts to expand the flows. Indeed, since 1986, the U.S. Federal Government, through its Water Resources Development Act, and the riparian states through interstate compact (the Great Lakes Charter) have essentially constructed a legal system giving each governor a veto over diversions both within and between states. So even though the Great Lakes constitute a single basin, three distinct institutional regimes exist – for small diversions, for large diversions in waters bounded by both countries, and for large diversions from Lake Michigan (and also domestic waters draining into the other lakes from U.S. territory).

In these examples, governance systems displayed either a desire for non-cooperative strategies or a desire to defect. On occasion, socio-economic systems may mesh with governance systems if there is concurrent concern with ecosystem reorganizations. Sovereign boundaries seem to make a cross-national coupling a sporadic response.

■ **THREE SYSTEMS DESCRIBED** (Based on information in SOLEC 1995, 2005, 2006; Sproule-Jones, 2002)

Ecosystems

The Great Lakes Basin exceeds 765 square kilometers or 295 square miles. The five Great Lakes occupy an area greater than half a billion square kilometers, have a shoreline of 17,000 kilometers (10,000 miles), and provide habitat for diverse biotic communities in the waters, coastal zones and lands.

Recent reviews of indicators designed to measure the status of biotic communities suggests that many community populations are deteriorating or reduced. These include benthic invertebrates, zoo plankton and fish species. This seems to be associated with loss of wetlands and other aquatic habitat as well as from contamination from point and nonpoint sources. Indeed, Lake Ontario has lost 80% and the other lakes some 60% of aquatic habitat and wetlands since the 1780's. Over 85% of the land area of the basin is in agriculture or forestry, but these habitats are also subject to developments for human settlement and transportation (Solec 1995; Solec 2006, 2008). Thus the geographical spaces available for ecosystems are reduced and deteriorating. Populations are smaller and less diverse. However, we lack sound knowledge of the upper or typical levels of multiplicity and diversity of sustainable ecosystems.

Socio-Economic Systems

The basin has historically supported a diverse range of human activities both on the land and on the waters. Some 35 million inhabitants reside in the basin and carry on the diverse activities of modern industrial economies, as well as a significant amount of farming in the lower portions of the basin land (28% of the land cover). The land also supports some forestry and mining. The urban areas cover barely 2% of the land mass even though it is home for three very large (4-8 million) urban populations around Detroit, Cleveland and Toronto.

Human activities are more accurately reflected in the variety of ways that the waters are used and enjoyed in the basin. A traditional activity is commercial shipping, mostly of bulk cargoes like iron ore and grains. Cargoes and vessel traffic have decreased by 30% and 57% respectively (since 1980) due to the development of subsidized grain production in the European Union (EU). Pleasure boating, on the other hand, has grown substantially due largely to the growth of sport fishing. "Angler Days" on and off the waters exceed 23

million in the five Great Lakes. (An angler day is an individual who fishes for at least 20 minutes in any one day.) In contrast, commercial fisheries which produced over 1 billion pounds in the early twentieth century now only lands 50 million pounds due to overfishing, pollution and habitat destruction.

The other important uses of the lakes are threefold. First, hydro electricity, largely from Niagara, provides 20% of Ontario's power and smaller amounts in Wisconsin, Michigan and New York. Second, nearly 2,493 cubic metres per second of Great Lakes water are withdrawn for irrigation (29%), public water supply (28%) and industrial uses (24%) other than hydro. The volume of groundwater withdrawals is unknown. Diversions also occur, with the largest at Chicago (91 cubic metres per second) for public water supply and sewage disposal. The largest diversion into the lakes occurs in Lake Superior where 158 cubic metres per second are diverted from Long Lac and Superior for hydro purposes downstream at Niagara.

The final use of the Great Lakes is for waste disposal, both in terms of point source liquid wastes from industries and municipalities, and non-point source pollution from agricultural and urban lands. One estimate places the liquid wastes at 57 million tonnes per year, much of which is partially treated for conventional pollutants like pathogens (Colborn, T., A. Davidson, S.M. Green, R.A. Hodge, C. Jackson and R.A. Liroff, 1990).

In sum, the basin has been a major contributor to the social and economic well being of large numbers of first, second and later generations of immigrants on both sides of the Canada-U.S. border. The basin has provided crops, energy, water, fishes and wildlife for burgeoning populations. Some negative consequences in terms of impacts on ecosystems through settlement patterns and waste disposal have already been alluded to.

