International Journal of Water Governance 4 (2014) 1–18
DOI: 10.7564/14-IJWG51

Governance of Aquatic Systems: What Attributes and Practices Promote Resilience?

Ryan Plummer[a,b]*, Julia Baird[a], Michele-Lee Moore[e], Oliver Brandes[c], Jack Imhof[d], Katrina Krievins[a]

[a]*Environmental Sustainability Research Centre, Brock University*
E-mail: rplummer@brocku.ca

[b]*Stockholm Resilience Centre, Stockholm University*

[c]*POLIS Project on Ecological Governance, University of Victoria*

[d]*Trout Unlimited Canada*

[e]*University of Victoria*

Aquatic environments embody the characteristics of complex social-ecological systems and as pressures on them intensify so does concern about their resilience. Resilience research has advanced the conceptual understanding of how aquatic systems function and underscored the need for an adaptive approach to management. More recently, a growing emphasis has been placed on resilience concepts in relation to water governance and thereby the broader social, political, and economic contexts in which aquatic systems are embedded. Using a two round online Delphi survey of global experts and water governance, this study identifies governance attributes that support specified and general resilience in aquatic systems, and describes practices or activities that enhance governance ability to respond to shocks and disturbances. The results of the Delphi study offer a prioritized list of attributes of governance for aquatic system governance resilience, including being adaptive, polycentric, inclusive and maintaining strong leadership. Similar to the attributes described in the existing literature on resilience and water governance, those identified through the Delphi remain somewhat abstract. This research highlights the need for future studies exploring how these concepts can be applied in practice and the extent to which they can be traded off.

Keywords: resilience; governance; aquatic systems; Delphi method

1. Introduction

In the context of water, the concept of governance has taken center stage during the past decade as awareness grows that many water problems are traceable to the manner in which specific actors hold power and the processes that shape decision-making about water use and allocation (United Nations World Water Assessment Programme, 2003; de Loë & Kreutzwiser, 2006; Ingram, 2008; de Loë, Armitage, Plummer, Davidson, &

* Corresponding author.

Moraru, 2009). While a diversity of perspectives exist on "what" water governance involves, it is generally described as "the range of political, social, economic and administrative systems that are in place to develop and manage water resources, and the delivery of water services, at different levels of society" (Global Water Partnership, 2003, p. 2). We would clarify that the services mentioned in this definition may be for humans or for ecosystems and the species inhabiting them.

Simultaneously, over the past 15 years, attention has been directed at the concept of resilience, and the need to ensure aquatic systems have the capacity to adapt and transform to the emerging changes in these ecosystems, such as changes in morphology, hydrology, biogeochemistry, native species loss, increasing invasive species, and emergence of disease (Carpenter, Stanley, & Vander Zanden, 2011). Resilience is defined as "(1) the amount of disturbance a system can absorb and still remain within the same state or domain of attraction, (2) the degree to which the system is capable of self-organization (versus lack of organization, or organization forced by external factors), and (3) the degree to which the system can build and increase the capacity for learning and adaptation" (Folke, 2006, pp. 259–260). Resilience is embedded with a social-ecological systems perspective whereby ecosystems and the social context – including governance – are viewed as inextricably linked.

Holling (1973) argued that when comparing resilience perspectives with a traditional perspective that treats aquatic ecosystems as static and stable, the management and governance approaches that follow are very different. The former "…would emphasize the need to keep options open, the need to view events in a regional rather than a local context, and the need to emphasize heterogeneity" (Holling, 1973, p. 21). As a theory of change, resilience focuses on building or protecting the capacity of a social-ecological system to ensure that it can adapt or transform when needed, as opposed to keeping it the same. Moreover, the linked social-ecological systems perspective embedded in current resilience theory posits the relationship between humans and the aquatic ecosystem as a central condition to any policy or governance approach, as opposed to traditional styles that consider humans as being able to control or "manage" an ecological system.

Attempts to bring the concepts of governance and resilience together have led to a diverse range of sub-fields. One of the first approaches advocated as a means to embody these concepts in practice involved adaptive management (e.g., Lee, 1993; Walters, 1997; Pahl-Wostl, 2007). Generally, adaptive management is oriented towards 'learning by doing' through iterative cycles of assessing opportunities, designing policies as experiments, taking action, and making adjustments after evaluation and monitoring (e.g., Walters & Holling, 1990; Lee, 1993; Walters, 1997).

A range of other terms have followed, including: adaptive governance (e.g., Dietz, Ostrom, & Stern, 2003; Folke, Hahn, Olsson, & Norberg, 2005; Olsson et al., 2006; Huitema et al., 2009), collaborative governance (e.g., Innes, Connick, Kaplan, & Booher, 2006; Kallis, Kiparsky, & Norgaard, 2009), adaptive and collaborative management (also called 'adaptive co-management') (e.g., Lee, 1999, Folke et al., 2002; Plummer & Armitage, 2007) and resilience management (e.g., Walker et al., 2002; Anderies, Walker, & Kinzig, 2006; Lebel et al., 2006). While themes such as adaptability, learning, and the inclusion of non-state actors in governance persist across these different, but related, fields

of inquiry, these emergent strands of scholarship have created a cacophony of jargon and terminology. A clear consensus across these scholars about what the key attributes are for governing aquatic ecosystems to ensure resilience has not been methodically established. Without this consensus, criticisms have emerged that the "language" of resilience is vague and challenging to use in a manner that truly changes governance approaches to ensure they build and protect resilience of social-ecological systems. Therefore, a review that consolidates and prioritizes conceptual insights as well as identifies the lessons learned to improve water governance in practice and the scholarship is needed.

