



Breaking Resilience for a Sustainable Future: Thoughts for the Anthropocene

Marion Glaser^{1,2*}, Jeremiah G. Plass-Johnson^{1†}, Sebastian C. A. Ferse^{1,3},
Muhammad Neil⁴, Dewi Y. Satari⁴, Mirta Teichberg¹ and Hauke Reuter^{3,5}

¹ Ecology Department, Leibniz Centre for Tropical Marine Research, Bremen, Germany, ² Faculty of Humanities and Social Sciences, University of Bremen, Bremen, Germany, ³ Faculty of Biology and Chemistry, University of Bremen, Bremen, Germany, ⁴ Research and Development Center for Marine, Coastal and Small Islands, Hasanuddin University, Makassar, Indonesia, ⁵ Theoretical Ecology and Modelling Department, Leibniz Centre for Tropical Marine Research, Bremen, Germany

OPEN ACCESS

Edited by:

Alberto Basset,
University of Salento, Italy

Reviewed by:

David Andrew Feary,
University of Nottingham,
United Kingdom
Donata Melaku Canu,
OGS Istituto Nazionale di
Oceanografia e di Geofisica
Sperimentale, Italy

*Correspondence:

Marion Glaser
marion.glaser@leibniz-zmt.de

† Present Address:

Jeremiah G. Plass-Johnson,
Centre for Ocean Life, National
Institute of Aquatic Resources
(DTU-Aqua), Technical University of
Denmark, Lyngby, Denmark

Specialty section:

This article was submitted to
Marine Ecosystem Ecology,
a section of the journal
Frontiers in Marine Science

Received: 31 December 2016

Accepted: 24 January 2018

Published: 16 February 2018

Citation:

Glaser M, Plass-Johnson JG,
Ferse SCA, Neil M, Satari DY,
Teichberg M and Reuter H (2018)
Breaking Resilience for a Sustainable
Future: Thoughts for the
Anthropocene. *Front. Mar. Sci.* 5:34.
doi: 10.3389/fmars.2018.00034

Strong resilience of a system usually enables the protection of a status quo. Most resilience studies assume that resilience-building is the central objective of sustainability work. Even though transformation has become a central theme in development and social-ecological debates, questions surrounding the weakening resilience of undesired system states are rarely analyzed. We suggest that resilience studies not only serve to protect systems and feedbacks we want to maintain, but may also help to understand and overcome chronic, undesirable,—and thus wicked—resilience. This contribution focuses on reef fisheries in the Spermonde Island Archipelago in Indonesia, based on social and ecological studies between 2004 and 2016. We identify a number of interlocking wickedly resilient vicious cycles as predominant drivers of the impoverishment of fishing households and the overexploited, polluted and degraded state of the coral reefs that fishers' livelihoods depend on. We argue that, more often than not in the Anthropocene, breaking resilience has a central role in the pursuit of sustainable human-nature relations. Therefore, the link between the resilience and the transformation debates needs to be much more explicitly made. Breaking interlocking, wicked resilience at multiple levels is needed to move toward sustainable human-nature relations from the local to the global level. There are lacunae in debate, literature, and research practice as to when, where and how wicked resilience might need to be weakened. A more complete resilience lens is particularly needed under Anthropocene conditions to support the unmaking of chronically resilient, anthropogenic systems.

Keywords: resilience management, wicked resilience, Anthropocene, ecosystem management, Spermonde Archipelago, Indonesia, transformation

Resilience is a focal theme in contemporary natural and social sciences, and in policy discourses. Materials, ecosystems, economies, societies, organizations, governance, livelihoods, people and their mind and spirit are all considered in need of resilience today (Brown, 2016).