Governance Systems

The governance systems for large scale multiple use river basins, like the Great Lakes Basin, are based on different patterns of relationships for different resources uses. These are "rules" that have "emerged" and were initially formalized in common law. Different patterns of rules exist for commercial fishing, for example, than for hydro-electric generation. The rules were often later codified into statutory laws, but they still tended to retain the differences based on use. This is a common feature of all regimes with a common law heritage (with a possible exception for New Zealand since 1990).

Because different patterns of rules are developed around different uses of the resource, we find a large and diverse number of rules in a governance regime such as the Great Lakes. There is no necessary hierarchy of rules; the patterns appear to form "nests" of rules built around different resource uses. So various shipping ports, the St. Lawrence Seaway Authority, public transportation agencies, the International Joint Commission and others will cluster and interact to develop and implement policy changes for commercial shipping (including lake levels). Different clusters will exist around the waste disposal and water quality uses of the Lakes or around the commercial and recreational fishing uses. The linkages can span levels of government, the boundaries between the public and private sectors and the organizations of different countries like Canada and the United States. Occasionally, the clusters will contain overlapping member organizations such as the IJC which overlaps many uses of the Lakes. However, generally the "coupling" across the clusters can be referred to as "loose coupling" compared to the "tighter coupling" within comparable policy network (Sproule-Jones, 1993; Dorcey, 1994; Young, 2002).

In this kind of regime, there is no necessary hierarchy of organizations (across policy networks) and no single basin wide authority. Interaction and coordination proceeds largely through a mutuality of interests by resource users, regulators and managers. Figure 2 displays an example of these governance structures (adapted from Scheffler, Wesley, Brock, Holmgren, 2002, 233; Sproule-Jones, 2008 B). Figure 3 portrays the clusters in relation to what the literature refers to as vertical linkages or coupling as opposed to the horizontal linkages or coupling between resource users themselves. The figure shows two clusters of regulatory agencies (RI; RII) with "vertical relationships" to user organizations and with relationships with organizations not in this particular watershed or basin (the lines with arrows) (Berkes, 2002; Young, 2002; Sproule-Jones, 2008).

The names and character of the horizontal and vertical relationships are fully described in many sources. On an international level, they include the Boundary Waters Treaty of 1909 which is the foundation of the operation of the International Joint Commission, and also include the Great Lakes Water Quality Agreements 1972, 1978; the Great Lakes Charter, 1985, 2007 and at least 20 further rules which we list in Appendix A. As the Appendices detail there are a plethora of rules for the multiple uses embodied in legislation of two Federal Governments, eight state/provincial governments, and the bylaws of some 6,000 local governments. Some pertinent ones are included in subsequent sections of this paper.

The governance systems show some analogous links and flexible boundaries as do ecosystems and open socio-economic societies.

FIGURE 2: WATER RESOURCE USERS AND THEIR CLUSTERS

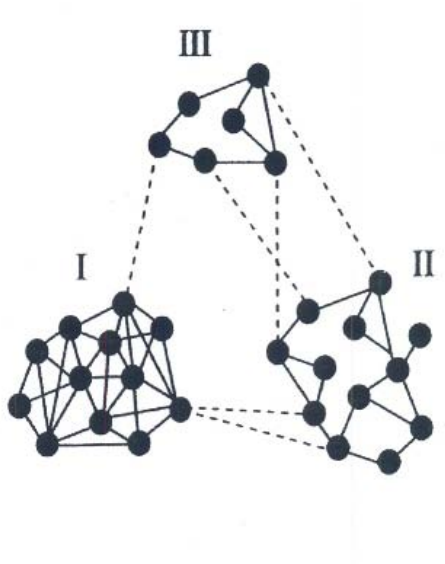
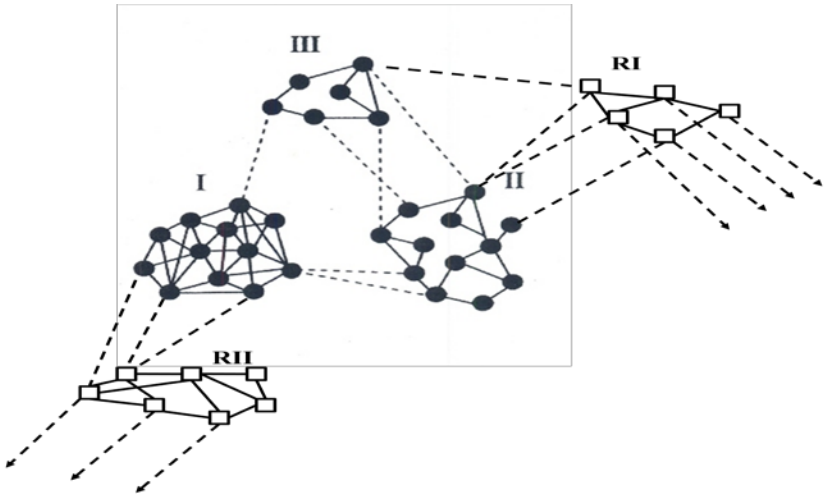


