

Global networks and global change-induced tipping points

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Abstract The existence of “tipping points” in human–environmental systems at multiple scales—such as abrupt negative changes in coral reef ecosystems, “runaway” climate change, and interacting nonlinear “planetary boundaries”—is often viewed as a substantial challenge for governance due to their inherent uncertainty, potential for rapid and large system change, and possible cascading effects on human well-being. Despite an increased scholarly and policy interest in the dynamics of these perceived “tipping points,” institutional and governance scholars have yet to make progress on how to analyze in which ways state and non-state actors attempt to anticipate, respond, and prevent the transgression of “tipping points” at large scales. In this article, we use three cases of global network responses to what we denote as global change-induced “tipping points”—ocean acidification, fisheries collapse, and infectious disease outbreaks. Based on the commonalities in several research streams, we develop four working propositions: information processing and early warning, multilevel and multinetwork responses, diversity in response capacity, and the balance between efficiency and legitimacy. We conclude by proposing a simple framework for the analysis of the interplay between perceived global change-induced “tipping points,” global networks, and international institutions.

Keywords Global environmental change · Anthropocene · Planetary boundaries · Global networks · Earth system governance · Adaptive governance

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1 Introduction

Global environmental change can unfold rapidly and sometimes irreversibly if anthropogenic pressures exceed critical thresholds. Such nonlinear change dynamics have been referred to as “tipping points”.¹ Evidence indicates that many global environmental challenges such as coral reef degradation, ocean acidification, the productivity of agroecosystems, and critical Earth system functions such as global climate regulation display nonlinear properties that could imply rapid and practically irreversible shifts in bio-geophysical and social–ecological systems critical for human well-being (Steffen et al. 2011; Rockström et al. 2009; Lenton et al. 2008).

The potential existence of “tipping points” represents a substantial multilevel governance challenge for several reasons. First, it is difficult to a priori predict how much disturbances and change a system can absorb before reaching such a perceived “tipping points” (Scheffer et al. 2009; Scheffer and Carpenter 2003), a fact that seriously hampers, and even undermines preventive decision making (Galaz et al. 2010a; Barrett and Dannenberg 2012). It has also been argued that even with certainty about the location of a catastrophic “tipping point,” present generations still have an incentive to avoid costly preventive measures, and instead are likely to pass on the costs to future generations (Gardiner 2009, see also Brook et al. 2013; Schlesinger 2009). Second, the transgression of “tipping points”—such as those proposed for coral reef ecosystems due to ocean acidification—can have social–ecological effects that occur over large geographical scales, creating difficult “institutional mismatches” as policy makers respond too late or at the wrong organizational level (Walker et al. 2009). Third, institutional fragmentation has been argued to seriously limit the ability of actors to effectively address perceived “tipping point” characteristics due to inherent system uncertainties, information integration difficulties, and poor incentives for collective action across different sectors and segments of society (Biermann 2012; Galaz et al. 2012).

Research initiatives such as the Earth System Governance Project have made important analytical advances the last few years (Biermann et al. 2012). This progress is particularly clear in research areas such as institutional fragmentation, segmentation, and interactions; the changing influence of non-state actors in international environmental governance; novel institutional mechanisms such as norm-setting and implementation; and changing power dynamics in complex actor settings (Young 2008; Biermann and Pattberg 2012; Oberthür and Stokke 2011). The mechanisms which allow institutions and state and non-state actors to adapt to changing circumstances (by some denoted *adaptiveness*) are also gaining increased interest by scholars (Biermann 2007:333; Young 2010).

Another stream of literature elaborates a suite of multilevel mechanisms that seem to be able to “match” institutions with the dynamic behavior of social–ecological systems (Dietz et al. 2003; Folke et al. 2005; Cash et al. 2006; Galaz et al. 2008; Pahl-Wostl 2009).

Despite an increased interest, however, few empirical studies exist that explicitly explore the capacity of *international* actors, institutions, and global networks to deal with perceived “tipping point” dynamics in human–environmental systems. As an example, recent syntheses of critical global environmental governance challenges in the Anthropocene identify important “building blocks” for institutional reform, yet do not elaborate governance mechanisms critical for responding to nonlinear environmental change at global scales (Biermann et al. 2012; Kanie et al. 2012). This is troublesome considering that the human enterprise now affects systems with proposed nonlinear properties at the

¹ See below for a more detailed discussion and references.

global scale (Steffen et al. 2011; Rockström et al. 2009) and that the features of global environmental governance—i.e., institutions and patterns of collaboration—required to address “tipping point” changes are likely to be very different from those needed to harness incremental (linear) environmental stresses (Folke et al. 2005; Duit and Galaz 2008). While some of the challenges explored here have parallels to attempts to understand the features of international responses to international social nonlinear “surprise” phenomena such as financial shocks and other global risks (e.g., Claessens et al. 2010; OECD 2011), we are particularly interested in the “tipping point” dynamics created by coupled human–environmental change.

2 A contribution

There is an increasing need to empirically explore and theorize the way state and non-state actors perceive, respond to and try to prevent large-scale abrupt environmental changes. This is a challenging empirical task for several reasons. First, because the definitions of “thresholds,” their reversibility, and their scale remain contested issues. There is currently an intense scientific debate on the most appropriate way to define and delineate the correct spatial (local–regional–global) and temporal (slow–fast) progression of thresholds (for example, see Brook et al. 2013, as well as debates about the “2-degree” climate target, Hulme 2012 in Knopf et al. 2012). Second, because the number and types of potential “tipping points” relevant for the study of biophysical systems at global scales are too large to be quantifiable, this makes it difficult to draw general conclusions from a limited set of cases studies. Third, while the governance challenges associated with “tipping points” have been studied extensively for local- and regional-scale human–environmental systems such as forest ecosystems, freshwater lakes, wetlands, and marine systems (see Plummer et al. 2012 for a synthesis), governance challenges associated with global scale or global change-induced tipping point dynamics are seldom explored despite their identified urgency (Young 2011: 6).

In this study, we analyze current attempts by three global networks to address perceived “tipping points” induced by global change, here exemplified by the combined impacts of loss of marine biodiversity and ocean acidification, pending fisheries collapse, and infectious disease outbreaks, respectively. While these “tipping points” are in many ways different, they have one important thing in common: they are all globally occurring phenomena where the interplay between technological change, increased human and infrastructural interconnectedness, and continuous biophysical resource overexploitation creates possible “tipping point” dynamics (see definition below). This is what we here denote as “global change-induced tipping points.”

It should be noted that the precise dynamics of the “tipping points” in each of the three cases differ and unfold at multiple scales ranging from local to regional and global (see Table 1 for details). Despite this diversity, the phenomena studied here all pose similar detection, prevention, and coordination challenges for social actors at multiple scales of social organization (as elaborated by, e.g., Adger et al. 2009; Pahl-Wostl 2009; Galaz et al. 2010a; Young 2011). Hence, they provide interesting and preliminary insights into the sort of multilevel governance challenges associated with nonlinear global change-induced change.

Our ambition is twofold: firstly, we investigate how these global networks attempt to identify, respond to, and build capacity to address global change-induced “tipping points.” We do this by identifying and empirically illustrating four working propositions that

Table 1 “Tipping points”—mechanisms and major uncertainties

| Network | “Tipping point/s” and time frame | Mechanism | Major uncertainties | References |
|--------------------------|--|---|---|------------|
| Pacfa | Ocean acidification, loss of carbon mitigating capacity of oceans, possible cascading fish stock collapse. Expected within decades for ocean acidification | (1) Anthropogenic CO ₂ dissolves and produces carbonic acid that strongly reduces the rate of calcification of marine organisms. (2) Risk that the capacity of oceans to act as “carbon sink” is undermined through changed carbon cycle feedbacks. (3) Possibilities for rapid collapse of fisheries as a result of multiple anthropogenic stresses | How will marine organisms and ecosystems adapt? How are chemical and ecological “tipping points” linked, and at what scales? What are key cascading impacts, and who is responsible for action? | [1–3] |
| Global epidemic networks | Risk of rapid (<weeks) uncontrolled infectious disease spread through transportation networks after transgression of pandemic phases | Spread of disease increasingly difficult to control if the basic reproduction number $R_0 > 1$ (i.e., threshold). This is defined by, e.g., virulence, transmissibility and severity | What infectious disease of international concern will emerge, when, where, how will it spread geographically, and how can it be addressed promptly? | [4, 5] |
| CCAMLR | Collapsing valuable fish stocks and extinction of globally threatened seabirds, expected within years | Illegal and unregulated fishing dramatically reduces naturally long-lived and late maturing fish, and affect seabird populations with proposed threshold dynamics | Where will IUU fishing (in the Southern Ocean) emerge next, where are products landed, and which actors and states are involved? | [6] |

Based on [1], Hoegh-Guldberg et al. (2007). [2]. Cox et al. (2000). [3] Hutchings and Reynolds (2004). [4]. Wallinga and Teunis (2004). [5]. WHO (2005). [6] Österblom H et al. (2010).

theoretically seem to be essential for understanding adaptiveness in global networks in the face of “tipping point” changes. Secondly, we explore the interplay between perceptions of human–environmental “tipping points,” international institutions, and collaboration patterns here operationalized as global networks. This perspective allows for a more cohesive view that combines both exogenous (i.e., perceived “tipping point” dynamics) and endogenous (i.e., information sharing mechanisms) factors (*sensu* Young 2010). We will return to this point in the end of the article. Note that, our ambition is not to “test” the proposed features in a statistical sense, but rather to combine in-depth analysis of the case studies, with tentative suggestions that bring to light a number of intriguing and poorly explored issues. While the selection of cases does not provide the generalizability of larger-N studies, it does allow us to examine how the theoretically derived propositions play out in the three different cases, and also provides an opportunity to explore around the

potential interplay between variables and causal mechanisms. Our ambition in the longer term is that the analysis presented here can underpin more systematic cross-case comparisons (cf. Gerring 2004). In some cases, this comparison could be done with “tipping points” which play out only in the social domain such as financial crises or responses to transnational security threats (e.g., World Economic Forum 2013).