At its academic debut in 1818, resilience was understood as a physical property of wood, and measured by the energy required to rupture material (Tredgold, 1818). Holling introduced the term into ecology in the 1970s (Holling, 1973). Ecologists distinguish two definitions of resilience: (1) ability to return to an initial state after impact, and (2) ability to stay constant throughout an impact (Folke et al., 2010). In ecological conservation, resilience has come to be implicitly considered

as desirable for pristine ecosystems (e.g., Biggs et al., 2015). For social networks, institutions, communities and other social units, resilience is characterized by the capacity to self-organize, and also by levels and quality of social capital (trust, norms, and networks), economic capital (wealth, income, savings, and investment) and human capital (education, health, skills, knowledge, and information) (Olsson et al., 2004; Lebel et al., 2006). Bousquet et al. (2016) call for “development resilience” including “household resilience to food insecurity or climate change” to support capacity building to withstand multiple shocks and to cross poverty traps” (Cinner, 2011). For the oceans, the Sustainable Development Goal 14 calls to “protect marine ecosystems... , including by strengthening their resilience” <http://www.un.org/sustainabledevelopment/oceans/>. Social-ecological resilience focuses on the boundaries humanity encounters in its relations to the natural environment at various levels from the local to the global (Rockström et al., 2009). In the Anthropocene, with entire research centers and global networks¹ dedicated to studying it, resilience has come to be regarded as a vehicle for interdisciplinary collaboration between natural and social scientists².

Resilience is usually understood to enable the protection of a status quo. This is often what is needed. Psychological resilience (Bonanno et al., 2002), defined as the ability of the human individual to return to normal functioning after a period of trauma and dysfunction with “relatively stable, health levels and psychosocial and physical functioning...”³ is a case in point. Increasing the resilience of ecosystem-services means strengthening ecosystem capacity to maintain desired services to humanity in the face of environmental and socio-economic change (Troell et al., 2014). Social-ecological resilience is interpreted as “the capacity of a social-ecological system to absorb recurrent disturbances... (...) so as to retain essential structures, processes and feedbacks” (Adger et al., 2005, p. 1036).

Although some key transformability and transformation papers (Walker et al., 2004, 2006; Graham et al., 2013) mention a need to break undesirable feedbacks at lower system levels as a possible precondition for supporting resilience at higher levels, the predominant assumption in resilience studies is that strengthening resilience is the main or even the only objective of sustainability-oriented resilience management (Olsson et al., 2014; Biggs et al., 2015). Pelling (2010 in Brown, 2016, p. 140) suggests that the resilience focus facilitates the protection of priority system functions in the face of external threat. Lebel and co-authors see three preconditions for a governance system to effectively manage resilience: (1) inclusive participatory engagement with stakeholders, (2) the polycentric organization of authorities, and (3) up- and down-ward accountability (Lebel et al., 2006). Kachergis and co-authors opine that “... models of social-ecological systems can inform management decisions and, ultimately, improve resilience” (Kachergis et al., 2013, p. 1).

The vast academic and policy debate [(Maru et al., 2014; UN Development Programme (UNDP), 2014; Quinlan et al., 2015)] focuses squarely on resilience-building while questions on the need for weakening resilience are touched by a few authors only (Nyström et al., 2012; Graham et al., 2013). Thus, in a recent book on resilience, the need for governance structures to weaken feedbacks that trap SES in undesired regimes is mentioned only as an aside (Biggs et al., 2015, p. 256). A leading proponent of resilience studies sees “resilience management” as aiming to “prevent a social-ecological system from *moving* into undesirable configurations” (Walker et al., 2002:1, emphasis added), implying that existing states and processes are indeed desirable, and thus leaving little or no common ground for social science fields including political ecology, conflict studies, and others. Adger and co-authors see social-ecological research as setting out to explore “how resilience changes in regional-scale SESs, and how it might be *increased, or lost*, through management” (Adger et al., 2005, p. 1036, emphasis added). The need for an *active* weakening of resilience as an objective of societally engaged sustainability research or action is absent or at best implicit in most resilience studies. Even a recent, in our terms well-advanced social-ecological description of resilience (condensed by Davidson et al., 2016: Table 1) as “the capacity of a SES to intentionally change its structure and functions to shift the system to an alternative regime or onto an alternative development trajectory when the system is trapped in an untenable regime” does not allow for bad forms of resilience of the “system to be governed” (Kooiman et al., 2008) that undermine sustainable human-nature relations. Walker et al. (2006) argued over a decade ago that “some regimes that are considered undesirable can also be very resilient, e.g., harsh dictatorships and desertified regions of the Sahel,” and static lock-ins and traps have been identified (Cinner, 2011; Olsson et al., 2014). Nonetheless, the debate on resilience dynamics has remained oddly one-sided, focusing almost exclusively on enhancing sustainability-supporting forms of resilience (e.g., Davidson-Hunt and Berkes, 2002, p. 77; Cutter et al., 2008; Barnosky et al., 2012; Jackley et al., 2016). That this entails the danger of depoliticizing our understanding and decision-making relating to human-nature dynamics has been pointed out recently (Olsson et al., 2015).