FIGURE 3: USER CLUSTERS & REGULATOR CLUSTERS



■ TOWARD NEXT STEPS

The case studies were chosen to illustrate the possibilities, or not, of compatibilities of ecosystem, socio-economic and governance systems co-existing without impingement on each other. They do not provide evidence of theoretical propositions, but rather illustrations of a concept of impingement. The next step would be to formulate an analytic theory for subsequent testing. This, our concluding section, will not proceed that far. Rather we will suggest how the theory could be developed from our current evidence.

First, one principle is that context matters. We have dealt only with the Great Lakes and some sites within these huge bodies of water Prima facie evidence and analyses would suggest that any set of conclusions must be adaptable to different contexts.

Second, our studies suggest that well defined ecosystem problems can be addressed in a positive sum way by socio-economic and governance systems. These include lamprey invasions, eutrophication, and beach management.

Thirdly, what the cases suggest in contrast is that there are few if any mediating arrangements to transform systems of negative interdependencies into positive ones. Explicit efforts to induce collaborations from antithetical interests rarely are successful, and across national boundaries, they can be exacerbated. "Collaborative science" and norms of "non-impairment" are insufficiently powerful to withstand the self interests of waste disposal and other interests that can span national boundaries. Mutually agreeable arbitration processes are difficult to establish and implement particularly across international boundaries and particularly in the face of long established rules about property rights. The medieval concept of "navigable servitude" is a prime example of the last phenomenon, a property right accorded to commercial shipping if in conflict with other uses.

Fourth, if these conclusions are correct, then it appears that well defined problems within ecosystems, within socio-economic systems and within governance systems need not impinge on each other even if they have potential consequences on another system. Recreational marinas can be established and operated without impingements on marshlands or upon waterfront vistas for clusters of riparian residents. Ballast waters of commercial ships can be scoured in distant marine waters even at the expense of newly constructed cargo hold linings to contain residue waters. Governance systems can regulate the production and discharge of endocrine disrupting toxic chemicals. The possibilities seem to exist for movement toward non-impingement with well defined problems. These possibilities are not inevitable processes. Human and other living systems may still wish to exploit any temporary and personal advantages of common pools without a res publica or res communes set of management tools.

In sum, our paper suggest the following propositions for both verification and inclusion in an analytical theory.

Sustainability is inversely related to the impingement of one of more of ecosystems, socio-economic and governance systems on each other.

- Well defined ecosystems, socio-economic or governance problems are inversely related to impingement.
- Multiple and mixed ecosystem, socio-economic or governance problems are directly related to impingement.
- Crafting well defined problems is directly related to interdependencies amongst ecosystems, socio-economic uses and governmental jurisdictions.
- A theory of impingement avoidance is a function of crafting information, expertise and collaboration across governance and socio-economic boundaries.

Clearly these propositions represent the conclusions of some first steps toward a proper theory of impingement. We await the next steps.

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■ APPENDIX A: BINATIONAL GOVERNANCE ARRANGEMENTS OUTSIDE THE GREAT LAKES AGREEMENT INVOLVING INSTITUTIONS INDEPENDENT OF THE IJC