3 Definitions

3.1 Global networks

We define “global networks” as globally spanning information sharing and collaboration patterns between organizations, including governmental and/or non-governmental actors. Each individual participating organization is not necessarily global, but the network as a whole is essentially international and aims to affect what is perceived as global-scale problems (c.f. Monge and Contractor 2003).

Our analytical approach is relational as it focuses on broad patterns of collaborations among actors in global networks, and on how patterns of collaboration and modes of operation relate to these networks’ abilities to address “tipping points.” It is particularly concerned with multiactor agency to understand changes in collaboration over time (Emirbayer and Goodwin 1994). Hence, the approach here differs and is complementary to other approaches such as “epistemic communities” and “regime complexes.” In the first case, the functions and membership of global networks are more diverse than those for epistemic communities as the networks of interest in this paper span beyond knowledge-based collaborations (Haas 1992, see however Cross 2012 for a wider definition). The analysis here also has some similarities to the studies of “regime complexes” (Orsini et al. 2013); however, our emphasis is not on the interplay between regimes or institutions (principles, norms, rules, decision-making procedures), but rather on the constellation, interplay, and functions that emerge between actors from a network perspective.

While we do not quantitatively measure collaboration patterns, nor quantitatively assess governance outcomes or relationships between such outcomes and various characteristics of the studied global networks, our network perspective complements previous analyses of international environmental regimes (e.g., Young 2011) as it examines the evolution and function of globally spanning network collaboration patterns and their embeddedness within more formal rules (cf. Ansell 2006).

3.2 “Tipping points” and thresholds

Various definitions for “tipping points” have been identified in the literature. Its theoretical origins can be traced to dynamical systems theory in the 1960s and 1970s, and has influenced a wide set of disciplines the last decades. Earth system scientists, for example, have explored nonlinear phenomena at different scales, with different degrees of reversibility and alternately defined these as “tipping elements,” “switch and choke points,” or “planetary boundaries” at a global scale (Lenton et al. 2008; Rockström et al. 2009b; Steffen et al. 2011).

Ecologists on the other hand find increasing evidence of ecosystem changes that are not smooth and gradual, but abrupt, exhibiting thresholds with different degrees of reversibility once crossed (Scheffer et al. 2009; Scheffer and Carpenter 2003). While “tipping points” thus refer to a variety of complex nonlinear phenomena (including the existence of positive

feedbacks, bifurcations, and phase transitions with or without hysteresis effect), they also play out at different scales (from local to global) in very complex, poorly understood (Kinzig et al. 2006), and contested ways (Brook et al. 2013).

Lastly, we believe there is an irreducible social component in identifying, elaborating, and organizing around the existence of “tipping points.” The role of mental models, cognitive maps, belief systems, and collective meaning making in decision making has a long history in the study of agency in politics (Benford and Snow 2000; Campbell 2002) and natural resource management (Lynam and Brown 2011). These aspects related to perceptions clearly also play a role as scientists, governments, and other actors discuss and sometime disagree on their possible existence and appropriate responses (Galaz 2014:16ff). The important connection between mental models and goal-oriented action are *causal beliefs*—perceptions of the causes of change—and about the actions that can lead to a desired outcome (Milkoreit 2013:34f). It should be noted, however, that this study explores the processes of collaboration that occur *after* social actors implicitly have agreed upon causal beliefs associated with perceived “tipping points.”

We thus recognize the multifaceted and complex nature of the term. However, as our goal is to understand how global networks address a diversity of “tipping points” induced by global change, we opt for a definition that relates to phenomena exhibiting nonlinear and potentially irreversible change processes in human–environmental systems, which require global responses (see Table 1). This definition is intended to capture global change-induced phenomena, which due to nonlinear properties such as synergistic feedbacks (c.f. Brook et al. 2013:2) have the potential to affect large parts of the world population (c.f. Lenton et al. 2008).

Our definition is akin to the “tipping elements” identified by Lenton et al. (2008), but we chose to make a distinction for two reasons: (1) because we explicitly acknowledge that the dynamics that create the tipping points in focus comprise both natural and social processes; (2) the tipping points addressed here span beyond those of relevance for the climatic system in focus in Lenton et al. (*ibid*).

4 Case studies and methods

The empirical analysis includes case studies of three global networks (Fig. 1) that with varying degrees of outputs and outcomes (*sensu* Young 2011) explicitly attempt to respond to global change-induced “tipping points” (Table 1). By “explicitly,” we mean that they all acknowledge and mobilize their actions around the notion of potentially harmful global change-induced “tipping points.” While this selection does not capture cases where “tipping points” exist, but global networks fail to materialize (c.f. Dimitrov et al. 2007), the ambition has been to include cases that reflect a diversity of global change-induced “tipping point” dynamics, with global network responses as common features.

As noted by Mitchell (2002), the complexity of human–environmental systems makes outcomes of international environmental collaboration hard to measure directly, since these often have indirect and non-immediate impacts (Mitchell 2002:445). To operationalize the analysis, we thus focus on the *outputs* and *outcomes* produced by the actors as they attempt to (a) anticipate, (b) prevent, and (c) respond to perceived “tipping points.” Again, our ambition is not to “test” the propositions, but rather to use the case studies to empirically explore how global networks attempt to respond to “tipping point” challenges, pose novel important questions, and explore how to potentially pursue these questions systematically.

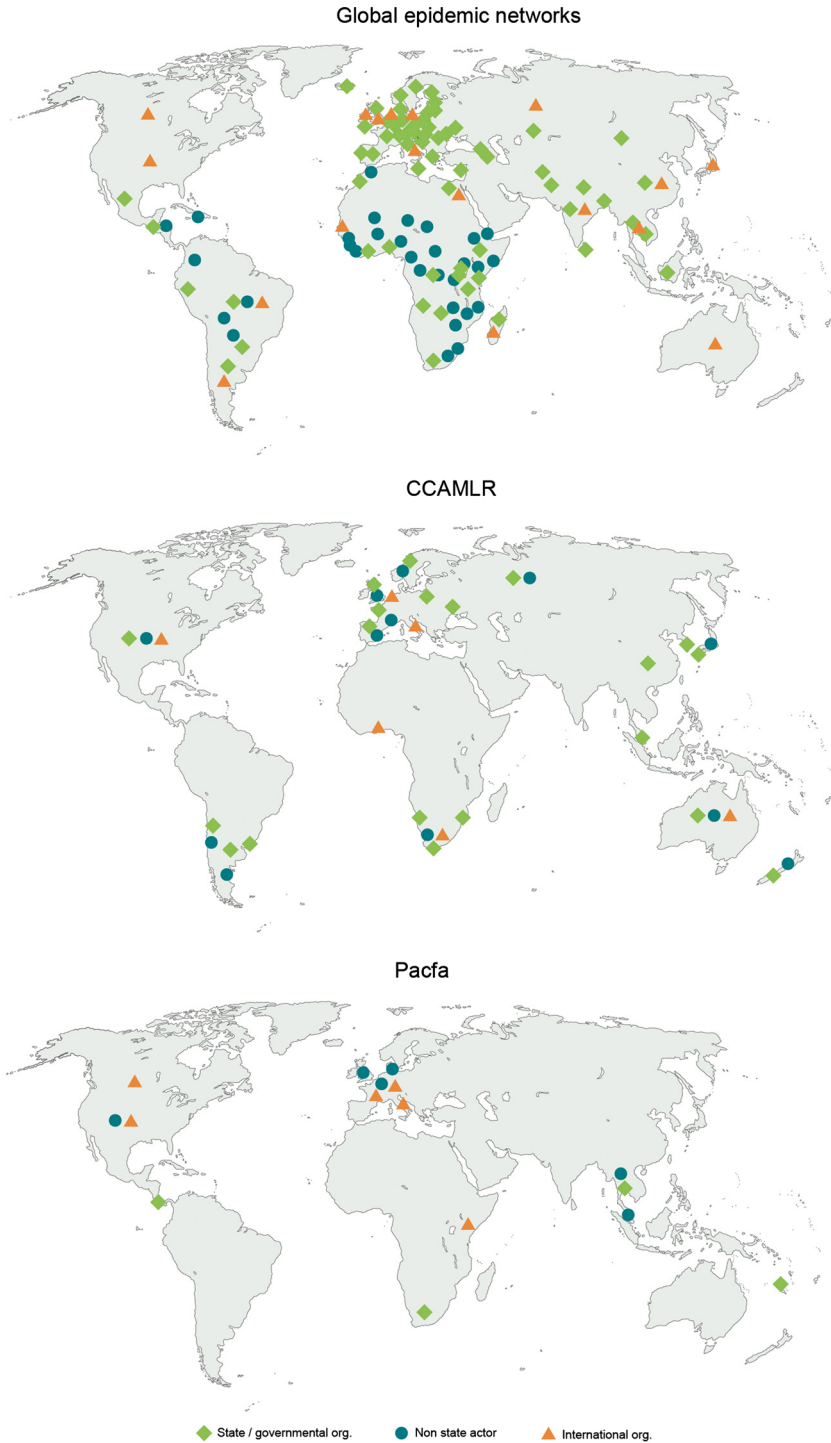


Fig. 1 Three global networks

4.1 Case 1. Pacfa: global partnership climate, fisheries, and aquaculture

Ocean acidification is likely to exhibit critical tipping points associated with rapid loss of coral reefs, as well as complex ocean–climate interactions affecting the oceans’ capacities to capture carbon dioxide. The global arena for addressing these interrelated aspects of marine governance is characterized by a lack of effective coordination among the policy areas of marine biodiversity, fisheries, climate change, and ocean acidification. This has triggered collaboration between a number of international organizations within the Global Partnership for Climate, Fisheries and Aquaculture (henceforth Pacfa). Currently, this initiative includes representatives from the Food and Agriculture Organization (FAO), the United Nations Environment Programme (UNEP), WorldFish, The World Bank, and 13 additional international organizations (Galaz et al. 2011, see also Fig. 1).