Positioned at the nexus of two quickly growing areas of expertise, water governance and resilience, this research seeks to identify the attributes of resilience that experienced scholars agree are essential for its governance. We use the term aquatic system here to refer to both marine and freshwater ecosystems, and we also distinguish between two types of resilience in this study: specified resilience and general resilience. Specified resilience (i.e. resilience of what, to what) refers to the ability of a specific part of a system to respond to a particular, known disturbance in order to maintain valued characteristics of the system, and general resilience refers to the system as a whole, and the capacity of a system to absorb disturbances of all kinds including unknown and unforeseen ones (Walker & Salt, 2012). Focusing on one aspect of resilience in management or governance, at the expense of the other, may actually reduce the resilience of the system and thus, the tradeoffs between specified and general resilience need to be considered when managing for them in practice.

The objectives in meeting the goal of this research include developing scholarly consensus around: 1) governance attributes that indicate specified resilience; 2) governance attributes that denote general resilience; and, 3) practices or activities that enhance governance ability to respond to shocks and disturbances. To meet these objectives, the Delphi methodology was employed to generate ideas about governance for resilience in aquatic systems and to assess the extent of consensus among scholars, which is described in the following section. Results from the research are then presented in accordance with the three guiding objectives and discussed in light of scholarship and experience with resilience and water governance.

2. Methodology

The Delphi method has been established as an effective tool for gaining insights and consensus on an emerging issue by experts while limiting the negative influences associated with group decision-making (Hasson, Keeney, & McKenna, 2000; van Zolingen & Klaassen, 2003; Landeta, 2006). Delphi methods are prevalent in many subject areas, including studies of natural resources and the environment. Within this subject area, the Delphi method has been utilized to explore complex policy questions (e.g., Needham & de Loë, 1990; de Loë, 1995; Taylor & Ryder, 2003; Frewer et al., 2011), scan future scenarios (e.g., Piecyk & McKinnon, 2010; Al-Saleh, Vidican, Natarajan, & Theeyattuparampil 2012), and gain insights about emerging issues/phenomena (e.g., De Urioste-Stone, McLaughlin, & Sanyal, 2006; Plummer & Armitage, 2007; Moore et al., 2009; Wentholt, Fischer, Gene, Marvin, & Frewer, 2010). It is the value of the tool to gain insights about

phenomena that prompts its use here. In building upon the general process associated with the Delphi method as well as the previous studies, the following specific procedures were adhered to in undertaking this research.

2.1. Selection of experts

A search of the scholarly literature was conducted to inform construction of the data collection instrument and to identify potential participants and gain their contact information. Several scholarly search engines (e.g., Taylor and Francis Journals Online, Science Direct, SpringerLink, Scholar's Portal, ProQuest, Elsevier, JSTOR, google scholar) were queried using the terms: "water governance" AND resilience; water AND governance AND "social resilience"; water AND "social resilience"; water AND "resilient governance"; and "governance resilience. Consideration of the results began with reviewing abstracts. If, after reading the abstract, the focus of a work did not appear to pertain to water, governance and resilience, the search tool was used to find these terms within the document and confirm whether they were only briefly mentioned or were discussed in greater detail and in relation to each other. Those with a clear focus on water, governance and resilience (as opposed to just mentioning the search terms) were selected. With one exception, all peer-reviewed, English results generated from each search engine and each combination of search terms were scanned. Google scholar yielded results in the thousands for the specific combination of search terms "water", "governance" and "resilience". Consequently, only those peer-reviewed results appearing on the first 100 pages were reviewed in this instance.

2.2. Development of questionnaires

Insights from the literature search (above) informed the development of the instructions and data collection instrument (see Appendix for the instrument). These materials were piloted with three individuals and revised to improve clarity. The instruction portion provided participants with the purpose of the study, definitions of resilience and governance, and information about ethical considerations as required by the University Research Ethics Board. In line with the objectives of the study and the Delphi method, the first survey consisted of open-ended questions asking respondents to provide responses to three questions: 1) what governance attributes of an aquatic system indicate specified resilience; 2) what governance attributes of an aquatic system indicate general resilience; and, 3) when thinking of an aquatic system with attributes of governance that signal low resilience, what practices or activities would enhance governance ability to respond to shocks and disturbances? Explanations for each of the key constructs queried (e.g., specified resilience, general resilience) were given and examples were provided for all questions. The term aquatic system was used to recognize ecosystems in both marine and freshwater. Respondents were given the opportunity to provide up to ten responses per question. The survey was administered online using the web development tool Fluid Survey and responses were anonymous.

Publishing in the scholarly literature on topics addressing the subject of the Delphi (e.g., water governance and resilience) was considered evidence of expertise. Individuals

with this expertise were identified through the comprehensive search of the scholarly literature described above and invited to participate in the study. Contact information was sought for all authors, based on information provided in the publication. Additional individuals were invited from the professional network of the senior author who displayed expertise through presentations at conferences and other scholarly exchanges. Supplementing the invitations lists in this way is consistent with previous Delphi studies (e.g., de Loë, 1995; de Loë & Wojtanowski, 2001; Edwards et al., 2012). A total of 70 experts were identified representing a range of perspectives and experience related to freshwater and marine systems.

Invitations to participate in the Delphi study were extended to the 57 experts for whom an e-mail address could be located. If an incorrect address notification was received an effort was made to identify an alternative address and re-send the invitation. A total of 54 invitations were successfully delivered. A friendly reminder of the invitation was sent one week later. A total of 23 experts positively responded to the invitation. The URL to the instructions and questionnaire was sent to the experts who wished to participate. The questionnaire remained open for three weeks, and a reminder was sent to all respondents at the end of the second week. A total of 15 questionnaires were received by the deadline and analyzed.

2.3. Data processing

Responses for each of the three questions in round one were carefully reviewed and grouped according to similarity of response (open coding) (Neuman, 2007). Where responses were essentially identical, they were grouped together as one response to reduce redundancy. However, when small differences among similar responses were identified, responses were kept separate to maintain the specific nuances of each response. Table 1 summarizes the number of responses to each question as well as the number of responses following the open coding process.

