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Collective impacts: using systems thinking in project-level assessment

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ABSTRACT
Systems thinking is a way to better assess the collective effects of impacts arising from an individual project. Organizational silos have led to individual project-specific impacts being assessed in isolation, often ignoring the systemic interactions between impacts from the same project. This myopic approach does not properly capture the interrelated collective and systemic impacts of individual developments. This paper explores the problem, looks at addressing it through systems thinking, provides practical examples, and reflects on what this means for impact assessment.

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Sometimes it can be hard to see the forest for the trees. Presently, 1) project-specific assessments usually analyze selected impacts of a proposed project in detail, and 2) cumulative impact assessment usually examines impacts of proposed projects in combination with the impacts of other past, present or reasonably foreseeable future activities. This paper explores a level of assessment between these two that is largely missed: **assessing the *multiple* impacts of a *single* project, which may not be individually significant, but may be collectively significant, particularly when considered as interrelated parts of a system**. In this paper, I refer to these as 'Collective Impacts'. (In part, I use the term to deliberately distinguish these from cumulative impacts from multiple developments, for reasons described below).

In project-specific impact assessments, the question of whether a project is likely to cause significant adverse impacts on valued components (VCs) is often practically interpreted to ask 'What part of the project affects what VC in what way?'. When proponents are predicting the project-specific impacts of their proposed projects, they often focus primarily on linear pathways (causal chains) from certain parts of the project to particular VCs. Proponents' impact predictions typically identify a source activity that leads to a change in an indicator and results in an effect on a VC.[1] Illustrated, it looks like this:

Project Activty → Change in Environment → Effect on VC

Unless a project-specific impact identified in this way is determined to be significant, it will be considered 'secondary' and usually will not be carried forward for any broader consideration because each impact is, in isolation, not expected to result in significant effects. In addition to overlooking certain impacts that may be significant only in a cumulative context, **this approach poses a different problem: It prevents assessments from examining whether the impacts arising from a single project may be collectively significant when considered together**. This matters, because an impact that is not significant to a particular VC in isolation could still be significant to the system that the VC is part of, or it could be one of many that are collectively significant to that system.

This paper examines how systems thinking can help IA practitioners better assess collective impacts, and why they matter. It is organized into three main parts:

(1) how ideas about silos and systems relate to assessing collective impacts, how this is different from cumulative effects assessment, and the concept of impact splitting
(2) recent Canadian examples from the Mackenzie Valley Environmental Impact Review Board (the Review Board) of assessments that identified collective impacts that were significant, and practical approaches to mitigation
(3) further reflections on what this means for scoping and VC selection, and simplified steps to assessing collective impacts systemically

An example of collective impacts

A practical example of a proposed project with project-specific impacts that were collectively significant at a system level serves to demonstrate the concept of collective impacts. The Mackenzie Valley Environmental Impact Review Board conducted an environmental assessment (EA) of a proposed

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expansion of the Taltson hydroelectric project in Canada's Northwest Territories. In this, the developer determined that impacts resulting from rare flooding events were not significant for any VC in a river downstream. For example:

- Although flooding could harm fish eggs from siltation or by washing them away, it was only for a short period in the spring.
- Flooding could also drown furbearers such as muskrat and beaver in their dens, but this too was for a short but different period.
- Flooding could also destroy eggs and nests of waterfowl, and drown their young chicks, but only for the relatively short nesting and brooding season.

Because the vulnerable period for any of these events was brief, and flooding was infrequent, the developer concluded that each impact was not likely to be significant. The developer concluded that each of 21 different impacts related to flooding were not significant (MVEIRB 2010, p. 51–62).

However, when the Review Board considered the impacts of this project collectively, it observed that all the short periods of vulnerability added up to a considerably longer one. It determined that a significant adverse impact *on the river ecosystem overall* was likely over the 40-year life of the project. Even though it could not say whether the impact would be on fish, fur bearers, or waterfowl, benthos, aquatic plants, bank erosion or wetland re-establishment, it could still identify the collective vulnerability of the river ecosystem that includes these components. This conclusion arose from collectively considering the combination of the individual impacts related to flooding that the proponent found not to be individually significant (p. 75). This assessment of the suite of interrelating and collective systemic impacts on a different VC (the river ecosystem), at a different level, was more realistic and meaningful than would have been possible assessing individual VCs in isolation.

This is a simple example, and is purely biophysical, unlike most of the other examples below. It shows how the effects of this single project on individual VCs were only significant when the assessment panned back to consider their collective impact, at the broader systemic level where they interact.

The world is made of systems, not silos

One of the reasons that collective impacts have been overlooked in most assessments of proposed projects is because of siloed thinking. The real world is made up systems, while project-specific impact assessment typically focuses on individual components (as the proponent's predictions in the above example illustrate). This is siloed thinking, the opposite of systems thinking. In the words of systems theorists Russel Ackhoff and Fred Emery (1972 p. 4):

> Nature does not come to us in a disciplinary form. Phenomena are not physical, chemical, biological and so on. The disciplines are the ways we study phenomena: They emerge from point of view, not from what is viewed. Hence the disciplinary nature of science is a filing system of knowledge. Its organization is not to be confused with the organization of nature itself. Over time our concept of nature has broken, like Humpty Dumpty, into bits and pieces, and, like all the king's men, we are having trouble putting it back together again.

It has proven organizationally convenient for various institutions and disciplines to conceptually separate and order a chaotic world into isolated parts. The problem of silos in impact assessment is widely recognized. Various types of IA, such as Risk Assessment, Health Impact Assessment, Strategic Assessment and so forth are also siloed (Morrison-Saunders et al. 2014). Government bodies with various social and ecological mandates are also divided. In Canada, one government body is responsible for the fish, another for the water, and another responsible for the people who depend on fishing. Resource regulation is also discipline specific, with separate authorizations for the use of different types of resources, such as water, land and wildlife. Most of us have been educated in elementary, secondary and post-secondary schools where different subjects are taught in isolated silos. Major environmental consulting companies are typically made up of many specialists and few generalists.

This compartmentalization is reflected in the major documents of many impact assessments, from the proponent's submissions such as Environmental Impact Statements to the EIA decision makers' decision documents. These might have separate chapters analysing impacts on each VC, such as one on fish, another on water, another on cultural impacts, and so forth. As Slootweg (2015) states, 'The world is organised according to sectors, each having its own educational background, its own working environment, its own language and culture and its own silo. Where silos do not meet, it works well. However, in an increasingly crowded and interconnected world it creates problems'.

The need for systemic integration

The need for integration of the silos in impact assessment has been recognized. *Principles of Impact Assessment Best Practice* (1999) of the International Association for Impact Assessment and the Institute of Environmental Assessment prescribe that, as a basic principle, 'EIA should be . . . (i)ntegrated – the process should address the interrelationships of social, economic and biophysical aspects' (p. 3). Integrative systemic thinking has long been an important aspect of sustainability assessment. As Gibson et al. (2005) expressed it, '(e)xperts increasingly agree that the key reality faced in environmental work, and in most other policy fields, is the functioning of intersecting, interdependent, dynamic and perhaps inconceivably complex systems' (p. 32).