INSTITUTION	PURPOSE	MEMBERS	ACTIVITIES/HISTORY	STAFF/FINANCES
Great Lakes Fishery Commission	Coordinate maintenance of fisheries	4 from each side, named by Privy Council and President	Control sea lamprey; coordinate and advise on other fishery matters	Lamprey costs splits 69%/31% U.S./Canada; other costs evenly
Council of Great Lakes Governors	Provide a forum on mutual interests	Governors, with premiers as associate members	Developed Great Lakes Charter and seek to promote economic development in region	$20,000 annual dues, plus foundation and private support for special projects
Great Lakes/St. Lawrence Maritime Forum	Promote trade and commerce	Includes government and nongovernment organizations	Promote use of Seaway but has no formal agenda	Funds raised ad hoc for projects
International Association of Great Lakes Ports	Promote Great Lakes shipping	4 US, 5 Canadian port authorities	Lobby on impediments to use of Seaway	Annual dues of $500
Niagara River Toxics Committee	Investigate toxic chemical problems	2 each EPA, NY, Ontario, and Environment Canada	Formed by agencies to recommend actions on Niagara toxics	Staffed and financed by initiating agencies
Upper Great Lakes Connecting Channels Study Committee	Assess toxics in rivers and Lake St. Clair	Fisheries and Environment agencies, with IJC observer	Formed in 1984, with study to be completed in 1988	Staffed and financed by initiating agencies
Coordinating Committee on Hydraulic and Hydrologic Data	Coordinate methodology for data collection	Environment Canada, Fisheries and Ocean Corps, and National Oceanographic and Atmospheric Administration	Formed in 1953 to assure compatibility of data	Staffed and financed by initiating agencies
Michigan-Ontario Transboundary Air Pollution Committee	Develop cooperative program for air pollution	Wayne County, Michigan Department of Natural Resources, and 2 from Ontario Ministry of Environment	Initiated by governors and premiers; worked closely with IJC air board to 1983	Staffed and financed by participating agencies

INSTITUTION	PURPOSE	MEMBERS	ACTIVITIES/HISTORY	STAFF/FINANCES
Memorandum of Intent on Transboundary Air Pollution	Develop basis for negotiating agreement especially on acid rain	Government scientists organized in 4 technical working groups	Committee work stalled, with negotiations now by formal diplomatic procedures	Expenses covered by governments through participating agencies
Migratory Birds Convention	Control killing of migratory birds	No formal body for implementation	Signed 1916	
International Migratory Birds Committee	Foster cooperation under 1916 convention	Resource ministers and cabinet secretaries	Established 1960s; has not met since 1970s	
Canada-U.S. Programme Review Committee	Advise governments on protection of migratory birds	3 each from federal governments	Developing North American Waterfowl Management Plan	Research and participation financed by agencies
Mississippi Flyway Council	Recommend hunt regulations	1 from each state and province	Recommend regulations to federal governments	Staffed and financed by participating agencies
St. Lawrence Seaway Authority and Development Corp.	Coordinate construction operation of seaway	Administrators appointed by federal governments	Determine policies jointly for separate implementation	95% financed by tolls; balance by federal transportation agencies
Seaway International Bridge Corp.	Operate bridge at Cornwall	8 members, mostly from Canada	Maintain bridges and collects tolls	95% by tolls; balance by Seaway agencies
International Boards of Control (4)	Assist IJC decision on levels and flows	Equal members from each side named by IJC commissioners	Develop and implement regulation plans since 1909	Staffed by agencies; report publication financed by IJC
International Great Lakes Levels Advisory Board	Advise IJC on levels and public information	16 members, 8 per side, with half the members from public	Carry out studies; reports twice a year	Financed by agencies and IJC
International Great Lakes Technical Info Network Board	Study adequacy of levels and flows measurements	Environment Canada, Fisheries and Oceans Corps, and NOAA	Reported to IJC 1984 on user needs and adequacy of data	Financed by agencies involved in study and data collection
International Air Pollution Board	Advise governments on air quality	EPA, 1NY, and 3 Environment Canada	Report twice yearly on transboundary pollution	
Joint Response Team for Great Lakes	Cleanup of oil/hazardous materials spills	Canada and U.S. Coast Guards and other agencies	Maintain Joint Contingency Plan, invoked 9 times since 1971	Staffed by agencies; cleanup costs where spill occurs

APPENDIX B: AREAS OF CONCERN IN THE GREAT LAKES-ST. LAWRENCE RIVER BASIN

Source: Environment Canada, *Our Great Lakes*, 1999 <www.ec.on.gc.ca/glimr/maps-e.html>