In the second survey, participants were provided with the responses from the first round, accompanied by the context (disturbance) for which the response was given, in the case of the first question regarding specified resilience attributes, or for questions two and three, the rationale for providing the response. The experts were asked to rate the importance of the responses to governance resilience using a five-point Likert scale using ratings from very important (5) to not at all important (1). The scale also included the option of 'no opinion' for the specified resilience questions, as the attributes identified in that question from round one were necessarily context specific and some respondents may not have felt comfortable rating the importance of attributes to a context with which they were unfamiliar. The instructions and instrument for the second round of the Delphi were again piloted with two researchers. Feedback from the pilot process was incorporated to enhance clarity. The second round of the Delphi was again administered via an online survey. Outlined in the consent form for participation in the study, was the assurance of anonymity for respondents. Accordingly, identifiers of any kind were not used to track respondents and thus, invitations for the second round of the survey were extended to the 23 experts who initially indicated a willingness to participate in the study. The experts were given

two weeks to complete the second questionnaire and a reminder notice was sent at the end of the first week. A total of 15 questionnaires were again received by the deadline, providing a response rate of 27% of all experts invited or 65% of those who affirmed participation. While concerns over anonymity preclude verification of respondent overlap between rounds one and two of the study, it is extremely likely that there is substantial, if not total, overlap between the two groups of respondents.

Analysis of data received from the second round of the Delphi took place through an iterative process. The responses received from participants were categorized by those that achieved consensus and those that did not. In order to achieve consensus, at least 75% of responses (12 respondents) must have ranked the attribute or activity as a '4' or '5' on the Likert scale (corresponding to 'Important' or 'Very Important (essential)') (following the operational rule of establishing consensus by Plummer and Armitage (2007)). The number of responses that achieved consensus are shown in Table 1. All responses for which consensus was achieved were then subject to open coding. In line with Neuman (2007), open coding was undertaken to identify themes (i.e. main concepts) emerging from the responses. Many of the responses were multi-dimensional and thus more than one theme was often present in a single response and themes were developed to capture all dimensions. These initial themes were then refined with a second round of axial coding, ensuring all aspects of responses for each question were encapsulated by the themes and that no new themes were required (Neuman, 2007). Following coding, responses were assigned to one or more themes. When a single response indicated more than one theme, the response was coded into two or more separate themes. Coding and response assignment was performed by a single researcher. Contexts or rationales for each response assigned to a theme were retained to understand the degree of potential transferability of themes. The themes were ranked according to the frequency with which they occurred within responses. The mean Likert scale rating for all responses included in the theme is also presented for each theme.

Although the Delphi method is well-established, there are limitations to this research design. These include the reliance on accurately establishing the initial questions posed, the possibility that panelists may withdraw during the study, and the influence of external events (Franklin & Hart, 2007). Also, the strengths of the method to some, such as drawing upon experts and encouraging anonymity, are contested or viewed as limitations by others (Kennedy, 2004). Thirdly, the specificity of responses to the questions posed to panelists in the first round is beyond the control of the researchers, and thus the results are limited by the quality of responses received in the first round. Furthermore, in particular to the design used in this research, we are cognizant that the individuals surveyed for their ideas on water governance and resilience are the same scholars who created the literature on water governance and resilience. Thus, the results can be expected to confirm rather than challenge the major themes from the existing literature. However, since the purpose of this study is to synthesize and facilitate a consensus among water researchers on the subject of governance and resilience, this limitation is not considered a concern. We reiterate the important acknowledgement by Goodman (1987) that the results represent the opinions of a particular group at a specific time.

3. Results

The results of the two round Delphi process are presented in this section of the paper, according to the three objectives of the study. All of the results presented were agreed upon by the experts as being important or very important (essential). Themes that emerged from the iterative process of coding are identified and ranked according to their frequency within all responses.

Table 1
Number of responses in the Delphi study by question, round and consensus achieved

Question	Total number of responses in round 1	Number of responses after grouping together like responses from round 1	Number of responses that achieved consensus in round 2
Q1. Specified resilience	57	50	15
Q2. General resilience	76	56	8
Q3. Activities	55	47	8

3.1. What governance attributes of an aquatic system indicate specified resilience?

Specified resilience was used as an entry point for the questionnaire because "… in all cases – it is crucial to specify what system state is being considered (resilience of what) and what perturbations are of interest (resilience to what)" (Carpenter, Walker, Anderies, & Abel, 2001, p. 777). In keeping with the scholarship on resilience assessments and practice (e.g., Walker & Salt, 2006; Walker Abel, Anderies, & Ryan, 2009; Folke et al., 2010), specified resilience was described for participants as concerning an aspect of the system in reference to a particular shock or source of disturbance. Respondents were asked to identify and rate the specific attributes of governance that enable it to respond to a particular disturbance in the aquatic system. Given the need to understand the system state and/or particular shock/source, respondents were also asked to provide a brief contextual description. These contextual descriptions were summarized and provided in the second round of the Delphi where attributes were rated to retain an understanding of the context within which they were identified.

The experts achieved consensus on 15 specific attributes of governance that enable it to respond to a particular disturbance in aquatic ecosystems. Table 2 summarizes these results by presenting the eight themes that emerged from the qualitative analysis as well as the responses and accompanying rating constituting each theme. Of those eight, adaptive planning, polycentric network structure / presence of boundary organizations, and diverse actor participation were the three specific attributes of governance to emerge with the greatest frequency. In relation to adaptive planning, the expert respondents most frequently described disturbances to water supply as context for their responses across aquatic systems, with four of the responses being explicitly linked to climate change.