4.2 Case 2. Global epidemic early warning and response networks

The need for early and reliable warning of pending epidemic outbreaks has been a major concern for the international community since the mid-nineteenth century. Early warning and coordinated responses are critical in order to avoid transgressing critical epidemic thresholds at multiple scales (Heymann 2006). A multitude of networks with different focus and functions (such as surveillance, laboratory analysis, and pure information sharing) have emerged the last two decades as a means to secure early warning and response capacities across national borders. These networks (henceforth global epidemic networks) also span across organizational levels and include among other the World Health Organization (WHO), the World Organization for Animal Health (OIE), the Food and Agricultural Organization (FAO), the Red Cross, Doctors without Borders. These networks facilitate responses to epidemic emergencies of international concern by providing early warning signals, rapid laboratory analysis, information dissemination, and coordination of epidemic emergency response activities on the ground (Galaz 2011) .

4.3 Case 3. A global network to address illegal, unreported, and unregulated fishing in the Southern Ocean

Illegal, unreported, and unregulated (IUU) fishing for Patagonian toothfish *Dissostichus eleginoides* can if unchecked, lead to the collapse of valuable fish stocks and endangered seabird populations (Table 1). The toothfish market and actors involved in IUU fishing are distributed globally, which necessitates coordination between states on all continents. State and non-state actors have increasingly developed their networks for cooperation and are currently operating at the global level (Fig. 1) through the Commission for the Conservation of Antarctic Marine Living Resources (henceforth CCAMLR) and associated actors (Österblom and Bodin 2012). Coordinated international responses on important fishing grounds have resulted in a dramatic reduction in IUU fishing. States now have well-developed mechanisms for coordinated monitoring and response when new actors, markets, or IUU fishing emerge in the Southern Ocean (Österblom and Sumaila 2011).

4.3.1 Methods

The data used in this article are drawn from previously published studies (see “Appendix 2”), but complemented with additional documents, and restructured with a focus on the four working propositions presented below. All cases used the same methodology,

combining document studies, simple network analysis, and semi-structured interviews with key international actors (a total of about 65 interviews for all cases). Interviewees have been selected strategically to reflect an expected diversity of interests, resources, and role in the network collaboration of interest. The empirical material was restructured and complemented to capture (1) the perceived risk of “tipping points” with cross-boundary effects, including major uncertainties, threshold mechanisms, and time frames of relevance; (2) the global nature of the problem, including the aspects of institutional fragmentation; (3) emergence of the network and evolution over time; (4) current monitoring and coordination capacity of the network; (5) the most important outputs and outcomes of the network. A detailed, fully referenced and structured compilation of the cases is for space reasons, available as “Appendix 2.”

5 Four working propositions

Several attempts have been made to identify how governments, organizations, and international actors attempt to not only maintain institutional stability, but also flexibility in the face of unexpected change (Duit and Galaz 2008). Studies of crisis management (Boin et al. 2005), network management and “connective capacity” in governance (Edelenbos et al. 2013), the robustness of social and organizational networks (Dodds et al. 2003; Bodin and Prell 2011), complexity leadership (Balkundi and Kilduff 2006), and the governance of complex social–ecological systems (Ostrom 2005; Folke et al. 2005; Pahl-Wostl 2009) all provide important insights into how social actors try to respond to unexpected changes. Based on these streams of literature, we extract four working propositions to guide the analysis of the empirical material. These propositions should not be viewed as all-embracing principles for “success,” but rather as suggested and empirically assessable governance functions at play as international actors aim to detect, respond, and prevent the implications of “tipping point” environmental change. The propositions also allow a concluding reflection of the interplay between international institutions, global change-induced “tipping points,” and global networks.

5.1 Proposition 1: information processing and early warnings

As a number of research fields—ranging from studies of social–ecological systems (Holling 1978; Folke et al. 2005; Galaz et al. 2010b), crisis management (Boin et al. 2005), global disaster risk reduction (Van Baalen and van Fenema 2009), and high-reliability management of complex technical systems (Pearson and Clair 1998)—have explored, the capacity to continuously monitor, analyze, and interpret information about changing circumstances seems to be a prerequisite for adaptive responses. These information processing capacities are for example identified as critical by, e.g., Dietz et al. (2003:1908) in their elaboration of the features of governance, which support adaptiveness to environmental change; Van Baalen’s and van Fenema’s (2009) analysis of global network responses to epidemic surprise; and by Boin et al. (2005:140ff) and their synthesis of information processing capacities, which allow state and non-state actors to respond to crises (see also Comfort 1988; Dodds et al. 2003).

We therefore propose that the ability of global networks to anticipate and reorganize in the face of new information and changing circumstances will depend on access to information about system dynamics and the ability to interpret these to facilitate timely coordinated response.

5.2 Proposition 2: multilevel and multinetwork responses

As a number of studies in a diverse set of research fields suggest, responding to changing circumstances often requires drawing on the competences and resources of actors at multiple levels of social organization, often embedded in different organizational networks. For example, Folke et al. (2005) explore the need to build linkages between a diversity of actors at multiple levels to be able to successfully deal with nonlinear social–ecological change (see also Pahl-Wostl 2009); Pearson and Clair’s (1998:13) synthesis of organizational crises identify resource availability through external stakeholders as key for successful responses (see also Boin et al. 2005; Van Baalen and van Fenema 2009); Galaz et al. (2010a:12) synthesis also indicate that cross-level and multiactor responses are key for overcoming institutional fragmentation in responses to abrupt human–environmental change; and Ede-lenbos et al. (2013) explore the features of “connective capacities,” which allow coordinating actors to constructively connect to actors from different layers, domains, and sectors.

Therefore, we propose that global networks need to build a capacity to coordinate actors at multiple levels and from different networks as they attempt to respond to potential “tipping points” of concern. It also seems reasonable that responses could focus on producing either a set of *outcomes* (regulation, policies, or supporting infrastructure) or *outputs* (behavioral changes with direct impacts on the system of interest, including coordinated action) (Young 2011).

5.3 Proposition 3: develop and maintain a diverse response capacity

The predictability of the timing and location of rapid unexpected changes is often limited. Hence, it is difficult to know beforehand exactly where and what kind of resources may be needed. As several scholars across disciplines have noted, developing and maintaining a diversity of resources is one way to help prepare for the unexpected. For example, Moynihan’s (2008:361) analysis of learning in organizational networks indicates that the maintenance of actor and resource diversity in networks is fundamental for reducing strategic and institutional uncertainty (see also Koppenjan and Klijn 2004). Bodin and Crona (2009) explore the role of social networks in natural resource management and note that actor diversity is key for not only effective learning, but also provides a fertile ground for innovation. Social–ecological scholars such as Folke et al. (2005:449), Low et al. (2003), and Dietz et al. (2003) also make a strong case for institutional and actor diversity as a prerequisite for coping with environmental change and as a factor that allows actors to quickly “bounce back” after shocks. These proposals bear resemblances with ideas inspired by cybernetic principles about the need to understand the impacts of “requisite variety” in governance, that is, the informational, structural, and functional redundancies that emerge as the result of inter-organizational collaboration in governance networks (Jessop 1998). It also has parallels existing studies about complexity leadership in network settings (Balkundi and Kilduff 2006; Hoppe and Reinelt 2010). To simplify the analysis, however, we focus less on the role of individual leaders, their cognition, and strategies, but rather on common structural properties and aggregated behavior across the cases.

Hence, we propose that global networks need to secure long-term access to a diversity of resources (human and economical), organizational forms (e.g., non-governmental to international organizations), and types of knowledge (e.g., scientific and context dependent) to be able to secure a capacity to monitor and respond in the longer term. These resources could comprise both physical and infrastructural investments (e.g., joint publications and monitoring systems), and immaterial resources, like information databases and

access to expertise through relations to a diversity of actors. This third proposition does not suggest that the network necessarily maintains the resources itself (which may be difficult given its inherently distributed nature), but rather that it maintains the capacity to access a portfolio of resources of different kinds, and the collective ability to adaptively use these.

5.4 Proposition 4: balancing legitimacy and efficiency goals

A last feature that has been identified across disciplines as critical for multiactor responses seems to be legitimacy. “Legitimacy” is a multifaceted concept with multiple proposed sources (Downs 2000). Here, we refer to legitimacy as the “generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate” (Suchman 1995, 574). As Young (2011) summarizes it, the “[m]aintenance of feelings of fairness and legitimacy is important to effectiveness, especially in cases where success requires active participation on the part of the members of the group over time.” Legitimacy relates not only to the ability of actors to follow appropriate rules or procedures (*input legitimacy*) but also to deliver expected results in the face of perceived urgent issues of common interest (*output legitimacy*) (van Kersbergen and van Waarden 2004). Moynihan (2008) also notes that trust based on perceived legitimacy plays a key role in the coordination of multiple networks by reducing strategic uncertainty (pp. 357). We therefore propose that the perceived legitimacy of the main coordinating actor(s) will be critical for the operation of global networks in this context.

With these propositions to guide our analysis, we now turn to examine how the three cases of global networks attempt to anticipate, prevent, and respond to global change-induced “tipping points.”

6 Summary of results²

6.1 Information processing and early warnings

Interestingly, all cases feature the role of a few centrally placed actors responsible for continuous data gathering and exchange of information. This is both related to monitoring of specific aspects of a system (e.g., number and location of epidemic outbreaks, or reports of IUU fishing), as well as to the compilation and analysis of other types of knowledge exchange (e.g., policy documents, technical guidelines, and scientific information).