A 2014 roundtable in *Journal of Impact Assessment and Project Appraisal* focussed on integration. In this, a paper titled 'Strengthening impact assessment: a call for integration and focus' by Morrison Saunders et al. observed that the world's first impact assessment legislation specified that agencies of the US government shall 'utilize a systematic, interdisciplinary approach which will insure the integrated use of natural and social sciences and the environmental design arts in planning and decision-making which may have an impact on [the] environment' (SHRUSA 1969, par. 102(2)(A)). The same paper identified over 40 different types of EIA that have arisen since as silos of practice, and called for integration which includes an interdisciplinary approach, 'developing a holistic collective understanding of the potential impacts of the proposal . . . ' (p. 5).

In the same roundtable,

- Kim and Wolf (2014) state that 'comprehensive assessment is inherently integrative', and that a focus on sustainable futures is a way to enhance EA practice towards more integration and sustainable development, a 'crucial goal'. Kim and Wolfe note that the Rio+20 conference report of 2012 emphasized the need for ' . . . integrating economic, social and environmental aspects and recognizing their interlinkages, so as to achieve sustainable development in all its dimensions'.
- Greig and Duinker (2014) state ' . . . the key to integration is rigorous systems analysis that seeks understanding of complex interactions between human actions and valued ecosystem components, and likewise among those components' (per Holling 1978), and that if integration is not happening in impact assessment, ' . . . then we need to admit that either the IA community does not know how to do it, or it is not essential to come to the inevitable finding in most EAs of no significant adverse environmental effect'.

Other authors have since identified a similar need for integration. Jones (2016) cites several disincentives to interdisciplinary research and collaboration, but notes that silos that separate fields such as natural sciences and social sciences need to be overcome to address sustainability issues. Stewart and Harding (2021) assert that siloing in EA is 'largely as a matter of practical management necessity, and so as to leverage the scientific method by focus upon discrete, analysable and measurable aspects of nature'. Stewart and Harding suggest that this is a reason why valued ecosystem components (VECs, per Beanlands and Duinker 1983) dominate the IA language and thinking, and observe that the spread of 'alternative, more holistic, ecosystem-based approaches' has been a worthy but uphill battle in impact assessment.

Arguments against integration in impact assessment

Not all authors agree about the need for greater integration in EIA. Fischer (2014) agrees with the principle of integration, but notes that there are good reasons for, and advantages to, the diverse types of impact assessment, which are based on the differing relevance of various types of issues in different places and political or social contexts, and have specialized terminology. Vanclay (2014) recognizes that '(t)he call for greater integration has been a long-running one in the International Association for Impact Assessment', but notes examples where integration has led to under-consideration of some types of issues (such as social issues) due to the dominance of others (such as technical issues). Vanclay expects that an integrative approach would only be acceptable if the kinds of impacts examined by diverse types of impact assessment (such as social impacts, health impacts and impacts on human rights) are fully considered. More recently, Fischer et al. (2021) raise a similar concern that integration can lead to under-consideration of some types of impacts when they are overshadowed by others. They describe health impact assessments in England where integration led to environmental impacts being subordinated to economic aspects, and ultimately under-considered as a result.

Using systems thinking more in impact assessment would move towards the integration called for by most of the authors cited above, but it also may help reduce the above disadvantages of integration identified by Vanclay and Fischer et al. By considering the systemic interrelationships between different valued components, a project's impacts on each VC within the system is brought into a more meaningful context in the assessment. Looking at how the different components fit together and interrelate means than no individual VC automatically overshadows the rest. Impacts to VCs that may be under-considered in typical project-level assessments (which examine them in isolation) may instead be recognized as important for their contribution to the collective systemic impact. For example, instead of considering economic factors above health or social issues (as in the case study of Fischer et al.), a systemic approach looks at how the economic, health and social factors combine and interact, and what that means for overall system functioning. This reduces the risk of one type of impact unduly overshadowing others.

Disregarding certain groups of impacts in light of economic benefits (as in the Fischer et al. case study) is effectively a form of unsustainable trade-off. Applying the sustainability trade-off rules when assessing impacts systemically can further protect against such concerns. Gibson's (2006 p. 175) trade-off rule states that 'trade-off decisions must not compromise the fundamental objective of net sustainability gain'. Ignoring impacts on certain valued components in light of economic aspects appears to compromise net sustainability gain when viewed in an integrated and systemic perspective. Morrison-Saunders and Pope's (2013) rules specify that trade-offs are ineffective mitigation if the benefit and impact are in different categories (meaning, for example, that an economic beneficial impact does not mitigate a social impact). Bearing these trade-off rules in mind, particularly in a systemic perspective, integration need not mean considering some types of effects at the expense of under-considering others.

Understanding systems

The separations of real-world systems into siloed parts are artificial, convenient, and ineffective in predicting the real impacts of projects on the systems of people and environments surrounding industrial projects. In the real world, the parts fit together in an interacting system that includes people (in their many facets) and nature. Berkes and Folke (1998) refer to these as 'socio-ecological systems', and consider any separation of these aspects to be artificial. In the words of Gibson et al. (2005, p. 95): 'Human well being is utterly dependent on the integrity of biophysical systems, at every scale from the local to the global. We rely on the key life support functions of these systems, and on the resources and conditions that these systems maintain. At the same time, we are active participants in the world's biological systems … ' Gibson also asserts that 'the trends observed in the maturation of environmental assessment … reflect broader influences such as those arising from a greater understanding of complex systems … ' (p. 36).

Some systems are complex, and systems theory may seem abstract and theoretical to most EIA practitioners. Unlike with simple linear models, changes in systems can be hard to predict, because some systems are complex and involve multiple moving parts that change in ways that are not linear, with processes that vary over space and time, and include (stochastic and random) surprizes (Holling 1973). They have emergent properties, can rapidly flip from one state to another with multiple equilibria, and have feedback loops (Ludwig et al. 1997; Liu et al. 2007). Different systems have different degrees of resilience and stability.

To further challenge simple prediction, systems have cyclic characteristics (following the adaptive cycle of exploitation/growth, conservation, release/collapse and reorganization/renewal phases [Holling 1986]) and exist within a hierarchy of other systems, like dynamic Russian matryoshka dolls. The set of scales is called a 'panarchy' (Gunderson and Holling 2002). Systems have nested dynamics at particular scales, and at 'at any particular scale, the system is a sub-system of the whole panarchy … ' (Ludwig et al. 1997; Walker et al. 2004). Social-ecological systems are nested in this way (Ostrom 2007). So, for example, some of my own cellular systems form tissues, some tissues in systems make my organs, my system of organs makes me function, I am part of my functioning community, I and it interact with local ecological systems in our surroundings, and those form part of the larger scale regional systems, on up to the planetary scale (which we as a species now have unprecedented potential to affect and, therefore, unprecedented responsibility to care for).