Table 2
Specific attributes of governance that enable it to respond to a particular disturbance in the aquatic system

Theme	Number of responses	Mean rating	Responses (context in italics and parentheses)
Adaptive planning	5	4.20	Adaptive planning *(Slow reduction in water supply (climate change or increased demand); extreme events and shifts related to climate change)*
			Adaptive and transparent allocation of water resources *(unexpected long-term drought)*
			Authority to adjust response in face of new information *(reduction in water supply from climate change, increased demand)*
			Capability/flexibility to account for uncertainties (social and ecological) *(changing flow regimes, or risk thereof; climate related shock disturbances*)
			Enabling policy conditions for adaptive, participatory governance *(climate change, intensification/globalization of economic drivers)*
Polycentric network structure/presence of boundary organizations	3	4.20	Polycentric network of all levels of government, able to respond at all levels *(weather, economics, political disturbances; flood)*
			Boundary organization presence (bridging the science-policy interface) *(climate variability and change)*
			Well developed, trusted and widely accepted inter-agency processes for addressing conflict *(disputes between governance levels regarding strategies/objectives)*
Diverse actor participation	3	4.13	Enabling policy conditions for adaptive, participatory governance *(climate change, intensification/globalization of economic drivers)*
			Policies and programs that ensure procedural equity in decision-making across diverse actors (including indigenous actors) *(conflicts among users)*
			Strong public participation and involvement *(resistance of affected actors to water management measures)*
Authority/ leadership for efficient, adaptive responses	2	4.30	Authority to adjust response in face of new information *(reduction in water supply from climate change, increased demand)*
			Leadership for organizing efficient responses *(major flooding event)*
Equity/ transparency	2	4.27	Adaptive and transparent allocation of water resources *(unexpected long-term drought)*
			Policies and programs that ensure procedural equity in decision-making across diverse actors (including indigenous actors) (*conflicts among users)*
Capacity to self-organize	1	4.30	Self-organization of local communities; capacity to organize *(corrupt government/authority; climate related shock disturbances)*
Social memory to maintain knowledge base	1	4.10	Social memory for necessary knowledge base and stability in times of crisis/reorganization
Precautionary risk assessment and reduction strategies	1	3.73	Precautionary risk assessment and reduction strategies *(failure of infrastructure (e.g., dams))*

3.2. What governance attributes of an aquatic system indicate general resilience?

The second question introduced the concept of general resilience. Contrasted with specified resilience, general resilience is concerned with the capability to cope/respond to uncertain/unanticipated shocks or disturbances (Walker & Salt, 2006; Walker et al., 2009; Folke et al., 2010). Respondents were thus asked about the governance attributes of an aquatic system that indicate general resilience.

Fifty-six items were identified in round one and then were presented to the experts for round two, which led to a consensus for eight of those items. Themes of governance attributes of an aquatic system conferring general resilience that emerged from the analysis include: inclusive participation and building shared understanding; institutional flexibility; decentralized system; wide range of ecosystem services included in long term planning; and, strong leadership. Table 3 summarizes the results by detailing the responses

Table 3
Governance attributes of an aquatic system that indicate general resilience

Theme	Number of responses	Mean	Responses (rationale in parentheses)
Inclusive participation and building shared understanding	5	4.14	Inclusive participation and deliberation (builds trust and shared understanding; can help mitigate conflict - includes marginal and vulnerable groups)
			Strong integration of local stakeholders in governance (legitimizes decisions, enhances goal achievement)
			Consideration of informal institutions (e.g., unofficial/voluntary agreements with user groups, social norms – increases likelihood of support of goals and measures by a range of actors)
			Institutions and governance (co-management with decentralized governance system for broad participation and institutional flexibility)
			Knowledge co-production (multiple types of knowledge required to build shared understanding)
Institutional flexibility	2	4.17	Institutions and governance (co-management with decentralized governance system for broad participation and institutional flexibility)
			Flexible regulatory frameworks (some degree of interpretation for adaptation, but stable; policy certainty and guidance at higher scales, create opportunities for resilience building/flexibility at local scales)
Wide range of ecosystem services included in long term planning	1	4.33	Wide range of ecosystem services explicitly included in long-term planning (condition for holistic management and reducing trade-offs)
Decentralized system	1	4.14	Institutions and governance (co-management with decentralized governance system for broad participation and institutional flexibility)
Strong leadership	1	4.13	Strong, but not individually concentrated, leadership

associated with each theme and the importance assigned by the experts. The theme of inclusive participation and building shared understanding emerged with the most responses. In these responses the experts highlight how inclusivity in terms of process enhances capability for coping and responding to unidentified disturbances by building trust, enhancing legitimization for decisions and developing shared understanding.

3.3. What practices or activities enhance the capability of governance for an aquatic system with low resilience?

Interest in applying the ideas of resilience in the form of a practice has emerged in recent years (Miller et al., 2010; Walker & Salt, 2012). Yet, documenting resilience practice is recognized as an outstanding challenge (Miller et al., 2010). Since resilience practice requires a firm understanding of resilience thinking (Walker & Salt, 2012), the final query in the Delphi study sought insights into the shift from resilience thinking to resilience practice. Respondents were asked to consider an aquatic system with attributes of governance that signal low resilience and to then identify practices or activities that would enhance governance ability to respond to shocks and disturbances.

Experts were presented with 47 responses from round one of the Delphi and consensus was gained on eight responses at the end of round two. Table 4 summarizes the responses according to the three themes that emerged from the qualitative analysis and presents the importance assigned to each response. The three themes of activities to enhance the capability of governance for an aquatic system with low resilience were forums/opportunities for participation, planning processes and tools to deal with disturbances, and improved transparency and legitimacy of decision making / planning processes.