The mobility of IUU fishing vessels and associated products requires network members to be able to instantly coordinate action in order to stop illegal activities. The CCAMLR-IUU network has developed mechanisms for obtaining, processing, and sharing of information related to IUU fishing operations and trade flows, where the CCAMLR secretariat serves as an important network hub (Österblom and Bodin 2012). This network benefits from several well-established compliance mechanisms developed over time, including an electronic catch documentation scheme and information collected from satellite monitoring of vessel activities (Miller et al. 2010). Non-state actors also contribute to monitoring by reporting suspected vessel sightings or trade flows (Österblom and Bodin 2012). All information collected is reviewed annually by CCAMLR, where consensus decisions are taken to blacklist suspected vessels or impose other sanctions.

² Note again that this part builds exclusively on a lengthier synthesis of the case studies presented in “Appendix 2.”

Fig. 2 Multilevel and multinetwork responses. **a** Examples of detection, coordination, and apprehension of vessels or corporations suspected of IUU fishing. The vessel “Viarsa” was detected in the Southern Ocean by the Australian coast guard and suspected of illegally fishing of Patagonian toothfish. After the longest maritime hot pursuit in maritime history (7,200 km) and substantial diplomatic coordination, the vessel was seized after the combined effort from Australian, South African, and UK assets. The charges were eventually dropped. **b** Examples of detection and response to emerging infectious diseases of international concern. The first signs of a new flu A/H1N1 (“swine flu”) could be found early in local news reports posted on HealthMap. It was one report by the early warning system GPHIN that alerted the WHO of an outbreak of acute respiratory illness in the Mexican state of Veracruz. This induced several iterations of communication between Mexico and the WHO (2), as well as sharing of virus samples to US and Canadian medical laboratories (3). At this stage, the WHO also issued several recommendations to its member states (4). This initiated a chain of national responses (some clearly beyond WHO recommendations), including thermal screening at airports, travel restrictions, and trade embargoes (5). The suspected causative agent of A/H1N1 induced stronger collaboration between WHO, FAO, and OIE, and the expansion of associated expert groups to include swine flu expertise resulting in continuous recommendations to member states (6). *DAFF (AU)* Department of Agriculture, Fisheries, and Forestry (Australia), *FCO (UK)* British Foreign and Commonwealth Office, United Kingdom, *ASOC* Antarctic Southern Ocean Coalition, *AFMA (AU)* Australian Fisheries Management Authority, *MCM (ZA)* Marine and Coastal Management (Department of Environmental Affairs, and Tourism), South Africa, *WHO* The World Health Organization, *FAO* The Food and Agricultural Organization, *PAHO* The Pan American Health Organization, *OIE* The World Organization for Animal Health, *GPHIN* The Global Public Health Intelligence Network, *PromED* Program for Monitoring Emerging Diseases

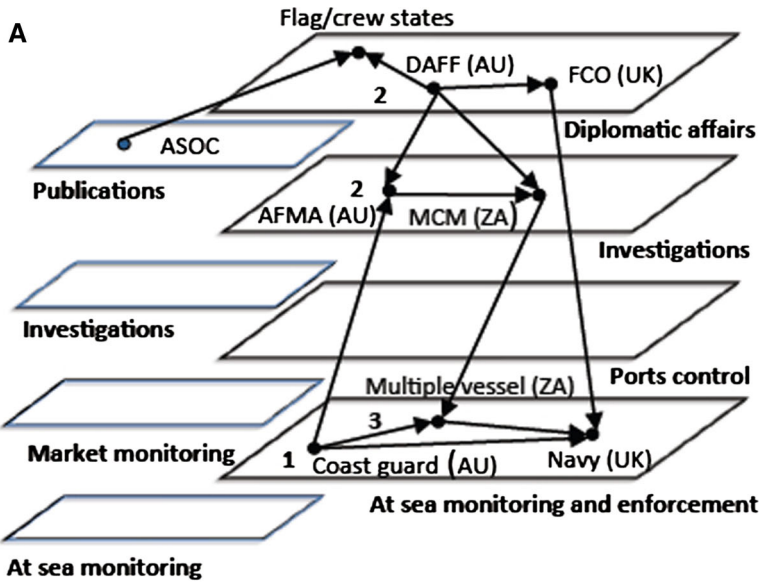
Similar features can be identified for information processing in global epidemic networks. Severe problems with national reporting of disease outbreaks spurred a new generation of Internet-based monitoring systems in the mid-1990s, including the Global Public Health Intelligence Network (GPHIN) hosted by Health Canada, combining Internet data-mining technologies and expert analysis, as well as global and moderated epidemic alert e-mail lists and platforms such as ProMED and HealthMap.org (Galaz 2011). These systems have vastly increased the amount of epidemic early warnings processed by key international organizations such as the WHO and the Food and Agricultural Organization (FAO). These organizations are key actors through their capacities to continuously assess, verify, and disseminate incoming epidemic alerts.

The rich flows of information and elaborate verification mechanisms in these two networks are very different from those identified for Pacfa. Information flows in this network are considerably less formalized and instead center on establishing dialogue between centrally placed individuals who act as points of contact in different international and regional organizations. The importance of trust-based communication between coordinating actors is important for Pacfa as alliances are forged to link international negotiations, scientific knowledge and local knowledge, and field projects (Galaz et al. 2011). Here, therefore, information processing is not about monitoring a particular system variable (i.e., number of infected cases or reports of illegal fishing vessels), but rather on achieving coordination benefits for its members.

Hence, while information processing is important in all cases, it differs in content and function between the networks. The fact that the first two networks respond to well-defined problems (inception of illegal vessels in one region and the isolation of disease outbreak) and the last to more complex global challenges (i.e., global interlinked bio-geophysical dynamics) seems to make an important difference.

6.2 Multilevel and multinetwork responses

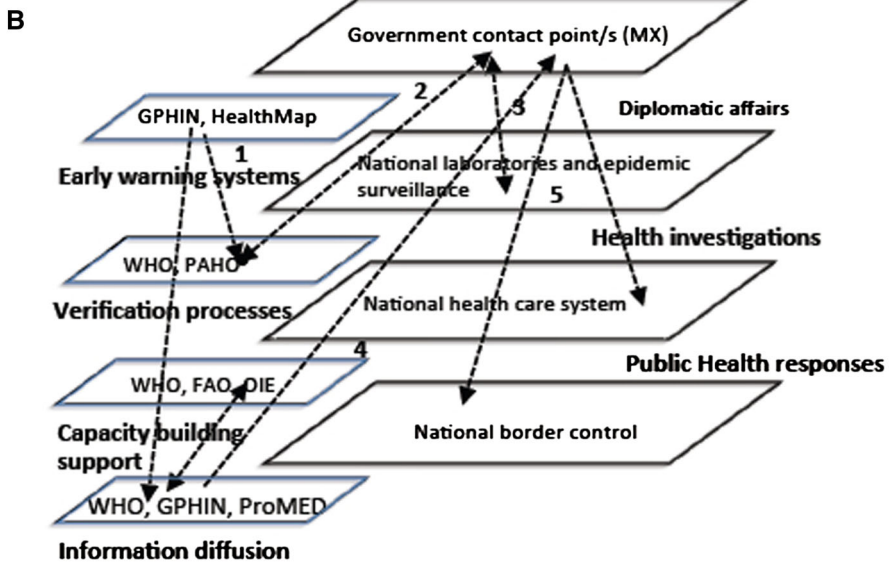
While multilevel governance is a common feature of environmental polity in general (Winter 2006), governing “tipping points” requires a capacity among centrally placed



Non-state actors

Governments

→ 2003 Detection and apprehension of the Viarsa



International Organizations and Non-State Actors

National

→ 2009 Detection and response of "new flu" A/H1N1

actors, to rapidly pool resources from participating network members at multiple levels. Figure 2 is based on two case analyses (see “Appendix 2” for details) and illustrates these multilevel collaboration and information sharing processes.

National delegations to CCAMLR integrate several types of actors, including NGOs and fishing industry representatives, who in turn are also members in ASOC, the Antarctic Southern Ocean Coalition (a global NGO network) or COLTO—Coalition of Legal Toothfish Operators (an industry network). This network can coordinate actors within matters of days and involve rapidly mobilizing capacity to apprehend illegal vessels (Fig. 2a).

Global epidemic networks are also nested in a larger global network landscape, with a similar ability to rapidly react to epidemic early warnings, including the identification of the SARS coronavirus, analysis and response to an unknown form of influenza in Madagascar, and prevention of epidemics of yellow fever in Côte d’Ivoire and Senegal. Which national, regional, or international organization that becomes the central coordinator depends on the disease agent and location of interest. However, the WHO Global Outbreak and Response Network (GOARN) and the FAO Emergency Centre that facilitates coordination for Trans-boundary Animal Diseases (ECTAD) (Fig. 2b) are well-known key coordinating players.

While the Pacfa network does not respond to rapidly unfolding system dynamics per se, it tries to identify political opportunities in international policy arenas as a way to prevent “tipping points” related to marine systems and biodiversity. Hence, the coordination challenges across multiple levels are similar as those identified for the other two networks, but with a different focus. For example, while a overall network aim was initially to influence international climate negotiations in Copenhagen 2009 to integrate marine issues, the path toward this goal consisted of multiple coordinated actions at multiple levels (from assessing potential adaptation needs locally, communicating these, and influencing national delegations at side events to COP15). This required a capacity among a core group of actors (FAO) to tap into resources and knowledge across levels and networks, including international scientific institutions (such as ICES), international organizations (World Bank), and place-based research NGOs (WorldFish) (Galaz et al. 2011).