The property of a system to absorb disturbances while maintaining its structure and functional properties is referred to as resilience (Gunderson et al. 2010). Resilience assessment is a developing practice in impact assessment that examines systems in depth to evaluate the vulnerability of a system to a disturbance crossing thresholds that affect system functions and states. This can help in developing ways to buffer or cope with changes.

This paper does not further explore the more abstract concepts of resilience assessment or systems theory, but rather focuses on practically applying some basic principles of **systems thinking** to project-specific impact assessment, as demonstrated in the examples provided later in this paper. Systems thinking has been defined as 'a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviors, and devising modifications to them in order to produce desired effects' (Arnold and Wade 2015). Applying systems thinking does not require an in-depth understanding of current systems theory. Systems thinking can be practically approached as 'a way of seeing and understanding a situation that emphasizes both the parts and the relationships among the parts rather than the parts in isolation' (Allen and Kilvington 2021). This approach is useful for impact assessment.

The system's properties come from the way its parts interact. Ackoff (2004) describes the method of inquiry for understanding those interactions as *synthesis* (examining how a component functions in a systemic context), as opposed to *analysis* (examining the parts of a component to see how it works). Thus, silo thinking strives to understand something by isolating its parts, and systems thinking strives to understand something by integrating it into a larger whole. I believe this is a key difference between assessing impacts on VCs in isolation (conventional linear *analysis*) and assessing impacts on VCs within systems (systemic *synthesis*).

Assessing impacts in systems involves a change of perspective to include a broader context. In project-specific IA we focus on predicting and *analysing* the potential impact of a proposed project on VCs. The act of analysis uses a method of inquiry involving zooming in, to examine in detail the potential impacts to a VC. The analogy of a camera is helpful. Like a camera, an impact assessor is able to focus on certain subjects, and can view them through different lenses. Also like a camera, an impact assessor can zoom in to see finer detail, or pan out to encompass a broader scene. Finally, an impact assessment, like a camera, has a scope that defines its focus (more on this below). I believe that project-specific impact assessment is often myopic, and is made better by sometimes moving from analyzing fine detail to seeing the interrelationships of multiple different parts of systems. To better understand impacts on systems, we need to move from a microscope to a fish-eye lens.

Perhaps it is time for IA practitioners to pan back from a rigid focus on valued *components* to also consider the impacts on the valued *whole*. The word 'component' means a part of something greater (from *componentum*, 'to put together, to collect a whole from several parts'). The reference to 'components' within the widespread concept of Valued Eco*system* Components (VECs) thus implies a system. Systems have therefore always lurked, usually in the background, of assessing impacts on VECs. The concept of valued components is used universally in EIA, but they should be considered in a holistic manner. If we make a point of considering systems, as well as their components, we will do a better job (and not be vexed by VECs).

Although most project-specific assessment to date focusses on individual valued components, some recent guidance supports systems thinking and assessing multiple impacts of a project collectively, similarly to what is advocated in this paper.

- Western Australia's EIA policy and guidance includes provisions for 'holistic impact assessment' to consider environmental interconnections between components and the acceptability of the project as a whole (Western Australian Government 2016 [s. 3.1.2.1]; Morrison-Saunders 2018).
- The first principle of the Impact Assessment Agency of Canada's Framework for Implementation of Sustainability Guidance, part of the new (2020) *Practitioner's Guide to Federal Impact Assessments under the Impact Assessment Act*, is 'Consider the interconnectedness and interdependence of human-ecological systems' (s. 2.3 ss. 3). It states '(i)n order to consider properly the interactions among effects, a project's contribution to sustainability should be examined using a "systems" approach' (s. 2.3 ss. 3.1). Another part of the *Practitioner's Guide* requires an Impact Statement to consider interactions between effects, and describe effects holistically using a systems approach (s.1.2 ss. 13.2).
- Morrison-Saunders and Arts (2021) recently included the concept in a paper describing the International Association for Impact Assessment's new draft best practice principles for follow-up in EIA. They state that impact assessment follow up should 'consider the overall effects of the proposal'.

Not just another name for cumulative effects assessment

Considering how multiple effects of a single project interact systemically is not the same as cumulative effects assessment as it is widely practiced. Although both involve integrating impacts, cumulative effects are usually defined in EIA to mean effects that result from the impacts of a proposed project (or action) in combination with **other** past, present or reasonably foreseeable future projects (or actions) (e.g. (US CEQ 1997), s. 1508.7; (World Bank 2013, p. 19); (Impact Assessment Agency of Canada 2020), par. 22(1)(ii); (Hegmann et al. 1999); (Ross 1998), (MVEIRB 2004)). This paper, up to this point, has not focussed on the impacts of multiple projects, but rather on the multiple effects of a *single* project on a VC (or system thereof).

As with cumulative effects assessment, this involves considering the combined result of multiple impacts, but unlike cumulative effects, these impacts are all caused within the lifespan of the same proposed project, and within the area affected by that single project. [Because term 'cumulative effects' is (rightly) associated with effects from multiple projects, to avoid confusion I deliberately avoid using the term here when referring to the combined impacts of a single project]. These differences are summarized in Table 1.

Despite the relevant differences, a common principle applies: Cumulative effects assessment tells us to assess combined effects of multiple impacts from

Table 1. Contrasting cumulative and collective impacts.

	Cumulative Impacts	Collective Impacts
Number of projects	multiple projects	single project
Timespan	past, present and future (RFFDs)	project lifespan
Extent	often large scale, regional +	area affected by one project

different projects, and the same logic applies to assessing the combined diverse impacts from one project. Sinclair et al. (2017) state, referring to a cumulative effects assessment mindset, that 'sources of stress, including the project at hand, can combine in ways that may bring undue compromise to VEC sustainability, ways that are masked or missed in any search for impacts of individual stressors on the VEC' (p. 7). The same applies to collective impacts.

This is not intended to suggest that systems level collective examination of project-specific impacts should replace detailed analysis of VCs. Each is valuable to understand project impacts. Similarly, understanding the collective systemic impacts of a project should improve cumulative effects assessment, which remains vital to making good decisions about proposed developments. I believe a thorough impact assessment of a proposed project should include considering the whole range of impact types, including:

(1) effects on traditional valued components
(2) broader synthesis of interacting project-specific collective impacts on systems, and
(3) integration of cumulative effects from other projects and activities.

At a tier beyond these is strategic impact assessment. It shares some characteristics with the approach I am advocating here (evaluating project-specific impacts collectively), but is a different kind of beast. While strategic impact assessment, done well, also uses a systemic perspective, it looks at potential futures arising from plans, programmes and policies, to identify underlying causes and inform decision makers of the implications of different options (Partidario 2007). This serves an important (and I believe, in North America, underused) function, but systems-level thinking for project-specific impacts is different. The focus here is on assessing impacts of *individual developments*, to determine if and how they should proceed, and to identify mitigations to reduce or avoid significant residual impacts or enhance positive effects. The results should then be useful to better inform cumulative effects assessment and, hopefully, strategic and regional impact assessment.