4. Discussion

4.1. Specified resilience

The governance attributes of aquatic systems were distinguished in the Delphi by drawing upon the concepts of specified and general resilience. In line with the research aim to consolidate and prioritize conceptual insights, consensus was established among 15 responses to the initial query regarding specified resilience and eight themes emerged from these responses. The theme of ‘adaptiveness’ occurred most frequently within these responses. In labeling the theme adaptiveness (sensu Biermann, 2007), we convey the emphasis placed on the qualities of dynamism and flexibility that permits adjustments in response to uncertainty. As the responses are not mutually exclusive to one theme, these qualities also emerged in themes of diverse actor participation, authority/leadership for efficient, adaptive responses, and equity/transparency. To summarize, the consensus indicates that if watersheds are facing specific shocks such as a severe drought or flood, having networked connections across community, sectors, and multiple levels of governance in place beforehand will ensure diverse actors are participating in the decisions about

Table 4
Practices or activities that enhance the capability of governance for an aquatic system with low resilience

Theme	Number of responses	Mean	Responses (rationale in parentheses)
Forums/opportunities for participation	6	4.15	Provide an enabling policy environment (provides secure arenas for participation and grants a voice to marginalized groups; allows identification of new/traditional ways of dealing with disturbances)
			Organize a moderated, participatory process to assess deficits leading to low resilience (e.g. using example of failure to deal with disturbance or assess how a response should look like for a future disturbance)
			Strengthening public deliberation around alternative development options
			Shift from public comment to public deliberation (enhances legitimacy of decision making)
			Support bridging organisations, networks and collaborative learning platforms (they enable social learning and provide information across levels and scales)
			Implement transparent and open communication structures (will build trust)
Planning processes and tools to deal with disturbances	5	4.19	Provide an enabling policy environment (provides secure arenas for participation and grants a voice to marginalized groups; allows identification of new/traditional ways of dealing with disturbances)
			Organize a moderated, participatory process to assess deficits leading to low resilience (e.g. using example of failure to deal with disturbance or assess how a response should look like for a future disturbance)
			Strengthening public deliberation around alternative development options
			Development of flexible water tools and instruments (implementation responsive to monitoring data)
			Transparent planning and decision making
Improved transparency and legitimacy of decision making/planning processes	3	4.18	Shift from public comment to public deliberation (enhances legitimacy of decision making)
			Implement transparent and open communication structures (will build trust)
			Transparent planning and decision making

responses to those events. In situations of longer term climate variability and change, the presence of boundary organizations was identified as a key attribute for bridging the science-policy interface. These findings highlight the role different governance attributes play in the face of acute shocks vs. longer term change. Additionally, having a mindset and plan to "learn by doing" (i.e. an adaptive plan) will contribute to the resilience of the

governance system itself; that is, the governance of the aquatic system and the aquatic system itself, will withstand the disturbance and still retain overall function, identity, and a capacity to adapt or transform as needed.

While the attributes of governance determined in this study as enabling a response to a particular disturbance in aquatic ecosystems (specified resilience) are not surprising for scholars working from a social-ecological perspective, the solidified insights fortify arguments by Galaz (2007) and Engle, Johns, Lemos, and Nelson (2011) about the shortcomings of existing frameworks used to inform water governance. More surprising perhaps, is that the scholars being surveyed could not move to more specific recommendations for governance approaches. For instance, how could a watershed governance body build boundary organizations or what attributes should they seek in existing organizations that could potentially play that role? Since it is unlikely that all boundary organizations are created equal, are there some characteristics that are better suited to specified resilience than others?

4.2. General resilience

The results from the Delphi also establish consensus regarding the governance attributes of an aquatic system that indicate the capability to respond to unanticipated disturbances (general resilience). Consensus established for eight responses was valuable in narrowing the scope from the 76 responses initially received. The five themes established from these responses offer an agreed upon agenda for those concerned with research and policy aimed at enhancing capacity for resilience. While coincidence with scholarship connected to resilience and water governance was logically anticipated given the nature of participant selection, the attributes of an aquatic system for general resilience do reflect some of the often cited principles of water governance from organizations and practitioners beyond the scholarly community. For example, the Global Water Partnership (GWP) (2003) initiated a dialogue on effective water governance. Principles or basic attributes for effective water governance arrived at by the GWP include approaches that are open and transparent, inclusive and communicative, coherent and integrative, and equitable and ethical as well as performance and operation that are accountable, efficient, and responsive and sustainable. Many of these overlap with ideas of inclusive participation and institutional flexibility or responsiveness, but there are also some distinctions to be made, such as the idea of retaining strong leadership within a decentralized governance model and the recognition of the inherent power dynamics that this brings, which is absent in the GWP discussion, and the need for ecosystem services to be considered in planning.

As stated in the results, the theme of inclusive participation and building shared understanding emerged with the greatest frequency within responses. It was unclear from the survey whether this result was based on some shared principle related to democracy or equality in decision-making, or if this was about generating broad support to shift behaviour and the relationships between the social and the ecological. A possible explanation for its prioritization may be the highly interconnected nature of it with many of the other

governance attributes, as well as its relationship to practices/activities and their consequences. Beyond the water governance literature, Muro and Jeffrey's (2008) compound model of social learning, developed from their review of the participatory natural resource management literature, illustrates this point. A central logic chain is set out – communication and interactive participatory processes enable social learning and contribute to common understanding, mutual agreement, and collective action – around which occur interrelated process features (e.g., facilitation, diverse participation, unrestrained thinking), elements taking place during the shared learning experience (e.g., co-creation of knowledge, understanding of system complexity), and products from social learning (e.g., change in cognitions, trust, relationships). The results from this research illustrate that practitioners and policy makers wishing to build resilience in aquatic systems may be confronted with a challenge of trying to determine how (or if) to untangle resilience from related, overlapping approaches such as social learning.

4.3. Practices to enhance resilience

Moving from resilience thinking to resilience practice, and documenting its application, is an identified challenge (Miller et al., 2010; Walker & Salt, 2012). The results of the Delphi study provide insights into the practices or activities that enhance the capability of governance for an aquatic system with low resilience. Consensus was again achieved for eight responses. The results reinforce the connection in the literature between nurturing resilience and governance that is adaptive and collaborative (e.g., Folke et al., 2005; Innes et al., 2006; Olsson et al., 2006). The themes established in this research (e.g., enabling opportunities for participation, crafting planning processes and tools to deal with disturbances, and improving transparency and legitimacy) offer a concerted set of agreed upon priorities for strengthening governance in situations of low resilience. They also coincide with persistent calls in natural resources management and governance more broadly for meaningfully engaging people in flexible participatory processes to enhance transparency and legitimacy (Parkins & Mitchell, 2005; Reed et al., 2009). Connections are also evident to the imperative for learning in natural resources management and enabling learning oriented processes (e.g., Fazey et al., 2007; Diduck, 2010; Evely, Pinard, Reed, & Fazey, 2011). The role of building and accessing knowledge and information, and creating opportunities within governance for learning, was highlighted throughout the attributes and practices that gained consensus. These attributes (both general and specified) and practices support finding a balance between timely access to relevant information and the ability to make decisions under conditions of uncertainty.