■ APPENDIX C: CATEGORIES OF USE IMPAIRMENTS FOR AREAS OF CONCERN ON THE GREAT LAKES

Area of Concern	Ecological health and reproduction						Habitat	Human health		Human use/welfare					
Lake Superior															
Peninsula Harbour	3			6			14	1				7	9		
Jackfish Bay	3	4	5?				14	1?			6	7		11	
Nipigon Bay	3	4?		6	8		14	1		2		7		11	
Thunder Bay	3	4	5?	6		13	14	1	10			7		11	12
St. Louis Bay/River	3	4	5?	6			14	1	10	2?		7		11	
Torch Lake				6											
Deer Lake-Carp Creek/River								1							
Lake Michigan															
Manistique River				6			14	1	10			7		11	
Menominee River	3			6			14	1	10			7			
Fox River/Southern Green Bay	3	4?	5	6	8	13	14	1	10	2?		7	9	11	
Sheboygan River	3	4	5	6	8	13	14	1				7			
Milwaukee Estuary	3	4	5	6	8	13	14	1	10			7		11	
Waukegan Harbor	3?		5?	6		13	14	1	10	2?		7	9?		
Grand Calumet River/Indiana Harbor Canal	3	4	5	6	8	13	14	1	10	2		7	9	11	12
Kalamazoo River			5?				14	1							
Muskegon Lake	3		5?	6	8	13?	14	1				7	9	11	
White Lake	3		5?	6	8	13?	14	1				7	9	11	
Lake Huron															
Saginaw River/Bay	3		5	6	8	13	14	1	10	2		7	9	11	
Collingwood Harbour															
Severn Sound	3			6	8		14	1				7		11	
Spanish River Mouth	3		5?	6?		13?	14?	1	10			7			12

Area of Concern	Ecological health and reproduction						Habitat	Human health		Human use/welfare					
Lake Erie															
Clinton River	3	4		6	8	13	14	1	10			7		11	
River Rouge	3	4		6	8		14	1	10			7		11	
River Raisin				6				1				7			
Maumee River	3	4		6	8			1	10			7	9	11	
Black River	3	4	5	6	8	13?	14	1	10	2?		7		11	
Cuyahoga River	3	4	5?	6	8	13?	14	1	10	2?		7	9?	11	
Ashtabula River	3	4		6			14	1				7			
Presque Isle Bay		4		6?					10			7			
Wheatley Harbour		4?		6?	8?		14		10?			7			
Lake Ontario															
Buffalo River	3?	4	5?	6			14	1		2?		7			
Eighteenmile Creek				6?			14?	1?				7?			
Rochester Embayment	3	4?	5	6	8	13	14	1	10	2?			9	11	12
Oswego River	3	4?	5?	6?	8	13?	14	1						11?	
Bay of Quinte	3	4?		6	8	13	14	1	10			7	9	11	
Port Hope												7			
Metro Toronto	3	4?	5?	6	8	13?	14	1	10			7		11	
Hamilton Harbour	3	4	5	6	8		14	1				7		11	
Connecting Channels															
St. Marys River	3	4		6	8		14	1	10			7		11	
St. Clair River		4?	5	6			14	1	10	2?		7	9	11	12
Detroit River		4		6			14	1	10			7	9	11	
Niagara River (ON)	3		5	6	8	13?	14	1	10			7	9		
Niagara River (NY)	3?	4	5?	6			14	1				7			
St. Lawrence River (Cornwall)	3	4	5	6	8	13?	14	1	10	2?		7	9	11	12
St. Lawrence River (Massena)	3?	4?	5?	6?		13?	14	1							

The numbers in this table identify specific use-impairment categories used in the Great Lakes Water Quality Agreement. (Question marks indicate the impairments being investigated.) The GLWAQ lists 14 beneficial uses that may be impaired and in need of restoration. The four general categories below contain the 14 impairments identified by number based upon the sequence in which they appear in the agreement.

Ecological health and reproduction

Degradation of fish and wildlife populations (3)
Degradation of benthic populations (6)
Degradation of phytoplankton and zooplankton (13)
Undesirable algae/eutrophication (which may cause low dissolved oxygen levels that may in turn cause other impairments) (8)
Fish tumours and other deformities (4)
Bird or animal deformities or reproduction problems (5)

Fish and wildlife habitat (14)

Human health

Restrictions on fish and wildlife consumption (1)
Beach closings (bacteria) (10)

Human use (welfare)

Tainting of fish and wildlife flavour (2)
Restrictions on dredging (7)
Taste and odour in drinking water (9)
Degradation of aesthetics (11)
Added costs for agriculture or industry (12)

Source: Adapted from Environment Canada and U.S. Environmental Protection Agency (1995), <http://www.epa.gov/grtlakes/atlas/use-impa.html>