Impact splitting

One critique of project-specific EIA is that proponents and their consultants very rarely, if ever, conclude that their proposed project is likely to cause significant adverse residual impacts (after the proponent's proposed mitigations). Such a conclusion would not be in a proponent's apparent interest. However, in the real world, if you explore most heavily industrialized landscapes, large-scale long term impacts of a high magnitude are self-evident and plainly obvious. This difference, between the developer's claims that there are would be no significant adverse impacts and the actual situation that results on the ground, does not help build societal trust in EIA (Schindler 2008). In over 20 years at the Review Board, I have yet to see a proponent predict that their proposed project, with their proposed mitigation, would likely cause significant adverse impacts (even though the Review Board usually has reached this conclusion, and therefore usually has required additional mitigation).

A system's properties come from the way its parts interact. This cannot be understood by looking at the parts separately, because when the system is taken apart, it loses its essential properties, and so do its parts (Ackoff 2004). Methodologically, siloed thinking about VCs may limit any further systems thinking of the collective significance of multiple impacts arising from a single project, if impacts are just considered 'secondary' and not individually significant. I call this impact reductionism 'impact splitting' (a close cousin to project splitting). Project splitting involves proponents seeking approvals for parts of a larger project separately, to avoid more rigorous EIA for the total project. Impact splitting involves considering significance determinations of individual impacts separately, to avoid a finding of significant adverse impact for the total effects of a project. Both involve flying below the impact assessment radar.

I believe that this is another reason why many assessments of major projects often have not resulted in determinations of significant adverse impacts (in addition to the developers sometimes choosing inappropriate thresholds of significance, examined in Ehrlich and Ross 2015). It is easier to argue that a project is not likely to cause significant adverse impacts if you only consider the project's impacts one at a time, in isolation. Looking at the effects of a proposed project only by reducing them to individual impacts on separate VCs is a reductionist approach that misses the whole picture – resulting in not seeing the forest for the trees. In reality, however, the total collective result of the impacts may be significant, even if the individual contributing impacts are not.[2] This impact reductionism may also be a reason why some developments cause impacts that seem greater than predicted, but rarely (if ever) less than predicted.

Systems thinking in the Review Board's EAs

Recent environmental assessments by the Mackenzie Valley Environmental Impact Review Board (Review Board) demonstrate a practical approach for using systems thinking to collectively assess the combined effect of project-specific impacts. The Review Board is a court-like tribunal that conducts participatory EIAs in Canada's Northwest Territories. It is empowered by the *Mackenzie Valley Resource Management Act*, a federal law that resulted from modern Indigenous land claim agreements that replaces other federal assessment legislation in the Mackenzie Valley (an area approximately seven times the size of England). The Review Board assesses a wide range of impacts, including biophysical, socio-economic and cultural impacts (even though its primary process is legally called '*environmental* assessment' [EA]). Board members are nominated by Indigenous organizations and by governments. At present, over half of the Board members are Indigenous.

Compared to the siloed perspectives described above, the Indigenous worldview is holistic and integrated.[3] The *Tlicho Agreement* [par.22.2.26 (d)], a modern land claim agreement in Canada's Northwest Territories with the Tlicho (formerly Dogrib) First Nation, reflects this worldview in its requirements for environmental impact reviews to consider 'the importance of conservation to the Tlicho First Nation well-being and way of life' (Government of Canada, 2005). This implies that the process must have regard for systemic connections between biophysical components and socio-economic and cultural components. This is reiterated almost verbatim (and includes other Indigenous groups) in the *Mackenzie Valley Resource Management Act*, where it is identified as a guiding principle and legal requirement of EIA processes (Government of Canada 1998, [par. 115(1)(c)]).[4] (It is worth noting that the more EIAs reflect reality to Indigenous people, in terms of the holistic and integrated worldview, the more likely those EIAs are to be trusted by them, and may better serve as a tool for Indigenous reconciliation).

As a co-management tribunal with Indigenous Board members who have lived in small Indigenous communities with traditional ties to the land, it should not be surprising that the Review Board is well poised to intuitively grasp the Indigenous systemic worldview. Board members understand that an Indigenous person living near a new industrial development is not likely to experience individual impacts in isolation. He or she may *simultaneously* experience changes in familiar wildlife patterns, loss of harvesting areas, loss of food sources, an influx of outsiders, more drugs and alcohol, water quality concerns, cultural changes and more.[5] It would be a mistake to assess such changes as if they were experienced one at a time.

In several recent EAs, the Review Board has holistically considered multiple impacts from single industrial developments. It has recognized that the impacts arising from a single project can be collectively significant when viewed through a systemic lens, even when some or most of the individual effects were not determined to be significant in isolation. The following visual tool and examples are from completed environmental assessments where this influenced the Review Board's EA decisions.

Visualizing the integrated system in EA

The system diagram below, from a recent Report of EA (the Review Board's formal decision document describing its EA findings, reasons, and, usually, mitigation measures), is a practical illustration that helps show the principle of what I am referring to as 'systems thinking'. It involves the environmental assessment of a proposed highway to Whati, a primarily Indigenous Tlicho First Nations community. Whati was accessible by winter ice road for several weeks a year, but without all-season road access to the highway system. In its Report of EA (MVEIRB 2018), the Review Board provided a diagram of the integrated system as described by Elders, traditional harvesters, youth and other community members during EA hearings and in other evidence submitted to the Review Board (Figure 1).

This system diagram is a simplified illustration of the complex relationships between selected parts of the socio-ecological system, indicating the interdependence and dynamics of the parts of the system.[6] The diagram focuses on the connections and interrelationships of the components of the subjects raised in the EA. Its breadth is vast and it spans many scales, from global phenomena of climate change and habitat loss, predator prey dynamics, traditional harvesting and language, to impacts on drug use and family connectedness.

The system diagram was accompanied by simple qualitative descriptions of some of the interrelationships it illustrates. For example (p. 24–25),

> Climate change, wildfires, and the effectiveness of habitat for wildlife are interrelated parts of the boreal forest ecosystem. For example, climate change is expected to result in an increased frequency and intensity of wildfires, which changes the effectiveness of habitat for different wildlife species. Mature forest, with lichen, is preferred boreal caribou habitat, but after forest fires the successional plants that