4.4. Interplay, connections to other concepts, and insights

The results have thus far been discussed in terms of governance attributes of an aquatic system that indicate the capability to respond to particular perturbations (specified resilience), unanticipated disturbances (general resilience), and practices or activities that enhance the

capability of governance in systems with low resilience. Collectively, they offer an identified list of prioritized attributes of governance for aquatic system resilience. In maintaining or enhancing these desirable system attributes in term of resilience, an alternative approach is offered to arriving at a single optimal strategy through ecological forecasting (Bennett, Cumming, & Peterson, 2005). While resilience holds intuitive appeal, Carpenter, Westley, and Turner (2005) observe that experience in estimating resilience of social-ecological systems is limited and challenging, as resilience itself is difficult (and sometimes inappropriate) to measure. The use of "surrogates" has been put forward as a workable alternative to capture attributes of resilience in social-ecological systems; that is, proxies that are indirectly inferable and measurable, but that will correspond to resilience conceptually, and are context dependent and dynamic (Bennett et al., 2005; Carpenter et al., 2005). However, as the attributes of governance established through the Delphi process illustrate, even the task of developing measurable proxies or surrogates for resilience may be extremely difficult. General attributes such as learning are not easily measured (Muro & Jeffrey, 2008) while others like polycentric governance arrangements may not be favourable in all forms (Huitema et al., 2009; Kemper, Dinar, & Blomquist, 2005). Thus, the use of surrogates for resilience in social sciences may require a level of specificity not attained by the Delphi results.

The interplay between specified and general resilience is critical given that concentrating on the former may enable robustness to frequent types of disturbances while at the same time increasing fragility of the system to infrequent and surprise perturbations (Cork, 2010; Folke et al., 2010; Walker & Salt, 2012). Results from the Delphi revealed relatively little distinction between themes for which consensus was achieved regarding specified (Table 2) and general resilience (Table 3). The context-specific nature of the question regarding specified resilience is an acknowledged limitation that may have influenced those attributes that gained consensus, despite the intention to scope the study sufficiently specifically by focusing on aquatic systems, and the provision of context within which specified resilience attributes were identified in the rating of importance in round 2. While the Delphi did not probe how governance attributes for specified and general resilience ought to be traded off, this consideration needs to be front of mind for practitioners and policy makers. Drawing upon their rich experiences of working with groups interested in applying a resilience approach, Folke et al., (2010) observe a tendency to focus on specified resilience, which consequently may actually narrow options to build overall general resilience.

Alignment between resilience attributes identified in the Delphi study and the resilience literature was not surprising as the scholars with expertise in this body of literature were those invited to participate. However, it became clear through this exercise that despite the expertise of respondents, the consensus concentrated upon abstract and somewhat vague attributes, even when asked specifically about practices that enhance resilience. Questions emerging from this finding include how resilience concepts can be described in "lay" language, and how these concepts can be effectively translated and implemented in practice. This reflects a similar gap in the resilience literature (see Walker and Salt, 2012 for a notable exception). Answering these questions is critical for moving from 'resilience thinking' to 'resilience practice'.

5. Conclusions

The state of marine and freshwater aquatic systems is generally deteriorating. Slowing this decline and being resilient in the face of such changes is critical. Governance has an important role to play in shaping the resilience of aquatic systems. This research utilized a Delphi method to ascertain the present state of knowledge about governance for resilience of aquatic systems. Through the multi-round process, the expert respondents arrived at consensuses as to the governance attributes that indicate specified resilience, those attributes that denote general resilience, and the practices or activities that enhance the governance ability to respond to shocks and disturbances.

Consolidation of these attributes and practices mark the state of thinking about governance and resilience of aquatic systems. Several avenues for future consideration have emerged from this process of taking stock. Future research questions open about: a) the governance attributes that need to be present and the extent to which they can be traded off (see Plummer, 2009 for similar questions related to adaptive co-management); b) the points of complementarity and tradeoffs between governance attributes for specified and general resilience; and, c) incorporation as surrogates to estimate the resilience of aquatic systems in terms of governance. While the Delphi study sought to offer a consolidated position by those writing on governance attributes and resilience of aquatic systems, it also provides a glimpse into how intertwined it has become with other concepts (e.g., IWRM, social learning) and future directions of water governance (e.g., Wiek & Larson, 2012; Pahl-Wostl et al., 2013). Miller et al., (2010: online) observe that "… resilience as a concept has significant colloquial and policy appeal" due to its positive connotation with transformative processes. Walker and Salt (2012) urge that caution be exercised in relation to the broad appeal of resilience, noting the tendency of "buzzwords" to be all things to all people subsequently providing little value to anyone. Ensuring the core aspects of resilience are held, while infusing the spirit of the concept into the important dialogue on governance and aquatic systems to move from concept to practice, is a challenge for researchers, decision-makers, and citizens moving forward.

References

Al-Saleh, Y. M., Vidican, G., Natarajan, L., & Theeyattuparampil, V. V. (2012). Carbon capture, utilisation and storage scenarios for the Gulf Cooperation Council region: A Delphi-based foresight study. *Futures, 44*(1), 105–115.

Anderies, J. M., Walker, B. H., & Kinzig, A. P. (2006). Fifteen weddings and a funeral: Case studies and resilience-based management. *Ecology and Society, 11*(1), 21.