6.3 Development and maintenance of diverse response capacity

Maintaining response capacity over time requires maintaining access to diverse resources and competences. All three cases examined here have evolved through time by strategically expanding the membership of the network to increase their “portfolio diversity.” CCAMLR hosts and funds strategic training workshops in regions where effective response capacities have been viewed as lacking (e.g., in Southern Africa and Malaysia). Several member countries cooperate extensively around offshore monitoring and training, in order to improve the joint enforcement capacity of the network (Österblom and Bodin 2012). Actors within the network—coordinated nationally, between organizations or between groups of countries—also continuously develop suggestions for new and revised policy measures to address IUU fishing.

Global epidemic networks have stretched over time as the result of an explicit strategy to expand international surveillance and response networks, particularly in epidemic hot-spot regions where surveillance is weak (e.g., Asia and Africa) and for diseases perceived as critical for the international community (such as avian influenza). The expansion is both strategic and crisis-driven, and involves continuous capacity building through workshops, conferences, and guidelines (e.g., Heymann 2006).

Similarly, Pacfa has expanded membership in parts of the world where representation is missing and where tangible field presence could prove useful for attempts to link local governance to global institutional processes. It has also included member organizations of various types—from NGOs to scientific organizations—as an explicit strategy to increase skills and resource portfolios. This has also proven as a fruitful way to create a platform for exchange of knowledge, ideas, and information among members. This seems to improve the network's capacity to coordinate local responses (such as improved local marine governance in the face of ocean acidification) and integrate scientific advice into negotiation texts for international policy improvement (Galaz et al. 2011).

6.4 Balancing legitimacy and efficiency goals

The synthesis indicates that issues of legitimacy are constantly being debated in all networks, but that their responses differ. In general, however, centrally placed actors seem to build legitimacy by strategically enhancing the diversity and number of members, increasing the degree of formalization in what originally were informal collaboration mechanisms, and by encouraging the entrenchment of the networks in various UN organizations.

Cooperation within CCAMLR to address IUU fishing emerged in a context where there was a significant risk of fish stock collapse, but where governments were unable to effectively act due to political sensitivities and constraints posed by consensus mechanisms in the network (Österblom and Bodin 2012). Controversial and unorthodox methods for conveying the importance of addressing IUU fishing were instead developed by a small NGO–fishing industry coalition in the mid-1990s (Österblom and Sumaila 2011). A few governments in parallel also began exerting diplomatic pressure on member states of the Commission that were associated with illegal fishing, for example as flag, or port states or with their nationals working on board IUU vessels or as owners of associated companies.

This has at times resulted in substantial controversy and heated debate between member states about responsibilities and the role of NGOs in CCAMLR. Joint enforcement operations in the Southern Ocean have been described as pushing the edge of international law (Gullett and Schofield 2007), and suspected offenders have stated that they do not recognize existing territorial claims in the CCAMLR area as legitimate (Baird 2004). Continuous improvements of conservation measures and decision-making processes in CCAMLR have proven important for securing legitimacy of procedures. Legitimacy issues are also addressed by making Commission reports available online (except for background reports and reports containing diplomatically sensitive material).

The Pacfa has also struggled to balance legitimacy and efficiency. As the goal to influence the UNFCCC process emerged, the ambitions of Pacfa also become more explicitly political. This created tensions in the network between actors wanting to achieve tangible outcomes (and thus output legitimacy), and those concerned with overstepping their respective organizations' mandate (thus maintaining input legitimacy). A clear fault line with respect to this was observed between central international organizations and those representing science-based organizations in the buildup to the climate negotiations in Copenhagen 2009. While most of the activities initially evolved through the work of a few centrally placed actors with modest formal support from the FAO and its member states (Galaz et al. 2011), the network has become increasingly formalized and recently became a *UN Oceans-Taskforce*, which is likely to increase the network's input legitimacy in the UN system.

Addressing the risks of novel infectious disease outbreaks has been very high on the political agenda for the last decade, especially in the face of recurrent outbreaks of novel animal influenzas with the capacity to infect humans. Information processing and

coordination work is currently supported through the revised International Health Regulation (IHR). However, this cooperation model orchestrated by the WHO has also raised severe issues of both input and output legitimacy, especially issues such as the role of scientific advice and the influence of pharmaceutical companies; vaccination recommendations associated with the last pandemic outbreak (“swineflu” A/H1N1); and unequal global access to treatments. This has led to repeated calls for governance reforms aiming to increase transparency, effectiveness, and benefit sharing.

It should be noted that border protection issues, primarily associated with the fear of new terror attacks after September 11 2001 in the form of intentional releases of novel diseases, have triggered substantial investments in global epidemic monitoring and response networks for disease outbreaks. Analogous national security concerns in Australia after the national elections in the year of 2001, and the Bali bombings in 2002, likely contributed to an increased political opportunity to invest substantially in monitoring technologies for the Southern Ocean, as border protection became “securitized” (Österblom et al. 2011). In addition, international cooperation and exchange of information between compliance officers has increased substantially after the terrorist attacks in New York City in 2001. The expansion of the studied two networks described here thus appears to be linked to the securitization of the issue areas, which may have important implications for their perceived legitimacy in the future (c.f. Curley and Herington 2011).

7 Networks, tipping points, and institutions: concluding reflections

Here, we examined three globally spanning networks that all attempt to respond to a diverse set of perceived global change-induced “tipping points.” As the analysis shows, the working propositions have highlighted several interesting functions worth further critical elaboration, associated with the attempts to govern complex, contested, and “tipping point” dynamics of global concern (summarized in Table 2).

In short, we have illustrated how state and non-state actors (here operationalized as global networks) attempt to build early warning capacities and improve their information processing capabilities; how they strategically expand the networks, as well as diversify their membership; how they reconfigure in ways that secures a prompt response in the face of abrupt change (e.g., novel rapidly diffusing disease, illegal fishery) or opportunities (e.g., climate negotiations); and how they mobilize economical and intellectual resources fundamentally supported by advances in information and communication technologies (e.g., through satellite monitoring and Internet data mining).

But crises responses are only one aspect of these networks. Between times of abrupt change, centrally placed actors in the networks examined are involved in strategic planning aiming to bridge perceived monitoring or response gaps, capacity building needs, and secure longer-term investments. Maintaining legitimacy seems to be critical also empirically for the ability of global networks to operate over time.

Preventing the transgression of perceived critical “tipping points,” however, requires not only early warning and response capacities, but also an ability to address complex and underlying human–environmental drivers that contribute to the problem at hand (Walker et al. 2009). It is important to note that none of the networks studied here have neither the ability nor the mandate to directly address key underlying drivers such as climate change (e.g., for ocean acidification), land-use changes (e.g., associated with changed zoonotic risks), or technological change (e.g., contributing to increased interconnectedness and the loss of marine biodiversity). Hence, it remains an open question whether global networks as the ones studied here will ever

Table 2 Summary of four working propositions in cases

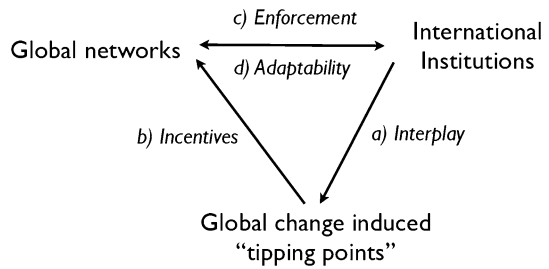
| | Pacfa | Global epidemics networks | CCAMLR |
|--|---|---|---|
| Information processing and early warnings | Mainly centered on bringing together scientific knowledge on topic of common interest; diffusion of this information to members and adapted to local contexts | New generation of early warning systems fundamental; key actors invest in capacities to rapidly gather, assess and disseminate information about unfolding epidemic events of international concern | Developed mechanism for obtaining, verifying, and sharing of information about, e.g., illegal vessels through its secretariat. NGO's and licensed fishing industry play key roles in complementing information |
| Multilevel and multinet network responses | Action involves using political opportunities to bring marine issues on top of international policy agendas, and secure support and funding | Action involves rapidly coordinating cross-national and multiexpert teams to analyze and respond to epidemic emergencies of international concern | Action involves rapidly mobilizing national and international agents and assets to apprehend illegal vessels. Coordinated action facilitated by CCAMLR protocols hosted by the secretariat |
| Development and maintenance of diverse response capacity | Strategic expansion of membership in networks to secure competences and regional representation; scientific workshops | Explicit strategy to expand and support networks in regions with weak monitoring and laboratory capacities; workshops and technical guidelines to secure coordinated action | Continuous information sharing and trust building through sustained, long-term, face-to-face interaction in the Commission. Joint training operations |
| Balancing legitimacy and efficiency goals | Attempts to increase legitimacy through more diverse and wider regional participation. Network embedded in UN system through FAO. Possible tensions with scientific members wishing to stay away from political lobbying activities | Information processing and coordination work supported through International Health Regulation. However, legitimacy issues have arisen, e.g., in cases of virus samples (Indonesia) and vaccination (polio in Nigeria, A/H1N1 epidemic) | Joint enforcement operations have been described as pushing the edge of international law. Enforcement and convicting sentences through US legislation has been described as unfair; prosecuted offenders do not recognize territorial claims as legitimate |

be able to collaborate if stipulated goals become more conflictive and complex, due to interactions between global drivers such as technological, demographical, and environmental (Galaz 2014).

7.1 Are global networks mere “symptom treatment”?

Yet, it would be a mistake to discard global networks as mere “symptom treatment.” The issues elaborated here not only exemplify how interacting institutions affect human–environmental systems at global scales (Gehring and Oberthür 2009). The cases also display how global networks attempt to complement functional gaps in the complex institutional and actor settings in which they are embedded. The perceived “sense of urgency” (i.e., avoiding the next pandemic, coping with potentially rapid ecological shifts in marine systems, or avoiding large-scale fish stock collapses) seemingly triggers the

Fig. 3 Suggested interplay between institutions, networks, and global change-induced “tipping points”



emergence of global networks created by concerned state and non-state actors. Figure 3 illustrates this proposed interplay between international institutions, perceptions of “tipping points,” and global networks.