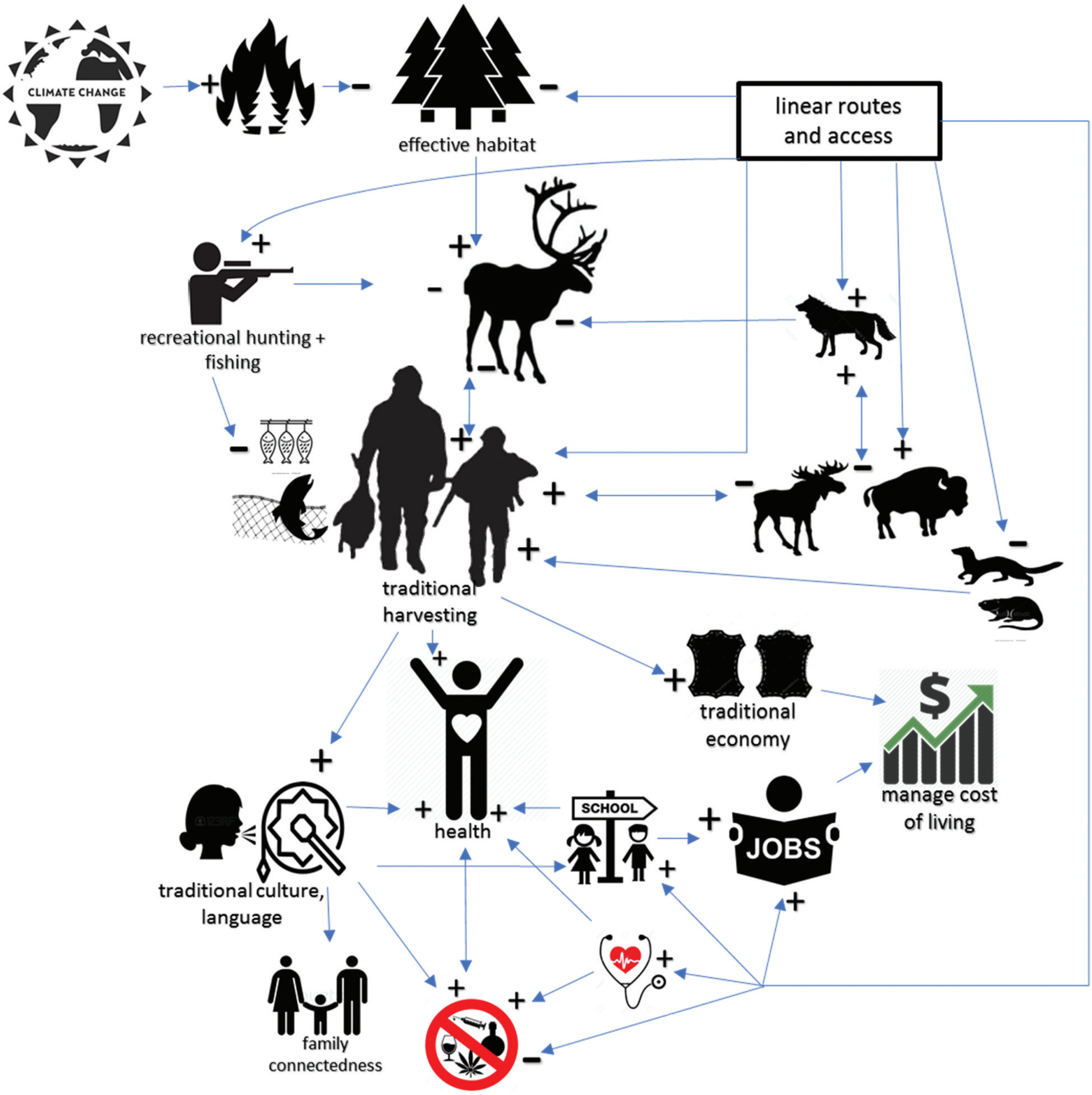

Figure 1. An integrated socio-ecological system. This system diagram is a partial illustration of connections between related and interdependent parts of human and ecological systems in the area of a proposed highway in Canada's subarctic (Mackenzie Valley Environmental Impact Review Board [MVEIRB] 2018, p. 26). Plus (+) and minus (-) symbols indicate whether an increase in one VC is expected to result in an increase or decrease in a connected one (e.g. an increase in linear routes and access results in increases in wolf predation and recreational hunting, which each result in decreasing caribou numbers).

> regenerate are preferred by moose ... Linear routes, such as trails, roads and any other linear feature that increases access can reduce effectiveness of habitat (through fragmentation), increase access and predation by wolves, and increase access for traditional harvesters and non-Aboriginal recreational hunters and fishers. All this affects the prey or hunted species. Increased human activity can also reduce numbers of some harvested furbearers, while roads may increase the presence of bison.

The relationships between socio-economic and cultural aspects of the illustration were also summarized. For example (p .25),

> Traditional culture and language can promote good health and family connectedness and reduce addictions. Recovery from addiction is also promoted by strong family connectedness, while addictions can erode family connectedness and health. Access to medical and health services (including mental health services) promotes recovery from addictions and promotes well-being in many ways.

This system diagram is a simple visual representation of the relationships between the VCs that parties to the EA focussed on, showing the systemic context in which the proposed highway would be developed. It is a snapshot of the baseline functioning of the system, the real world as seen through an Indigenous worldview as it was relayed to the Review Board for the purposes of the EA. It described the Board's understanding of the interactions of the VCs which were further analyzed individually and synthesized collectively in the remainder of its Report of EA.

In addition to showing some interrelationships between components, the system diagram shows the nature of the relationships (whether an increase in one part leads to an increase or decrease in a connected part), and the greater centrality of some components compared to others. This can help indicate the complexity of the system, but may also be useful in the impact assessment to show where impacts might be more significant at the system level, and where mitigative efforts might be most effective.

I believe this type of system diagram may prove a useful tool for other impact assessments, for more than just integrating the existing relationships between VCs. It is easy to imagine (perhaps following the analysis and conclusions of impacts predictions on each VC) a corollary illustration that shows how the VCs are likely to be affected by the suite of impacts caused by a proposed project, and indicates which connections in the system are strengthened or weakened *as the combined result*. This could be shown graphically using colours or by changing icon size to indicate impact severity, or changing the thicknesses of arrows to indicate strengthened or weakened relationships. By visually illustrating the resulting impacts to system functioning, this would show the change to the overall system (in contrast with the diagram of the baseline system). It could also help identify any opportunities for mitigations to address the systemic impacts (such as by increasing resilience by fostering redundancy of key functions).

A similar graphic could be used to show the collective effect of multiple entangled project-specific impacts in non-Indigenous contexts. This spiderweb of interactions in a system diagram (modified to show collective impacts) would be a distinct contrast to the linear model put forth by many proponents (project activity → change in environment → effect on VC).

Although I prepared the system diagram to show the relationships that Indigenous participants in Whati described to the Review Board during the Tlicho All-Season Road EA hearing, I have been happily surprised at the level of interest expressed in the diagram outside of that context. Board staff have shown the system diagram to Indigenous leaders, Indigenous EA participants, and Indigenous EA practitioners from across Canada in conferences and webinars, who have routinely remarked that the graphic more effectively portrays an Indigenous holistic worldview than any they have seen in impact assessment. The Impact Assessment Agency of Canada now features the Review Board's system diagram in the *Practitioner's Guide to Federal Impact Assessments under the Impact Assessment Act* and encourages practitioners to develop such images for use in engagement and to inform decision-makers (IAAC 2020). Based on feedback from recent meetings and conferences, IA practitioners' interest in the system diagram remains high.