Bennett, E. M., Cumming, G. S., & Peterson, G. D. (2005). A systems model approach to determining resilience surrogates for case studies. *Ecosystems, 8*, 945–957.

Biermann, F. (2007). 'Earth system governance' as a crosscutting theme of global change research. *Global Environmental Change, 17*(3–4), 326–337.

Carpenter, S. R., Stanley, E. H., & Vander Zanden, M. J. (2011). State of the world's freshwater ecosystems: Physical, chemical, and biological changes. *Annual Review of Environment and Resources, 36*, 75–99.

Carpenter, S. R., Walker, B. H., Anderies, J. M., & Abel, N. (2001). From metaphor to measurement: Resilience of what to what? *Ecosystems, 4*, 765–781.

Carpenter, S. R., Westley, F., & Turner, M. G. (2005). Surrogates for resilience of social-ecological systems. *Ecosystems, 8*(8), 941–944.

Cork, S. (2010). Resilience of social-ecological systems. In S. Cork (Ed.), *Resilience and transformation: Preparing Australia for uncertain futures* (pp. 131–142). Melbourne, Australia: CSIRO Publishing.

de Loë, R. C. (1995). Exploring complex policy questions using the policy Delphi: A multi-round, interactive survey method. *Applied Geography*, *15*(1), 53–68.

de Loë, R. C., & Kreutzwiser, R. D. (2006). Challenging the status quo: The evolution of water governance in Canada. In K. Bakker (Ed.), *Eau Canada: The future of Canadian water governance* (pp. 85–104). Vancouver, British Columbia, Canada: UBC Press.

de Loë, R. C., & Wojtanowski, D. (2001). Associated benefits and costs of the Canadian flood damage reduction program. *Applied Geography*, *21*(1), 1–21.

de Loë, R. C., Armitage, D., Plummer, R., Davidson, S., & Moraru, L. (2009). *From government to governance: A state-of-the-art review of environmental governance*. Report prepared for Alberta Environment, Environmental Stewardship, Environmental Relations. Guelph, Ontario, Canada: Rob de Loë Consulting Services.

De Urioste-Stone, S., McLaughlin, W. J., & Sanyal, N. (2006). Using the Delphi technique to identify topics for a protected area co-management capacity building program. *International Journal of Rural Management*, *2*(2), 191–211.

Diduck, A. (2010). The learning dimension of adaptive capacity: Untangling the multi-level connections. In D. Armitage & R. Plummer (Eds.), *Adaptive capacity and environmental governance* (pp. 199–221). London: Springer.

Dietz, T., Ostrom, E., & Stern, P. C. (2003). The struggle to govern the commons. *Science, 302*(5652), 1907–1912.

Edwards, D. M., Jay, M., Jensen, F. S., Lucas, B., Marzano, M., Montagné, Peace, A., & Weiss, G. (2012). Public preferences across Europe for different forest stand types as sites for recreation. *Ecology and Society*, *17*(1), 27.

Engle, N. L., Johns, O. R., Lemos, M. C., & Nelson, D. R. (2011). Integrated and adaptive management: Tensions, legacies, and the next best thing. *Ecology and Society*, *16*(1), 19.

Evely, A. C., Pinard, M., Reed, M. S., & Fazey, I. (2011). High levels of participation in conservation projects enhance learning. *Conservation Letters*, *4*(2), 116–126.

Fazey, I., Fazey, J. A., Fischer, J., Sherren, K., Warren, J., Noss, R, & Dovers, S. R. (2007). Adaptive capacity and learning to learn as leverage for social-ecological resilience. *Frontiers in Ecology and Environment, 5*, 375–380.

Folke, C. (2006). Resilience: The emergence of a perspective for social-ecological systems analyses. *Global Environmental Change, 16*(3), 253–267.

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience thinking: Integrating resilience, adaptability and transformability. *Ecology and Society*, *15*(4), 20.

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C. S., Walker, B., . . . Danell, K. (2002). *Resilience and sustainable development: Building adaptive capacity in a world of transformations.* Report prepared for the Swedish Environmental Advisory Council. Stockholm, Sweden: Ministry of the Environment.

Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources, 30*, 441–473.

Franklin, K. K., & Hart, J. K. (2007). Idea generation and exploration: Benefits and limitations of the policy Delphi research method. *Innovative Higher Education, 31*(4), 237–246.

Frewer, L. J., Fischer, A. R. H., Wentholt, M. T. A., Marvin, H. J. P., Ooms, B. W., Coles, D., & Rowe, G. (2011). The use of Delphi methodology in agrifood policy development: some lessons learned. *Technological Forecasting and Social Change, 78*(9), 1514–1525.

Galaz, V. (2007). Water governance, resilience and global environmental change—A reassessment of integrated water resources management (IWRM). *Water Science & Technology, 56*(4), 1–9.

Global Water Partnership. (2003). *Effective water governance: Learning from the dialogues*. Stockholm, Sweden: UNDP.

Goodman, C. M. (1987). The Delphi technique: A critique. *Journal of Advanced Nursing, 12*(6), 729–734.

Hasson, F., Keeney, S., & McKenna, H. P. (2000). Research guidelines for the Delphi survey technique. *Journal of Advanced Nursing*, *32*(4), 1008–1015.

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics, 4*, 1–23.

Huitema, D., Mostert, E., Egas, W., Moellenkamp, S., Pahl-Wostl, C., & Yalcin, R. (2009). Adaptive water governance: Assessing the institutional prescriptions of adaptive (co-) management from a governance perspective and defining a research agenda. *Ecology and Society, 14*(1), 26.

Ingram, H. (2008, June 26). *Beyond universal remedies for good water governance: A political and contextual approach*. Paper presented at the Rosenberg International Forum on Water Policy, Zaragoza, Spain.