In line with Brown (2014; 2016, p. 12), we suggest that, in the pursuit of sustainability, resilience-building as the main, or only, intervention strategy for social systems that are characterized by oppressive relationships and institutions, by chronic poverty or extreme inequality can be insufficient or even harmful. An interpretation of resilience which fails to consider resilience-breaking as part of resilience management may strengthen existing power structures, something which is often at odds with sustainability-supporting work (Desai, 1996; Jentoft, 2007; Scholtens et al., 2013; Olsson et al., 2015). The tendency of resilience studies to assume that a resilient social-ecological system will always foster positive attributes such as fairness, inclusiveness and diversity (O’Brien et al., 2009, p. 6) ignores resilient pathologies such as inequality and poverty (Fabinyi et al., 2014). For the social sciences it is thus clear that “resilience is not always a good thing or a healthy attribute, a highly resilient system may reside in undesirable states, and may even

¹e.g., The Stockholm Resilience Center; The Resilience Research Center at Dalhousie University, Halifax; The Resilience Alliance <http://www.resalliance.org/about>

²e.g., the MaCORAS and REPICORE projects see www.leibniz-zmt.de.

³<http://torrensresilience.org/resilience-of-individuals>

be described as pathologically resistant to change (Brown, 2016, pp. 158–159). The recognition of this in the context of social-ecological resilience studies is necessary but still too rare (Crona and Bodin, 2010).

Not only in the social sciences but also in ecology and conservation, it is becoming apparent that under Anthropocene conditions, undesirable resilience needs to be increasingly reckoned with. Biotic and abiotic parameters are often so altered that novel ecosystems and new human-nature relations with changed and often surprising features are emerging (Hobbs et al., 2006). Identifying and breaking chronic, bad resilience is thus likely to become a necessary ingredient of ecosystem governance and management in the Anthropocene.

We argue that future resilience studies need to help us to better understand and overcome “wicked” resilience dynamics. In line with the definition of a “wicked problem” (Jentoft and Chuenpagdee, 2009, p. 553) we understand wicked resilience as “difficult to define and delineate from other bigger problems” and in need of a multi-level, multi-actor governance approach (op.cit:554).

WICKED RESILIENCE IN A CORAL REEF BASED SOCIAL-ECOLOGICAL SYSTEM

We now illustrate some exemplary, interlocking, wickedly resilient social-ecological dynamics encountered in our long-term research (2004–2016 in the SPICE programme⁴) in the Spermonde Coral Reef Archipelago of some 80 small islands off the larger island of South Sulawesi, Indonesia.