By shaping state and non-state action, international institutions play a critical role in affecting the creation of potential global change “tipping points” (a in Fig. 3) (Young 2008, 2011). These perceived “tipping points” also create mixed *incentives* (b) for collective action. While coordination failure is likely due to actor, institutional, and biophysical complexity (Young 2008), the perceived urgency of the issue can also create *incentives* for action among international state and non-state actors, and spur the emergence of global networks based on common causal beliefs (b). These networks can support the *enforcement* (c) of existing international institutions through their ability to process information and coordinate multinet network collaboration, as well as create the endogenous and exogenous pressure needed to induce changes in international institutions. As Young notes, these sort of self-generating mechanisms can help build *adaptability* (d) and combat “institutional arthritis” (Young 2010, 382).

For example, the emergence of novel zoonotic diseases (such as avian influenza) is intrinsically linked to the effectiveness of a suite of institutional rules at multiple levels, e.g., though urbanization, land-use change, and technological development (*interplay*). The potential of these diseases to rapidly transgress dangerous epidemic thresholds creates *incentives* for joint action, in this case through the emergence of global early warning and response networks, despite malfunctioning formal institutions (e.g., IHRs before the year 2005). As nation states agreed to reform the IHRs in 2005, the revisions built on technical standards, organizational operation procedures, and norms developed by WHO-coordinated networks years in advance (*adaptability*) (Heymann 2006).

A similar mechanism seems to be at play for illegal, IUU fisheries. As the regional mandate of the existing international governance institution for IUU fishing proved insufficient (*interplay*), and the perceived threat of potential detrimental “tipping points” was perceived as valid (*incentives*), state and non-state actors increasingly developed their networks to operate at the global level, thereby drastically improving the *enforcement* capacities of existing international rules (Österblom and Sumaila 2011).

International actors trying to prepare for the possibly harmful human well-being implications of ocean acidification and rapid loss of marine biodiversity, also illustrate this triad. As these actors perceive the possible transgression of human–environmental “tipping points” (*incentives*), they coordinate their actions in global networks to increase their opportunities to bring additional issues to existing policy arenas created by international institutions (*adaptability*). At the same time, these institutions fundamentally affect the biophysical, technological, and social drivers that affect the “tipping points” at hand (*interplay*, e.g., the Convention on Biological Diversity, climate change agreements under the UNFCCC, and the United Nations Convention on the Law of the Sea).

The analysis is only tentative of course, especially considering the small number of cases, the contested nature of “tipping points,” and the need to explore additional working propositions. For example, we have not elaborated the cognitive and leadership processes leading up to a joint problem definition among the collaborating actors, nor a number of associated issues such as transparency and accountability in complex actor settings.

However, the analysis brings together a number of theoretically and empirically founded propositions worth further attention. More precisely, how state and non-state actors perceive and frame global change-induced “tipping points,” the unfolding global network dynamics, and how these are shaped by international institutions (Fig. 3) remain an interesting issue to explore further by scholars interested in the governance of a complex Earth system.

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Appendix 1: data for visualization of global networks

Figure shows key members in each respective network, including the type (state/governmental, non-state actor, international organization).

Data: Global epidemic networks based on WHO database on collaborating partners for outbreak and emergencies (<http://apps.who.int/whocc/Default.aspx>), OIE/FAO Network of expertise on animal influenza (<http://www.offlu.net/index.php?id=76>), European Center for Disease Prevention and Control (<http://www.ecdc.eu>), the US CDC Influenza Division International Program (Centers for Disease Control and Prevention. International Influenza Report FY 2010. Atlanta: US Department of Health and Human Services; 2010), and *Medecins Sans Frontieres* (http://www.msf.org/msf/countries/countries_home.cfm). It should be noted, however, that there are additional networks involved in global epidemic preparedness and response depending on the location and disease of interest.

Pacfa is based on official Web page (http://www.climatefish.org/index_en.htm) and Galaz et al. 2011.

The network around *IUU fishing in the CCAMLR* area is based on Österblom and Sumaila (2011). Note that not all members of CCAMLR <http://ccamlr.org/pu/e/ms/contacts.htm> are actively engaged in reducing IUU fishing as this is an organization tasked with multiple issues related to natural resources in the Southern Ocean.

Appendix 2: summary of case studies and template for data collection

Here, we briefly summarize the case studies and the protocol for data collection. Data have been collected through semi-structured interviews, literature reviews, and surveys (see individual articles for details, i.e., Galaz 2011, Galaz et al. 2010b, Österblom and Sumaila 2011, Österblom and Bodin 2012, Österblom et al. 2011). All cases used the same methodology, combining document studies, simple network analysis, and semi-structured interviews with key international actors (a total of about 65 interviews for all cases). Interviewees have been selected strategically to reflect an expected diversity of interests, resources, and role in the network collaboration of interest. The material has been

structured and complemented with additional published and “gray” literature to elaborate the five overarching subjects below. These five subjects were identified during a series of author workshops and aimed to provide a structured overview of the perception of the problem to be addressed, the emergence of the network studied, as well as its function, effectiveness, and perceived legitimacy. Original data sources and detailed methods are available in the literature cited.

Subject

- (1) What is the risk of a global change-induced “tipping point”?
 - a. What is the “tipping point” of interest?
 - b. Over which time frame does it operate and what is the response capacity required?
 - c. What social and ecological uncertainties exist?
 - d. What underlying social and ecological mechanisms increase the risk of “tipping point” behavior?
- (2) Why is global coordination needed?
- (3) How did the global network emerge and evolve?
 - a. How did the network emerge?
 - b. Which key actors/organizations were responsible for this development?
 - c. What existing networks/governance features did these actors/organizations build on?
 - d. How did the network develop over time and what is the current trajectory (how is capacity maintained and developed)?
 - e. In what political context did the network emerge and develop?
 - f. To what extent were they supported, or counteracted by state actors and/or other institutions?
 - g. How is it coordinated (and what are the pros and cons of coordination)?
 - h. What framework (legal or otherwise) is regulating network activities (and what are the pros and cons with the framework/lack of framework)?
 - i. How are transparency issues addressed?
 - j. What is known about the perceived legitimacy, fairness, and biases of the network?
 - k. What are the primary tools of action for the network?
- (4) How is monitoring, sense-making, and coordinated responses enabled?
 - a. What are the monitoring capacities of the network (is both ecological and social monitoring conducted)?
 - b. How does the network achieve sense-making around “tipping points”?
 - c. How does the network enable rapid and coordinated responses?
 - d. What role does information and communication technologies play in monitoring, sense-making, and response?
 - e. What are major barriers for a continued evolution of the network?
- (5) What outputs and outcomes can be attributed to the network?
 - a. What are the major outputs from the network?
 - b. What are the most important outcomes from the network?

Case 1. Pacfa: global partnership on climate, fisheries, and aquaculture

Summary

Oceans capture approximately one-third of anthropogenic emissions of greenhouse gases. This process is changing ocean chemistry, making oceans more acidic, with potentially enormous negative consequences for a wide range of marine species and societies as a result of losses of ecosystem services. Recent research suggests that ocean acidification is likely to exhibit critical “tipping points” associated with rapid loss of coral reefs, as well as complex ocean–climate interactions affecting the oceans’ capacities to capture carbon dioxide. The global arena for addressing these interrelated aspects of marine governance is characterized by a lack of effective coordination among the policy areas of marine biodiversity, fisheries, climate change, and ocean acidification. This has stimulated an attempt to better bridge these policy domains to increase coordination aimed at addressing potential critical tipping points. A number of international organizations primarily involved in fisheries initiated the Global Partnership on Climate, Fisheries, and Aquaculture (from hereon Pacfa) in 2008. Currently, this initiative includes representatives from FAO, UNEP, WorldFish, The World Bank, and 13 additional international organizations (Fig. 1). Joint outputs include synthesizing information as a way to monitor the status of unfolding nonlinear dynamics, dissemination of information in science-policy workshops, and lobbying international arenas.

- 1a. Pacfa is working with understanding and communicating the risk of tipping points related to ocean acidification, loss of carbon mitigating capacity of the oceans, and fish stock collapses. These tipping points are closely related to human activities (eutrophication, loss of marine biodiversity, degradation of coastal and marine habitats, and overfishing) with substantial impacts on livelihoods Galaz et al. (2011).
- 1b. Tipping points related to these variables are possible within decades, but there is currently limited institutional capacity or development to address these integrated challenges Galaz et al. (2011).
- 1c. Important uncertainties are related to the speed at which ocean acidification is likely to spread, where tipping point is located and what the social–ecological implications of such tipping points are? No agency or institutions is responsible, and the potential institutional development around this issue is also unclear (Galaz et al. 2011; Dimitrov et al. 2007).
- 1d. (i) Anthropogenic CO₂ dissolves in the water and produces carbonic acid that strongly reduces the rate of calcification of marine organisms. (ii) There is a risk that the capacity of the oceans to act as a “carbon sink” is undermined through changed carbon cycle feedbacks. (iii) There are also possibilities for rapid collapse of fisheries as a result of multiple anthropogenic stresses (Hoegh-Guldberg et al. 2007; Cox et al. 2000; Hutchings and Reynolds 2004).
2. The problem domain is defined by multiple global environmental stresses (especially climate change and ocean acidification) and cannot be addressed at the sub-global level. The policy domain is characterized by a wide variety of global actors and initiatives Galaz et al. (2011).
- 3a. The network has evolved incrementally through informal personal contacts between centrally placed actors in international organizations. One of the networks first meetings of the was held in 2008, in Rome, see Galaz et al. (2011).
- 3b. The FAO, World Bank, UNEP, and WorldFish were key for developing the network Galaz et al. (2011).