Practical examples of assessing collective impacts' significance

In recent EAs the Review Board has deliberately considered collective impacts using a systemic approach when assessing project-specific impacts on VCs, in addition to examining the linear impact pathways as is more typical of project-specific impact assessment. As described above, this involved looking at the collective interactions and effects of multiple aspects of the project at a systemic level. The following examples describe environmental assessments where the Review Board concluded that impacts from a single project were collectively significant even though they may not have been significant in isolation. In these EAs, such impacts were considered at a higher systemic level:

- In its Report of EA for the Tlicho All-Season Road (Mackenzie Valley Environmental Impact Review Board [MVEIRB] 2018), where the above system diagram first appeared, the Review Board considered several project-specific impacts in a collective systemic manner. This included socio-economic impacts[7] (p. 92–107), impacts on boreal caribou[8] (p. 179–180) and cultural impacts (p. 271). For each, the Review Board considered the collective significance of multiple related adverse impacts that were not necessarily considered likely to be significant individually. For example, the Board integrated socio-economic impacts at the broader systemic level of community well-being, saying 'considering the combined impacts of all of the above collectively . . . the project will have a short-term significant adverse impact on community well-being during the construction and initial operation period of the road unless additional mitigation occurs' (p. 107).
- In the EA of a major diamond mine expansion in the arctic called the Jay Diamond Project, the Review Board's collective consideration of individual project-specific impacts to barren-ground caribou followed a similar approach.

The Review Board concluded that a combination of project-specific impacts were significant when taken together, and found these collective impacts to be even more significant when considered in the context of pre-existing cumulative impacts on barren-ground caribou (MVEIRB 2016, p. 115).

- In its most recently completed EA, assessing a long-term mine waste project at the Diavik Diamond Mine, the Review Board further developed its approach to considering project impacts with an integrated holistic perspective. It identified connections between the environment, culture and well-being and said it ' … incorporated this understanding into its evaluation of Project impacts, recognizing the interconnectedness of all parts of the human environment, biophysical environment, and well-being … Project impacts are considered both in terms of how they interact with those individual ecosystem components and the environment as a whole.' (MVEIRB 2020, p. 18).

Well-being as a systemic lens

The guiding principles of the *Mackenzie Valley Resource Management Act* [par. 115(1)(b) and (c)], require the Review Board to consider well-being in environmental assessments (Government of Canada 1998). For the Tlicho All-Season Road, Jay Diamond Project and Diavik EAs, the Board used the lens of well-being to consider a variety of impacts, because it recognized that social impacts are best understood and considered at the level of the system at which they interrelate. In these, well-being was the systemic lens which made the interconnections between impacts visible. This recognition was made explicitly in a perspectives paper published by the Review Board after these assessments, where the first theme the Board identified as a priority in its evolving EIA practice was 'Understanding effects to well-being: Improving understanding of the interconnectedness of the bio-physical world to the well-being of people, families, and communities in the context of major projects' (Mackenzie Valley Environmental Impact Review Board [MVEIRB] 2020b, p 12). The Review Board continues to develop this thinking (e.g. NeOlé Inc 2021) and is producing formal guidelines on assessing impacts to well-being using a systemic integrative approach.

Using a well-being lens in the Review Board's assessments appears to be a meaningful system-level approach for several reasons. Well-being is broadly (and innately) valued by potentially affected communities, and considering a project's impacts on well-being lends itself to systemic integration of multiple impacts in a holistic way, including ecological, social and cultural components. In the Review Board's assessments, this is partly a reflection of the intimate relationship of Indigenous peoples to natural systems. Using a well-being lens also has the advantage of being open to other kinds of assessment. In considering connections between people and the biophysical environment, well-being can also reflect an ecosystem services approach, which the Millennium Ecosystem Assessment (2005, p. 2)described as the 'inescapable link between ecosystem condition and human well-being'. Consideration of lasting well-being also evokes a sustainability lens (Gibson et al. 2005, p. 60). In the new impact assessment practitioners' guidance material from the Impact Assessment Agency of Canada, consideration of lasting well-being and systems thinking feature prominently in the material related to sustainability (Impact Assessment Agency of Canada 2020, s. 2.3 ss.3.4).

Mitigating collective impacts systemically

Just as the Review Board considered project impacts systemically, in some EAs it prescribed mitigations that were also collective and systemic. The mitigations were collective in that they were designed to work together as a suite, and systemic in that they were intended to mitigate multiple impacts, often at the system level related to well-being. For example

- In the Tlicho All-Season Road Report of EA, the Review Board's measures created a framework for the Government of the Northwest Territories to support the regional Indigenous government (the Tlicho Government) to engage communities annually in adaptive management of health and well-being impacts from the project for a minimum of ten years. This was intended to increase government's understanding of how the road is influencing daily life and well-being in a timely fashion, to help develop an effective governance response for a suite of undesirable impacts (Mackenzie Valley Environmental Impact Review Board [MVEIRB] 2018, p. 110).
- The Review Board concluded in the Diavik Report of EA that an 'integrated suite of measures is required to prevent significant adverse impacts on cultural use', and that the prescribed measures 'will protect both the biophysical and cultural aspects of the environment' (Mackenzie Valley Environmental Impact Review Board [MVEIRB] 2020, p. 74). The measures address water quality objectives, culturally relevant water quality criteria, modelling, and community engagement, and require the Government of the Northwest Territories to work with communities to develop indicators of cultural well-being.
- In its Report of EA for the Jay Diamond Project the Review Board prescribed measures to collectively mitigate a variety of social and cultural impacts,

which were framed in the systemic context of 'community health and well-being' (Mackenzie Valley Environmental Impact Review Board [MVEIRB] 2016, p. 174–175).

Mitigating systemic impacts can require broader tools than are required in the usual approach to VCs, but the interconnected characteristic of systems presents new kinds of options for creatively mitigating impacts.[9] In each of these three EAs, the Review Board's measures were intended to mitigate system level impacts resulting from collective impacts of each project (and certain pre-existing cumulative impacts). In each, the Review Board directed measures not only to the proponent but also to the territorial government.

- One of the Jay EA measures required the Government of the Northwest Territories to meet with potentially affected Indigenous communities to discuss priority social issues, effectiveness of government programs to address them, and improvements to mitigate them, with an annual public reporting requirement (Mackenzie Valley Environmental Impact Review Board [MVEIRB] 2016, p. 177).
- A measure in the Diavik EA required the Government of the Northwest Territories to work with Indigenous communities 'to develop indicators of cultural well-being, and to monitor and adaptively manage impacts from the Project and other sources', to deal with collective project-specific and pre-existing cumulative impacts on cultural well-being (Mackenzie Valley Environmental Impact Review Board [MVEIRB] 2020, p. 90).
- The measures in the Tlicho All-Season Road Report of EA described above require the Government of the Northwest Territories and the Tlicho government to conduct community engagement and adaptively manage impacts on health and well-being for the first decade of the project (Mackenzie Valley Environmental Impact Review Board [MVEIRB] 2018, p. 110).