Spermonde is a subnational region in eastern Indonesia (Glaser and Glaeser, 2014). Until 2015, the governance of the island archipelago and its reefs has stretched across several administrative units (Gorris, 2015). The archipelago is intensely affected by human activities, and both on the island terrains and under water, may be considered as consisting of numerous “anthropocene spaces” (Moore, 2016), where novel human-nature ecologies are coming to predominate. On the small reef atolls, high population densities combine increasingly western consumer habits with growing lack of space and fresh water. Under water, chronic exposure to anthropogenic effluents and overfishing have created “non-coral” reefs that display a resilient combination of turf algae-dominated habitats and functionally deficient fish communities (Plass-Johnson et al., 2016, 2018; Teichberg et al., 2018). This undesirable system state is subject to strongly rooted stabilizing feedback loops the coral predator and after *Acanthaster planci* (crown-of-thorns outbreak in 2013; Plass-Johnson et al., 2015, 2018) and is, at the same time, unresponsive to destabilizing forces (coral recruitment; Sawall et al., 2013) that might put the reefs on a more desirable trajectory. **Figure 1** shows how Spermonde social-ecological dynamics surrounding fisheries result in a resilient degraded and depleted marine ecosystem. Social-ecological traps lock the system in a perpetual state of overexploitation with a

high incidence in fishing households of poverty, fishing-related diseases, injuries and deaths (Glaser et al., 2015).

Figure 1 illustrates several “wickedly resilient” vicious cycles at the center of the social-ecological dynamics surrounding reef fisheries in Spermonde. These cycles, - to paraphrase the resilience definition -, appear capable of adapting and changing and yet manage to maintain a highly undesirable functionality (Holling, 1996).

In **Figure 1A**, fisher clients engage in illegal destructive fishing with cyanide and explosives. To fund this, and as a fallback in family emergencies, they obtain loans from patrons. Patrons protect their clients from legal sanctions and provide access to marine product markets. In return, they obtain client fishers’ products below market prices to sell profitably in national and international markets. Thus, client fishers gain food and livelihood security, but their poverty continues as economic surpluses are realized by patrons. As catches fall, indebted client fishers illegally fish further out and deeper down, with dangers to their health and life, sometimes forced into life-threatening conditions against their will (Glaser et al., 2015, p. 200).