Innes, J. E., Connick, S., Kaplan, L., & Booher, D. E. (2006). *Collaborative governance in the CALFED program: Adaptive policy making for California water* (Working Paper 2006-01). Retrieved from http://www.iurd.berkeley.edu/publications/wp/2006-01.pdf

Kallis, G., Kiparsky, M., & Norgaard, R. (2009). Collaborative governance and adaptive management: Lessons from California's CALFED water program. *Environmental Science & Policy, 12*, 631–643.

Kemper, K., Dinar, A., & Blomquist, W. (Eds.). (2005). *Institutional and policy analysis of river basin management decentralization. The principle of managing water resources at the lowest appropriate level—When and why does it (not) work in practice?* Washington, DC: World Bank.

Kennedy, H. P. (2004). Enhancing Delphi research: Methods and results. *Journal of Advanced Nursing, 45*(5), 504–511.

Landeta, J. (2006). Current validity of the Delphi method in social sciences. *Technological Forecasting and Social Change, 73*, 467–482.

Lebel, L., Anderies, J. M., Campbell, B., Folke, C., Hatfield-Dodds, S., Hughes, & Wilson, J. (2006). Governance and the capacity to manage resilience in regional social-ecological systems. *Ecology and Society, 11*(1), 19.

Lee, K. (1993). *Compass and gyroscope: Integrating science and politics for the environment*. Washington, DC: Island Press.

Lee, K. N. (1999). Appraising adaptive management. *Conservation Ecology, 3*(2), 3.

Miller, F., Osbahr, H., Boyd, E., Thomalla, F., Bharwant, S., Ziervogel, G., . . . Nelson, D. (2010). Resilience and vulnerability: Comparability or conflicting concepts? *Ecology and Society, 15*(3), 11.

Moore, S. A., Wallington, T. J., Hobbs, R. J., Ehrlich, P. R., Holling, C. S., Levin, S., . . . Turner, M. G. (2009). Diversity in current ecological thinking: Implications for environmental management. *Environmental Management, 43*(1), 17–27.

Muro, M., & Jeffrey, P. (2008). A critical review of the theory and application of social learning in participatory natural resource management. *Journal of Environmental Planning and Management, 51*, 325–344.

Needham, R. D., & de Loë, R. C. (1990). The policy Delphi: Purpose, structure, and application. *The Canadian Geographer/Le Géographe Canadien, 34*(2), 133–142.

Neuman, W. L. (2007). *Basics of social research: Qualitative and quantitative approaches*. Boston, MA: Pearson.

Olsson, P., Gunderson, L. H., Carpenter, S. R., Ryan, P., Lebel, L., Folke, C., & Holling, C. S. (2006). Shooting the rapids: Navigating transitions to adaptive governance of social-ecological systems. *Ecology and Society, 11*(1), 18.

Pahl-Wostl, C. (2007). Transitions towards adaptive management of water facing climate and global change. *Water Resources Management, 21*, 49–62.

Pahl-Wostl, C., Arthington, A., Bogardi, J., Bunn, S. E., Hoff, H., Lebel, L., . . . Tsegai, D. (2013). Environmental flows and water governance: Managing sustainable water uses. *Current Opinion in Environmental Sustainability, 5*, 341–351.

Parkins, J. R., & Mitchell, R. E. (2005). Public participation as public debate: A deliberative turn in natural resource management. *Society & Natural Resources, 18*(6), 529–540.

Piecyk, M. I., & McKinnon, A. C. (2010). Forecasting the carbon footprint of road freight transport in 2020. *International Journal of Production Economics, 128*(1), 31–42.

Plummer, R. (2009). The adaptive co-management process: An initial synthesis of representative models and influential variables. *Ecology and Society, 14*(2), 24.

Plummer, R., & Armitage, D. (2007). Charting the new territory of adaptive co-management: A Delphi study. *Ecology and Society, 12*(2), 10.

Reed, M. S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., . . . Stringer, L. C. (2009). Who's in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of Environmental Management, 90*(5), 1933–1949.

Taylor, J. G., & Ryder, S. D. (2003). Use of the Delphi method in resolving complex water resources issues. *Journal of the American Water Resources Association (JAWRA), 39*(1), 183–189.

United Nations World Water Assessment Programme. (2003). *Water for people, water for life: The United Nations world water development report*. New York, NY: UNESCO Publishing

van Zolingen, S. J., & Klaassen, C. A. (2003). Selection process in a Delphi study about key qualifications in senior secondary vocational education. *Technological Forecasting and Social Change, 70*, 317–340.

Walker, B. H., Abel, N., Anderies, J. M., & Ryan, P. (2009). Resilience, adaptability, and transformability in the Goulburn-Broken Catchment, Australia. *Ecology and Society, 14*(1), 12.

Walker, B., & Salt, D. (2006). *Resilience thinking: Sustaining ecosystems and people in a changing world*. Washington, DC: Island Press.

Walker, B., & Salt, D. (2012). *Resilience practice: Building capacity to absorb disturbance and maintain function*. Washington, DC: Island Press.

Walker, B., Carpenter, S., Anderies, J., Abel, N., Cumming, G., Janssen, M., . . . Pritchard, R. (2002). Resilience management in social-ecological systems: A working hypothesis for a participatory approach. *Ecology and Society, 6*(1), 14.

Walters, C. (1997). Challenges in adaptive management of riparian and coastal ecosystems. *Conservation Ecology, 1*(2), 1.

Walters, C. J., & Holling, C. S. (1990). Large-scale management experiments and learning by doing. *Ecology, 71*(6), 2060–2068.

Wentholt, M. T. A., Fischer, A. R. H., Gene, R., Marvin, H. J. P., & Frewer, L. J. (2010). Effective identification and management of emerging food risks: Results of an international Delphi survey. *Food Control, 21*(12), 1731–1738.

Wiek, A., & Larson, K. L. (2012). Water, people, and sustainability—A systems framework for analyzing and assessing water governance regimes. *Water Resources Management, 26*, 3153–3171.