As Ackoff (2004) states, in a system 'the place to attack the problem is not necessarily where the problem appears' (which is why one swallows a pill for a headache, instead of beginning with brain surgery, even though the pain is in the head, not in the stomach where the pill is digested). The Review Board's approach in these mitigations recognizes that although proponents are expected to mitigate the significant adverse impacts of their projects on particular VCs, when the collectively significant impact occurs at the system level, it is not always most efficient nor within the ability of a particular proponent to deal with impacts at this level (particularly when the collective impact of the project adds to pre-existing cumulative impacts that are already significant). Although a proponent may be well-placed to mitigate a project's impact on a VC, it may take an agency such a government body with a more expansive mandate to implement mitigations for impacts on a higher level system, because the system is broader than its components.[10]

Panning out

It is partly the nature of systems that enabled the Review Board to examine several impacts, each with a different impact pathway, to discern a greater collective impact resulting from the overall project. Because systems are nested within other systems at multiple scales (Gunderson and Holling 2002), the Review Board was able to pan back to see the broader picture (the *pan*orama) in its consideration of the impacts, to see the level where individual impacts coalesce. Although certain identified impacts were individually not significant, at the system level where they interact, the impacts of the project taken as a whole were significant.

In the above examples, the Review Board panned back to a more expansive view, and saw impacts on fish, semiaquatic furbearers and waterfowl in the context of the whole river system in the Taltson EA; in the other examples, the Review Board panned back from the narrower impacts of a project on habitat, wildlife, water quality, traditional harvesting, families, safety and more to recognize that they collectively add up to significant impacts from the project on people's overall well-being. In each, the separate impacts are viewed together to form an impact constellation.

Returning to the camera analogy, the challenge for the impact assessor is to find the appropriate scale of focus – to zoom in and pan out until a meaningful picture emerges. Just as the values of potentially affected people should inform decisions about impact acceptability in significance determination (Ehrlich and Ross 2015), the evidence or concerns of potentially affected people should be a source of insight to the level of the system where multiple project-specific impacts can be meaningfully considered in an integrated way. As Robert Gibson put it, speaking of systems thinking when assessing well-being, 'the further you get from a university, the more people get that this is a package' (pers comm. 9 March 2021). What is a meaningful scale of consideration to a member of a potentially affected Indigenous community may be very different from what it is to an industrial proponent, a bureaucrat in a siloed government department or a specialized academic or consultant. As with determining impact significance, in the above examples the Review Board's co-management approach to EIA decision-making made it easier for it to recognize, consider, and incorporate Indigenous views on the relevant scale for integrating and considering project-specific impacts.

Does scoping imply zooming in instead of panning out?

Superficially, the approach of broadening EIA consideration to include systems appears to conflict with the well-established and valuable practice of issue scoping. Scoping of issues is widely recognized as an important part of efficient and effective EIA. As Beanlands and Duinker (1983) described it almost four decades ago, this involves identifying and prioritizing the issues to be assessed, to focus on the few valued components that matter most, 'to reduce the scope and focus the study of impacts' (p. 133). Impact scoping has been well described as 'the process of identifying important issues of a proposal and focusing the environmental impact assessment on high-priority issues' (Kennedy and Ross 1992). Several authors describe the hazards to impact assessment that come from a failure to prioritize issues selectively enough during scoping (e.g. Ross et al. 2006; Canter and Ross 2014). Morrison-Saunders et al. (2014) and Sanchez (2014) specifically identify the hazards of scoping in too many issues as a barrier to greater integration in impact assessment.

No assessment can study everything about everything. Good scoping involves prioritizing issues specifically to focus on carefully selected VCs that matter most, while systems thinking involves considering interactions of multiple parts of the larger system. In terms of the camera analogy, scoping suggests zooming in to narrow the focus on fewer issues, while systems thinking involves panning the camera out to include interrelated parts of larger systems. Would more systemic thinking in EA risk backsliding on prioritizing in scoping, a crucial part of EA, with its decades of proven benefits?

Despite appearances, this conflict is not real. Issue scoping is intended to figure out what issues matter the most for an EA. Good issue scoping does not mean only zooming in. It means deciding carefully what direction to point our metaphorical camera (that is, towards which issues). Once those issues have been identified, the decision of whether each issue is best assessed by zooming in (in-depth analysis of impacts on the VC) or by panning back (examining the effects of the impacts on broader systems) depends on the nature of each selected issue. As indicated earlier in this paper, sometime the fish-eye lens is more useful than the microscope.

Doing this may involve asking some bigger questions. Scoping does not mean putting blinkers on the assessor, nor that impacts follow simple linear pathways. Kennedy and Ross defined scoping to mean 'an EIA activity in which a process is followed to identify the attributes of the environment for which there is concern (public and scientific) and a plan is provided that enables the EIA to be focused on these attributes' (p. 476). Even though many EAs have focussed their project-specific considerations on narrow VCs, that does not mean that the 'attributes of the environment about which there is concern' need to be defined narrowly.

This is one of the advantages of a participatory scoping process (such as one involving, in a culturally appropriate manner, the people who may be affected by a proposed project). Scoping is an opportunity to gather information about the appropriate scale to best consider the issues that are most important to potentially affected people. Defining priority issues is what matters in scoping, and some of the most important issues may involve complex multifaceted systems.

This maintains the importance of careful prioritization of issues during scoping, while also reflecting the observation of Canter and Ross (2014):

> There are relationships within and between biophysical resources, historic and cultural amenities, social issues, and socio-economic and infrastructure conditions in local project study areas as well as surrounding regional areas. These intertwined relationships are not merely theoretical; they have implications regarding analyses of effects and the application of impact mitigation measures. **Analyses of impacts on individual valued ecosystem components (VECs) without consideration of holistic perspectives lead to less-than -complete information for decision-making processes**. [*emphasis added*]

Practically, it is ultimately up to the body conducting the assessment to decide how to define the VCs. The assessor can frame the scale of the VC, to make it reflect the potentially affected system (W.A. Ross, pers. comm., 21 November 2019). A project's effects on something systemic, such as the well-being of people in a nearby community, can be just as legitimate a VC as the effects of a project on a very narrow VC, such as a subspecies of rare moss. Even though the term 'component' implies a part of something greater, the nested characteristic of systems means that entire systems also function as components in higher level or bigger systems (Gunderson and Holling 2002). For example, impacts on lynx, grouse and berries may be part of a predator-prey system that is part of a specific forest ecosystem, and that forest ecosystem may also be a component of a larger sub-regional system. The same is true of socio-ecological systems (Ostrom 2007). **Those conducting an impact assessment can choose, in scoping, to scale up a VC to encompass a broader system that matters. The functioning of the larger system could thus be identified as a valued component**. Scoping would still prioritize the focus towards an efficient and effective EA.