- 3c. The network emerged after repeated discussions between individuals centrally placed at international organizations. There was a perceived need to coordinate marine activities and connect them to the global climate agenda Galaz et al. (2011).
- 3d. The network started with a few individuals and their respective organizations, and has grown over time. PaCFA has evolved from a loose communication network, to a formal partnership and recently (2010) became a UN Oceans-Taskforce.³ It is currently unclear how it will develop over time, but it will likely remain (as a minimum) a communication-based learning and coordinating network. Evolution toward tangible joint field projects depends heavily on funding, see Galaz et al. (2011).
- 3e. In a context where climate change is high on the political agenda, but where there is a limited understanding of the associated challenges and limited political connection between those challenges.
- 3f. The evolution of the network has gained modest support from governments through the FAO and its member states. The network successfully coordinated their activities with the Indonesian government during the climate negotiations leading up to the meeting in Copenhagen 2010 (COP 15). We have not identified any explicit opposition to the network.
- 3g. Coordination is assumed by a small number of key organizations, centered around the FAO. This institutional affiliation provides the network with legitimacy, connections, and necessary competence. However, it is also vulnerable as much of the coordination is centered around a small number of individuals, see Galaz et al. (2011).
- 3h. Key coordinator of network has clear mandate by the FAO, and its work is embedded in UN Law of the Seas, and the Convention on Biological Diversity Galaz et al. (2011). It should be noted however that ocean acidification and protection of marine ecosystems such as coral reef ecosystems have been denoted as “non-regimes” Dimitrov et al. (2007). The lack of formal regimes or institutions devoted to ocean acidification has however not been identified as a problem by key actors in network. Key barriers perceived by the network to further develop their work is rather a lack of funding and political support for the implementation of ecosystem-based approaches in marine systems, see Galaz et al. (2011).
- 3i. Transparency is limited due to the informal structure of this network, see Galaz et al. (2011).
- 3j. A number of issues related to internal legitimacy have been raised by network members especially related to the use of scientific organizations as leverage to influence international policy processes (Galaz et al. 2011). Coordinating actors try to resolve external legitimacy challenges through actively recruiting members that secure a representation of diverse interests in the network, e.g., ranging from international organizations, to scientific organizations and NGO’s in the global south.
- 3k. Political lobbying aimed at influencing policy makers and policy processes through providing science-based synthesis describing the risk of transgressing possible future “tipping points” (Galaz et al. 2011).
- 4a. Network members monitor different aspects of problems associated with climate change—ocean acidification—marine biodiversity, however, only in a fragmented way. Marine ecological parameters are the main focus of monitoring activities (Galaz et al. 2011).
- 4b. There is an explicit focus on the need for action before critical “tipping points” have been transgressed. The network describes this situation as “self-regulating and

³ http://www.oceansatlas.org/www.un-oceans.org/Documents/tf_pacfa_tor.pdf. Accessed 2012-05-21.

- buffering processes [could] break down, leading to irreversible consequences.”⁴ This message is part of the information material and technical reports produced by the network.
- 4c. The network primarily coordinates its activities around political opportunities. The network deals primarily with knowledge diffusion among its members, attempts to coordinate local coastal marine management or climate adaptation projects, and high-level lobbying. Scientific syntheses coordinated by the network play a key role for this last activity. For example, actors in the network were trying to gain international momentum for their cause and focused all their activities on trying to influence the international climate negotiations in Copenhagen 2009, with an ambition to integrate marine issues in those discussions. This required the capacity of all core actors in the network to tap into resources and knowledge, including international scientific institutions (e.g., ICES), international organizations (FAO, World Bank), and place-based research NGOs (WorldFish, with over a hundred partners, including universities and non-government organizations in the South). These syntheses not only provide an opportunity to bring together insights, but also feed into lobbying at high-level policy arenas (Galaz et al. 2011).
 - 4d. E-mail and Web pages are the primary tools for information dissemination and communication in the network
 - 4e. Funding over the long term and a lack of political support for implementing ecosystem-based management
 - 5a. Scientific reports and workshops where members are updated about scientific advances related to marine systems, and climate change and ocean acidification are the major outputs of the network. Members also engage in continuous information sharing about relevant meetings.
 - 5b. The outcomes have hitherto been limited. The network does currently not have the necessary infrastructure or economic and human resources to engage in large-scale projects related to marine climate adaptation.

Case 2. Global epidemic early warning and response networks

Summary

The need for early and reliable warning of pending epidemics has been a major concern for the global community since the mid-nineteenth century, when cholera epidemics overran Europe. The fact that there are strong disincentives for individual states to report disease outbreaks (due to associated losses of income from export and tourism) has created severe problems with detecting early warning signals and response problems. This is particularly critical, as coordinated responses are needed in order to avoid transgressing critical epidemic thresholds. A range of networks, from surveillance, laboratory, and expert networks, have emerged to secure information on early warning signals, mechanisms for rapid dissemination of information and coordinating responses. These networks are both global and regional, and include the WHO, the World Organization for Animal Health (OIE), the Food and Agriculture Organization of the United Nations (FAO), the Red Cross, Doctors without Borders, and additional international and national organization. The networks

⁴ ftp://ftp.fao.org/FI/brochure/climate_change/pacfa/pacfa.pdf.

facilitate responses to epidemic emergencies of international concern by providing early warning signals, rapid laboratory analysis, information dissemination, and coordination of activities in the field.

- 1a. There is a risk of uncontrolled spread of infectious disease through global transportation networks. Complex interacting social (e.g., connectivity through international travel combined with limited infrastructure for public health in parts of the world) and ecological (land-use change, urbanization, habitat loss) drivers interact and may result in the spread of disease (Galaz 2009).
- 1b. Tipping points where disease becomes a matter of international concern can develop within the time frame of weeks. A global response capacity may be required within days or weeks, depending on disease characteristics (Wallinga and Teunis 2004).
- 1c. Key uncertainties include: what disease will emerge, when, where will it emerge, how fast can it spread, and how can it be addressed?
- 1d. The spread of disease will be increasingly difficult to control if the spread of the disease exceed the basic reproduction number $R_0 > 1$. The basis reproduction number is defined by virulence, transmissibility, and severity (Wallinga and Teunis 2004).
2. Spread of novel infectious disease can become a global pandemic and require coordination among a diverse set of actors, including international organizations, laboratories, health ministries, and NGO's (in locations where international organizations have weak representation).
- 3a. International collaboration on infectious diseases originated in 1947 (the Global Influenza Network coordinated by the WHO). There has been a rapid evolution of health-related networks (regional and/or disease specific), especially since the 1990s and 2000s. A coordination mechanism at the WHO specifically designed for rapid response to infectious disease emerged around 2000 and became formalized in 2005 (Fidler 2004; Galaz 2009).
- 3b. The WHO is the main coordinator of relevant networks; operation, and collaborating partners depends on disease and location.
- 3c. A number of serious disease outbreaks of international concern in the early 2000s (Rift Valley fever, Ebola, Anthrax, avian influenza, SARS) led to a change in cooperation and the development of a new international legal framework (The IHRs) in 2005. An increased awareness of the potential global nature of pandemics thus enabled better coordination of networks that had developed from the 1990s (Fidler 2004; Galaz 2009).
- 3d. The networks have evolved incrementally over several decades, but with a rapid increase from 2003 and onwards. This development was stimulated by an increasing international concern and improved funding opportunities from international organizations and the USA (Fidler 2004; Galaz 2009).
- 3e. Increasing international concerns of emerging infectious diseases from the 1990s and onward, such as outbreaks of avian influenza (years 1997, 2003–2004,) and US border protection security concerns related to terrorist attacks (deliberate introduction of lethal infectious disease) after the September 11 attacks in 2001, triggered rapid investments in global monitoring and response networks. These events also contributed to changes in the IHR in 2005 (Fidler 2004).
- 3f. There is strong international support. However, some countries have also raised concerns. Indonesia, for example, supplied H5N1 virus to the WHO Global Influenza Surveillance Network for analysis and preparation of vaccines for the world. The

- model where commercial companies produce the resulting vaccines was questioned by Indonesia arguing that the produced vaccines would be unavailable to the country. In 2007, Indonesia decided to suspend its sharing of viruses with the WHO, a decision that created serious tensions with the international community (Fidler 2008). More recently, there has also been concerns voiced by a wide set of groups about the connection between the WHO and pharmaceutical companies as the result of the last pandemic outbreak (“swineflu” A/H1N1) (Zarocostas 2011).
- 3g. Coordination is facilitated by international organizations such as the WHO, FAO, and OIE. The ability to rapidly receive, analyze, and disseminate alerts and responses is substantially facilitated by this coordination. Rapid evaluation is key and is supported by crisis management structures such as early warning and confirmation mechanisms (Galaz 2011).
 - 3h. The activities are regulated by the IHRs and related technical plans [e.g., WHO’s pandemic response plans (WHO 2005)] provide formal guidance for coordination and action. However, these formal mechanisms are complemented with informal response procedures to maximize flexibility. The informal procedures create flexibility to emerging surprise events, but within a legal framework (WHO 2005). However, responses to emerging infectious diseases such as avian influenza tend to be contested and may be conceptualized differently by different actors depending on national political agendas and cultural contexts (Dry and Leach 2010).
 - 3i. WHO and associated partners redefine key policies based on criticism and changing circumstances. The importance of such activities has become apparent after controversial events, such as recent discussions about the role of WHO in issuing a pandemic alert for the 2009 outbreak of A/H1N1 (“swineflu”).
 - 3j. The coordinating actors in the network (mainly WHO, FAO) are generally viewed as legitimate, but concerns have also arisen. Events that generated criticism include the association between the network and corporate interests (Zarocostas 2011) and controversy about the best effective means to respond to outbreaks, and the distribution of costs related to these responses (Dry and Leach 2010).
 - 3k. The networks take action through the coordination of information (laboratory analysis, early warning, confirmation) and collaboration around response options on the ground.
 - 4a. A wide variety of sophisticated monitoring systems are in place and are enabled depending on the disease. The WHO is collaborating extensively with the Canadian GPHIN, which has created an effective system for early detection of the spread of epidemic disease through Web-monitoring. The use of satellite technology is important in some cases and is complemented with information platforms such as HealthMap and the moderated e-mail list ProMED (Galaz 2011). Monitoring centers on reports on disease outbreaks, but underlying drivers (e.g., land-use change and urbanization trends) are not included in such monitoring (Galaz 2009).
 - 4b. Actions and investments are coordinated around pandemic phases, where action at the national and international level is dependent on the current assessment of the current status and spread of the disease (the pandemic phase), but also on the need for actions that maintain spread within certain levels (WHO 2005).
 - 4c. Through well-developed formal and informal mechanisms for cooperation, elaborate monitoring systems and large geographical spread and capacity (Galaz 2011).
 - 4d. Information and communication technologies are crucial in all aspects of coordinated network responses, ranging from early warnings to on-the-ground responses. WHO