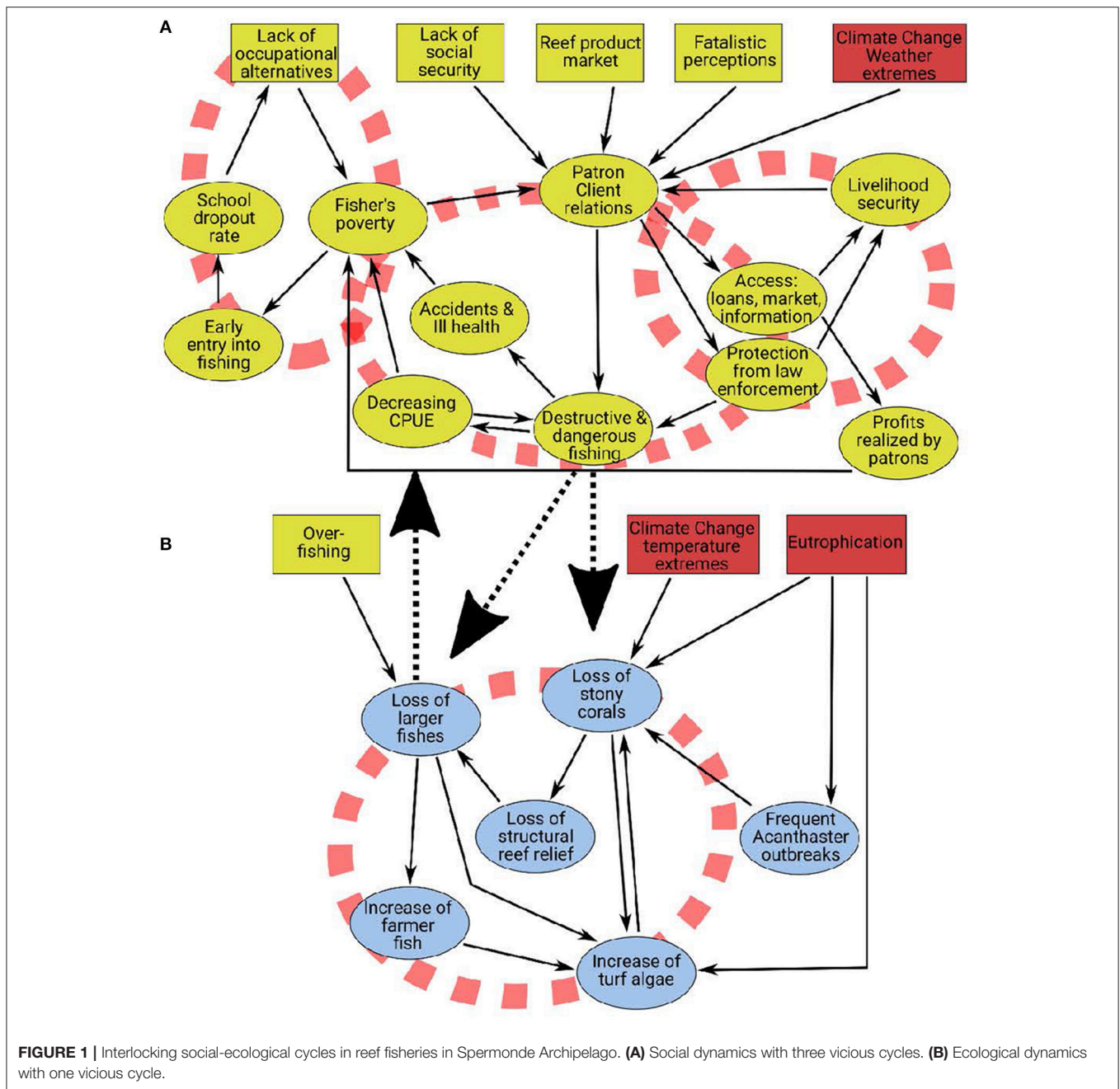
The absence of formal social security and alternative livelihood options, and a set of underlying perceptions and social values reinforce client fishers’ dependence on their patrons (Ferse et al., 2012). Client fishers are thus unable to obtain better prices for their products. Their major option for overcoming their poverty is to engage in “more effective fishing,” in larger areas, and spend more time fishing. Blast and cyanide methods with associated increasing self-exploitation, morbidity, and mortality are the result (Glaser et al., 2015; Miñarro et al., 2016; film Sangkarang: People by the Sea: Social-Ecological Analysis in an Indonesian Island Archipelago <http://www.leibniz-zmt.de/de/tropenforschung/organisation/wissenschaftliche-abteilungen-struktur/sozialwissenschaften/ag-sozial-oekologische-systemanalyse.html>). These further degrade resources and reduce catch per unit effort (CPUE) in this case example.

Fatalism (i.e., considering the disappearance or degradation of marine species as either God-given or unimaginable) is driven by the strong opinion leadership of traditional patrons in the Spermonde Archipelago. The resilience of such perceptions and associated behaviors supports fishers’ patterns of destructive reef use.

There is a high and persistent school drop-out rate among 10–12 year old boys on most Spermonde islands. These children immediately enter into fishing as helpers. Financial and knowledge barriers later obstruct their access to alternative occupations, thus increasing the number of fishers across the generations.

In **Figure 1B**, overfishing leads to direct and indirect loss of larger fishes. Indirect losses occur through destructive fishing that damages stony corals and thereby the structural complexity of reef habitat that is needed to maintain fish production. Such reef destruction also increases rubble, providing suitable substrate for turf algae to recruit. Other anthropogenic impacts, such as eutrophication and climate change lead to further indirect loss of fishes by promoting turf algae growth, *Acanthaster* outbreaks

⁴Science for the Protection of Indonesian Coastal Ecosystems (SPICE II and III, funded by the German Ministry for Education and Research (BMBF) Grant Nos. 03F0474A & 03F0643A



and loss of stony corals. The loss of larger fishes brings a greater number of territorial damselfishes that cultivate more turf algae which again results in less hard coral and lower reef relief complexity. The reduced availability of larger fishes also increases fishing effort, a crucial social-ecological link (Figure 1A).