The assessments presented above as practical examples of system thinking each involved rigorous participatory issue scoping. The Review Board's process reflects the vital importance of rigorous scoping in EIA, and goes so far as to formally categorize issues specifically on their importance to the EA. In its EAs, a small of issues number (usually five to seven in total) are explicitly identified as Key Lines of Inquiry as a result of its scoping process early in the EA (Ehrlich 2011; e.g. Mackenzie Valley Environmental Impact Review Board [MVEIRB] 2016, p. 13, 2018, p. 6). The conclusions of these EAs nonetheless included systems thinking in the Review Board's significance determinations, as the examples given above indicate. This further demonstrates that there is no inherent conflict or tension between focussed scoping and systemic assessments.

Steps to assessing collective impacts systemically

Combining the characteristics of systems, Ackoff's synthesis, lessons from the above examples and the principles of impact assessment, the following steps are offered as an approach to considering project-specific impacts collectively and systemically

(1) **Pan back to look at the roles each VC plays in the broader system**

In addition to gathering evidence about the baseline conditions of VCs, we should deliberately gather evidence on how the VC relates to other components. Is it part of a larger system, and if so, what are the properties of the system? What other components of the system is the VC interconnected with, and by what mechanisms or pathways is it connected? By panning back in this way, we try to visualize and understand the broader system and examine the functions of the VCs within it.

(1) **Assess the predicted changes on system functioning**

Understanding the role and context of the VC within the system, we can consider the predicted impacts of the proposed project on each of the VCs, and consider their combined predicted impacts. Do the predicted impacts affect system functioning? Do they collectively reduce system resilience? As with specific VCs, we then make a significance determination, applying relevant societal values when determining whether the collective impact of the project as a whole is acceptable, or whether the collective impact matters enough to merit additional mitigations to reduce or avoid it.

(1) **Mitigate the impacts to the VCs or to the ways they interact**

If the collective impact on the system matters enough to merit additional mitigations to reduce or avoid the impact (i.e. the collective impact is significant), then mitigate the impacts to the affected VC(s), or to the way they interact. As with cumulative effects assessment, one way to reduce the collective impact is to avoid or minimize the change to each VC that contributes collectively to the impact on the system.

(1) **Mitigate any remaining significant impact on the system**

If the collective impacts on the system cannot be addressed well enough by mitigating impacts on the VCs that it is composed of, it may be possible to offset impacts on the system by reducing net impacts or enhancing other aspects that foster resilience of the system. Because the system level is broader, there may be additional mitigative options that are not open to the proponent, but fit within the mandates of others, such as government agencies. Otherwise, if the project will cause unacceptable collective impacts on the system level, the proposal should be further improved or rejected.

Conclusion

In summary, this paper has shown a widespread need for better integration in impact assessment, recognized over different years, many countries and different cultures. I have described the collective and systemic assessment of project-specific impacts as a missing level of most impact assessment. Conceptually, it fits between 1) assessing the project-specific analysis of impacts on individual VCs and 2) the assessment of a project's cumulative effects with impacts from other activities. Sometimes the real impacts of a single project are the collective result of multiple effects. These affect the interactions of individual VCs at the system level. A different kind of thinking is required to assess these impacts of individual projects on the systems (ecological, socio-cultural or both). The case studies provide practical examples of how this has been done, by visualizing systems, considering impacts collectively, and prescribing mitigations that reflect the holistic nature of the impacts on systems.

Steps for considering impacts of a project collectively and systemically are as follows: 1) Pan back to look at the roles each VC plays in a system; 2) Assess the predicted changes on system functioning; 3) Mitigate the impacts to the VCs or the ways they interact; and 4) Mitigate any remaining significant impact on the system. This would help project-specific assessments evaluate the project impacts that have been largely missed – collective impacts on people and ecosystems together, from effects of projects on multiple components. Missing these has likely caused impact assessment to overlook some of the biggest impacts of individual projects. Reality is made of systems. We should assess projects accordingly.

Notes

1. Examples of this model of linear pathway abound in proponents' predictions of their projects' impacts, such as in Dominion Diamond Corp. 2014, (p. 6–13); Fortune Minerals Ltd 2011, (p. 6–11); Indian and Northern Affairs Canada [INAC] 2010, (p. 3–12); and De Beers Canada 2010, (p. 6–13 to 6–15).
2. Morrison-Saunders and Bailey (2000) observed such a risk over 20 years ago in a review of the EIA process of Western Australia. They state, with respect to ecological components, that '[t]here is a danger that, by breaking each proposal down into discrete parts and assigning environmental objectives to them, it may not adequately represent overall environmental functions ... There is a need for the evaluation stage in EIA to consider the overall performance of a particular proposal, not just the constituent parts alone' (p. 270). This conclusion does not appear to have widely adopted in EIA practice in the two decades since.
3. The Indigenous interconnected worldview was poetically described, allegedly by Susquamish Chief Seattle (Seathl) in 1854, saying 'All things are connected ... Man did not weave the web of life; he is merely a strand in it. Whatever he does to the web, he does to himself' (Kaiser 1987, p 527). For more recent examples, please see (Alberta Education 2005, p. 12); (Indigenous Corporate Training Inc 2017; Kaminski 2013; and; First Nations Health Authority 2021). Zen Buddhism teaches a similar worldview (e.g. Rahula 1974; Allendorf 2018).
4. The same act says that in an EA the Review Board will decide whether 'the development' is likely to cause significant adverse impacts on the environment (128 (1)). This wording suggests that the test pertains to the development as a whole – the test is not about 'components of the development' – and therefore should include collective impacts as described here.
5. Indigenous communities elsewhere share similar struggles. Roche et al. said that for Indigenous communities in Papua New Guinea impact assessment 'is about living with the impacts, individually **and collectively** [*emphasis added*], perhaps over generations ... '.
6. Meadows (2008 p. 5) describes the advantages of using diagrams instead of words for describing systems, noting that '(w)ords and sentences must, by necessity, come only one at a time in a linear, logical order. Systems happen all at once. They are connected not just in one direction, but in many directions simultaneously ... Pictures work for this language better than words, because you can see all parts of a picture at once'.
7. The predicted socio-economic impacts included reduced hunting and trapping success, less harvesting, more alcohol and drug use, increased safety risks for young women, and increased pressure on health and social service providers, and greater risk of vehicle accidents and emergency response challenges. (Mackenzie Valley Environmental Impact Review Board [MVEIRB] 2018 p. 92–107).
8. The predicted impacts on boreal caribou included direct habitat loss, indirect habitat loss of effective habitat from sensory disturbance, barriers to movement and habitat fragmentation, increased predation and more hunting from increased access (p. 179–180).
9. Meadows (2008 p. 145–165) identifies leverage points in systems where interventions may be used to deliberately influence system functioning. These may be applicable in impact assessment as ways to mitigate impacts on systems. Meadows' leverage points include introducing incentives, disincentives and constraints; balancing and reinforcing feedback loops; increasing buffers; increasing information flows for adaptive management; and, identifying new goals for the larger system.
10. The same approach has been applied to cumulative effects, and in this case included both cumulative effects and collective effects. Ross (1998, p. 274) describes the how the range of mitigative options to manage cumulative effects can be broader than for impacts that are not cumulative.

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