- regularly sets up videoconferences and secure Web pages to facilitate rapid scientific collaboration on urgent epidemic issues (Galaz 2011).
- 4e. There are concerns that reduced future funding will hamper current monitoring and response infrastructure. There are also concerns that additional funding and political interest for investigating in general (preventive) health infrastructure is lacking in many developing countries (IOM and NRC 2008). Critics have raised the issue that the focus is perhaps too much on disease of international concern, thereby obscuring other and more urgent national epidemic needs (Dry and Leach 2010).
 - 5a. The network has generated a large number of reports and technical documents (e.g., 12 and the WHO Weekly Epidemiological Record available online: <http://www.who.int/wer/en/>). Continuous national, regional, and national meetings are being conducted for information sharing and capacity building (both disease specific and with regional focus).
 - 5b. Outcomes are difficult to measure as evaluation criteria are contested. There are several successful case studies where unprecedented rapid international responses have been reported, especially for severe acute respiratory syndrome (SARS) in 2002. A synthesis by (Chan et al. 2010) shows that international support in epidemic contingencies over time has become more timely due to changes in the IHRs and improved surveillance.

Case 3. Illegal, unreported, and unregulated fishing and the commission for the conservation of Antarctic Marine living resources

Summary

When illegal, IUU fishing for Patagonian toothfish emerged in the Southern Ocean in the mid-1990s, it was perceived that if unchecked, it would lead to the collapse of valuable fish stocks and endangered seabird populations (Table 1). Illegal overfishing around South African sub-Antarctic islands consequently resulted in a collapse of these stocks, in turn resulting in estimated losses in the order of hundreds of millions US dollars. The toothfish market is essentially global, where products are caught around the Antarctic, landed in the Southern hemisphere, and primarily consumed in the USA, Japan, and Europe. The fact that actors involved in IUU fishing are also dispersed globally necessitates coordination between states on all continents. The regional mandate of the existing international governance institution, CCAMLR (Commission for the CCAMLR), initially proved insufficient to address this global challenge. As a response, state and non-state actors increasingly developed their networks and are currently operating at the global level (Fig. 1, SI). Continuous coordinated international responses around adjacent islands have resulted in a dramatic reduction in IUU fishing. States now have a well-developed mechanism for coordinated monitoring and response when new actors, markets, or IUU fishing are emerging in the Southern Ocean.

- 1a. The scientific committee of the Commission for the CCAMLR has repeatedly warned for the imminent risk if collapsing valuable fish stocks and the extinction of globally threatened seabirds throughout the Southern Ocean (SC-CAMLR 1997, SC-CAMLR 2002). This has caused serious concern in the Commission and threatened perceived critical commercial and environmental interest. Passing regional tipping points for these resources would represent a failure of CCAMLR to live up to the Convention

- on the CAMLR, which explicitly state that these resources should be protected for the benefit of mankind.
- 1b. Tipping points related to fish stocks and seabirds was expected within years, and a coordinated response was required before such tipping points were passed (Österblom and Sumaila 2011).
 - 1c. Key uncertainties include where IUU fishing (in the Southern Ocean) emerge next, where the products are landed and which actors and states would be involved in such activities (Österblom et al. 2010)?
 - 1d. A failure to regulate coastal fisheries and fishing capacity has resulted in collapsing fish stocks combined with an overcapacity of existing fishing fleets. Such fleets will move elsewhere (further South, further offshore, and fishing at larger depths (Pauly et al. 2003; Swartz et al. 2010), which may result in IUU fishing (Agnew et al. 2009). Such IUU fishing dramatically reduced naturally long-lived and late maturing fish and seabird populations to low levels in the Southern Ocean (SC-CAMLR 1997; Österblom et al. 2010; Miller et al. 2010).
 2. The problem is global as IUU vessels are highly mobile across large geographical areas. These vessels may change their flag state, call sign and other identifying markers to avoid detection and apprehension (Österblom et al. 2010). IUU actors use loopholes in international legal frameworks to their advantage and adapt faster than formal institutions develop (Österblom and Sumaila 2011; Österblom et al. 2010).
 - 3a. The network started to emerge from 1997 as a result of the scientific information provided to the meeting of CCAMLR that year (SC-CAMLR 1997).
 - 3b. The Australian government, together with NGOs from Australia and Norway, collaborated with licensed fishing industries to collect initial information (Fallon and Kriwoken 2004).
 - 3c. The global network evolved from CCAMLR, an organization with a regional mandate. The rationale for the network to start cooperating informally was a perceived inability of governments to take actions before tipping points would be passed (Österblom and Bodin 2012).
 - 3d. The network used CCAMLR as a basis for action and developed starting with a small number of countries, which invested substantially in monitoring and enforcement, policy making and diplomatic demarches (Österblom and Sumaila 2011; Österblom and Bodin 2012). A small number of NGOs also cooperated to collect and spread information, in collaboration with licensed fishing companies (Fallon and Kriwoken 2004). Over time, an increasing number of states and non-state actors became involved in collecting and sharing information and formalizing cooperation (Österblom and Sumaila 2011). Members of the network have carried out training workshops in strategic locations. Strategic capacity building has been directed toward regions with limited capacity but where ports have been used for offloading IUU catches.
 - 3e. Depletion of coastal fish resources shifted commercial fishing enterprises, but also political interests, toward the high seas (beyond the 200 nautical mile zone). This led to increasing global policy concern about IUU fishing and could also be politically connected to border protection security. This was evident in Australia and the USA, particularly after the September 11 attacks in New York City in 2001, the *Tampa* affair and the Bali bombings in 2002 (Österblom and Sumaila 2011; Constable et al. 2010).
 - 3f. Addressing IUU fishing has been a key challenge for CCAMLR as some member states have been associated with IUU fishing, e.g., as flag, or port states or with their

- nationals working on board IUU vessels or as owners of IUU companies. This has at times resulted in substantial controversy and heated debate (Österblom and Sumaila 2011).
- 3g. CCAMLR has a well-developed mechanism for obtaining, processing, and sharing of information (from state and non-state actors) through its secretariat. Non-state actors are improving the effectiveness of monitoring and enforcement, by for example reporting on suspected vessel sightings, and by creating peer-pressure directed at states and corporations associated with IUU fishing (Österblom and Bodin 2012).
 - 3h. An international convention (CAMLR) is regulating the activities within CCAMLR, and governments are also bound by global legal agreements (UN-FSA 1995) and codes of conducts (FAO 2005). Information sharing has been facilitated by CCAMLR protocols specifically designed to address IUU fishing. CCAMLR provides an operational and transparent platform for cooperation but new measures can be hampered by the need to arrive at consensus.
 - 3i. All Commission reports are published online but background reports, including reports on diplomatically sensitive issues, are only published at a password protected Web site for delegates
 - 3j. Disputes about some sub-Antarctic islands (notably between Argentina and the UK) represent a long-standing conflict. Arrested IUU operators have expressed the opinion that exclusive economic zones in the Southern Ocean are illegitimate. Several nations have clear benefits from fishing and also conduct expensive monitoring and enforcement. There are no benefit or burden sharing mechanisms in place (Österblom and Sumaila 2011).
 - 3k. Operational management, coordinated response, and policy making are the primary tools for action. Countries collaborate to monitor and enforce compliance and form alliances to develop new policies (Österblom and Bodin 2012).
 - 4a. Cooperative international scientific surveys document the dynamics of fish stocks (Constable et al. 2010). This network around CCAMLR to address IUU fishing monitor fishing vessel activities and trade flows (Österblom and Bodin 2012).
 - 4b. The scientific committee reports annually on the estimated levels of IUU catches and estimate the risk of tipping points, both in relation to fish stocks and seabird populations. A corresponding committee for evaluating compliance-related information review, at an annual basis, related social information (trade flows, vessel activities, etc.) (Österblom and Bodin 2012).
 - 4c. The secretariat serves as an important hub in the network by coordinating information flows. Responses are coordinated through either rapid engagement of partners to secure the seizure of a catch or vessel (between states), cooperation to perform alternative investigations (the fishing industry) or information campaigns (NGO community), or political lobbying for new policy tools (Österblom and Bodin 2012).
 - 4d. Satellite technology monitor vessel activities and an electronic catch documentation schemes provide information on trade flows (Österblom and Bodin 2012). Forensic accounting is an important tool for criminal investigations, which has been pioneered by US agencies and applied in convicting cases associated with IUU operations in the CCAMLR area.
 - 4e. Financial costs (monitoring is very expensive) depends on a small number of actors, governance capacity is limited in several countries used as port or flag states, and political will may influence the capacity of CCAMLR to adapt to new challenges.

- 5a. CCAMLR have developed a number of compliance mechanisms over time and is increasingly developing formal and informal governance mechanisms in order to effectively respond to IUU fishing in the Southern Ocean (Österblom and Sumaila 2011).
- 5b. Continuous coordinated international responses around sub-Antarctic islands and beyond have resulted in a dramatic reduction in IUU fishing (Österblom and Bodin 2012).

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