Where there are interlinking cycles of chronic, wicked resilience as here shown for the Spermonde reef fishery, strategic resilience-breaking interventions are needed. In Spermonde, the values and perceptions of fishers may be addressed. Ironically, in view of their overall role, it is the opinion leadership of patrons that may eventually play a pivotal role in changing

wickedly resilient values and perceptions in Spermonde (Glaser et al., 2015, pp. 199–200; Miñarro et al., 2016). Real economic alternatives for client fishers may also undermine wickedly resilient fishery dynamics: When the Asian financial crisis in 2008 greatly increased the returns in Indonesian Rupiah for fish sold abroad, patrons were competitively “buying out” the loans of the indebted clients of other patrons. At the same time, the influx of extra money rendered the social security function of the patrons less important for client fishers. Under these conditions many client fishers were able to leave their patrons and enter more advantageous

arrangements to market their produce. However, in subsequent years, many former fisher-clients themselves became patrons for reef fishers, reinforcing the wicked resilience of patron-client dynamics (Figure 1A). It remains clear though that higher market prices for fishing products may undermine the wicked resilience of the vicious social-ecological cycles in patron-client contexts.

BREAKING WICKED RESILIENCE FOR SOCIAL-ECOLOGICAL TRANSFORMATION

In the Anthropocene, resilience management will increasingly need to break the wicked resilience of vicious cycles. This is so far hardly recognized in the international resilience networks and debates. Questions as to when and where the deconstruction of wicked resilience may be required, and how this might be achieved, are rarely addressed. Our example from Indonesia indicates that a more complete resilience lens, will more fully support the transformation of human-nature relations by identifying promising leverage arenas for breaking wicked resilience. The recent, as yet unimplemented decision of the Indonesian government to provide health and life insurance for “small fishermen” will reduce the scarcity of formal social security which enforces client dependence on patrons (Figure 1A). Further wickedly resilient elements in our case example are access to more sustainable fishing technology, produce markets, and finance. To undermine the vicious cycles that support undesirably resilient system dynamics, such as the destructive and dangerous reef fishing in our Spermonde example, the analysis of chronically resilient system cycles and their feedbacks will need to assume a more central place in the resilience debate. A next step would be to develop context-specific, methodologically sound approaches for assessing and prioritizing strategic intervention arenas for breaking wicked resilience in human-nature dynamics. Some such arenas, known to have been effective during periods (“windows”) of opportunity are cross-level analysis and collaboration, social and technical innovation, and the enabling of strategic actors and agency. The suggested, more explicit focus on wicked forms of resilience could become an important interface between the strong but insufficiently connected resilience and transformation debates. Transformation has become a central theme in the debate on sustainable human-nature relations (Westley et al., 2011, 2013; O’Brien and Barnett, 2013; Bousquet et al., 2016). In line with this, Brian Walker, recently proposed (2014 reported in Bousquet et al., 2016) that social-ecological feedbacks can lead to undesirable and strongly resilient features. That breaking such “wicked” forms of resilience at multiple levels is needed to move toward global sustainability has been implicit at least since Rockström et al. (2009) so effectively kindled the debate on planetary boundaries. Newly emergent, human-generated social-ecological systems may or may not provide a desirable set of functions and services. Deciding on such desirability is a complex and

controversial, normative process (Glaser and Glaeser, 2011); but the eventual pursuit of a collectively envisioned desirable social-ecological future is likely to require the active disabling of wicked resilience in an Anthropocene type social-ecological system.

A strangely “resilient,” narrow interpretation of resilience and its management continues to dominate the resilience debate, however. The Resilience Alliance, for instance, remains dedicated “to the promotion of building resilience and enabling self-organization along sustainable trajectories” (<http://www.resalliance.org/about> accessed in November 2016) without reference to the other, wicked, side of the resilience coin. We ask ourselves: In this age of transformational science (O’Brien and Barnett, 2013; Future Earth, 2014) why is there so little concern with chronic resilience and its deconstruction? Why are the transformation and resilience debates developing almost in isolation?

Brown (2016) argues that while the study of resilience can enable transformation, main current policy discourses on resilience are promoting business-as-usual rather than radical responses to change. With growing human powers to bring about change in the Anthropocene, research needs to engage more comprehensively with the question of where and how breaking the resilience of undesirable social-ecological system elements and feedbacks is needed to enable a sustainable and desirable future. Thinking about, and engaging with power, will be a difficult but inevitable part of this.

AUTHOR CONTRIBUTIONS

The central idea of the paper came from discussions between MG and SF. JP-J, MT, and HR then collaborated in the further development of the conceptual framework. All authors contributed to the social-ecological analysis in the Spermonde Archipelago. HR condensed all author thoughts into Figure 1. MG wrote the manuscript with improvements from all contributing authors.

FUNDING

This study was carried out within the frame of the Indonesian-German SPICE Program (Science for the Protection of Indonesian Coastal Marine Ecosystems) from 2004 to 2016. The SPICE research program is funded by the German Federal Ministry of Education and Research (BMBF, Grant no. 03F0474A and 03F0643A). SF was additionally funded by BMBF REPICORE Grant no. 01LN1303A.

ACKNOWLEDGMENTS

For continuing interest, support and hospitality for over a decade of collaboration, we thank the Spermonde Islanders and their leaders. We also thank our two reviewers and for stimulating and pertinent comments.

REFERENCES

- Adger, W. N., Hughes, T. P., Folke, C., Carpenter, S. R., and Rockström, J. (2005). Social-ecological resilience to coastal disasters. *Science* 309, 1036–1039. doi: 10.1126/science.1112122
- Barnosky, A. D., Hadly, E. A., Bascompte, J., Berlow, E. L., Brown, J. H., Fortelius, M., et al. (2012). Approaching a state shift in Earth's Biosphere. *Nature* 486, 52–58. doi: 10.1038/nature11018
- Biggs, R., Schlüter, M., and Schoon, M. L. (2015). *Principles for Building Resilience. Sustaining Ecosystem Services in Social-Ecological Systems*. Cambridge: Cambridge University Press.
- Bonanno, G. A., Wortman, C. B., Lehman, D. R., Tweed, R. G., Haring, M., Sonnega, J., et al. (2002). Resilience to loss and chronic grief: a prospective study from pre-loss to 18 months post-loss. *J. Pers. Soc. Psychol.* 83, 1150–1164. doi: 10.1037/0022-3514.83.5.1150
- Bousquet, F., Botta, A., Alinovi, L., Barreteau, O., Bossio, D., Brown, K., et al. (2016). Resilience and development: mobilizing for transformation. *Ecol. Soc.* 21:40. doi: 10.5751/ES-08754-210340
- Brown, K. (2014). Global environmental change: a social turn for resilience? *Prog. Hum. Geogr.* 38, 107–117. doi: 10.1177/0309132513498837
- Brown, K. (2016). *Resilience, Development and Global Change*. Oxford, NY: Routledge.
- Cinner, J. E. (2011). Social-ecological traps in reef fisheries. *Global Environ. Change* 21, 835–839. doi: 10.1016/j.gloenvcha.2011.04.012
- Crona, B., and Bodin, Ö. (2010). Power asymmetries in small-scale fisheries: a barrier to governance transformability? *Ecol. Soc.* 15:32. doi: 10.5751/ES-03710-150432
- Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., et al. (2008). A place-based model for understanding community resilience to natural disasters. *Global Environ. Change* 18, 598–606. doi: 10.1016/j.gloenvcha.2008.07.013
- Davidson, J. L., Jacobson, C., Lyth, A., Dedekorkut-Howes, A., Baldwin, C. L., Ellison, J. C., et al. (2016). Interrogating resilience: toward a typology to improve its operationalization. *Ecol. Soc.* 21:27. doi: 10.5751/ES-08450-210227
- Davidson-Hunt, I. J., and Berkes, F. (2002). “Nature and society through the lens of resilience: toward a human-in-ecosystem perspective,” in *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*, eds F. Berkes, J. Colding, and C. Folke (Cambridge: Cambridge University Press), 53–82.
- Desai, V. (1996). Access to power and participation. *Third World Plan. Rev.* 18, 217–242. doi: 10.3828/twpr.18.2.d92127r670300350
- Fabinyi, M., Evans, L., and Foale, S. J. (2014). Social-ecological systems, social diversity, and power: insights from anthropology and political ecology. *Ecol. Soc.* 19:28. doi: 10.5751/ES-07029-190428
- Ferse, S. C. A., Knittweis, L., Krause, G., Maddusila, A., and Glaser, M. (2012). Livelihoods of ornamental coral fishermen in South Sulawesi/Indonesia: implications for management. *Coast. Manag.* 40, 525–555. doi: 10.1080/08920753.2012.694801
- Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., and Rockström, J. (2010). Resilience thinking: integrating resilience, adaptability and transformability. *Ecol. Soc.* 15:20. doi: 10.5751/ES-03610-150420
- Future Earth (2014). *Future Earth Strategic Research Agenda 2014*. Paris: International Council for Science (ICSU).
- Glaser, M., Breckwoldt, A., Deswandi, R., Radjawali, I., Baitoningsih, W., and Ferse, S. C. A. (2015). Of exploited reefs and fishers - a holistic view on participatory coastal and marine management in an Indonesian archipelago. *Ocean Coast. Manag.* 116, 193–213. doi: 10.1016/j.ocecoaman.2015.07.022
- Glaser, M., and Glaeser, B. (2011). “The social dimension of social-ecological management,” in *Treatise on Estuarine and Coastal Science*, eds E. Wolanski and D. McLusky (Waltham, MA: Academic Press), 5–30.
- Glaser, M., and Glaeser, B. (2014). Towards a framework for cross-scale and multi-level analysis of coastal and marine social-ecological systems dynamics. *Reg. Environ. Change* 14, 2039–2052. doi: 10.1007/s10113-014-0637-5
- Gorris, P. (2015). *Entangled? Linking Governance Systems for Regional-Scale Coral Reef Management: Analysis of Case Studies in Brazil and Indonesia*. Ph.D., thesis, Humanities and Social Sciences, Jacobs University Bremen.
- Graham, N. A. J., Bellwood, D. R., Cinner, J. E., Hughes, T. P., Norström, A. V., and Nyström, M. (2013). Managing resilience to reverse phase shifts in coral reefs. *Front. Ecol. Environ.* 11, 541–548. doi: 10.1890/120305
- Hobbs, R. J., Arico, S., Aronson, J. S., Bridgewater, P., Cramer, V. A., Epstein, P., et al. (2006). Novel ecosystems: theoretical and management aspects of the new ecological world order. *Glob. Ecol. Biogeogr.* 15, 1–7. doi: 10.1111/j.1466-822X.2006.00212.x
- Holling, C. S. (1973). Resilience and stability of ecological systems. *Annu. Rev. Ecol. Syst.* 4, 1–23. doi: 10.1146/annurev.es.04.110173.000245
- Holling, C. S. (1996). “Engineering resilience versus ecological resilience,” in *Engineering within Ecological Constraints*, ed P. C. Schulze (Washington, DC: National Academy Press), 31–44.
- Jackley, J., Gardner, L., Djunaedi, A. F., and Salomon, A. K. (2016). Ancient clam gardens, traditional management portfolios, and the resilience of coupled human-ocean systems. *Ecol. Soc.* 21:20. doi: 10.5751/ES-08747-210420
- Jentoft, S. (2007). In the power of power: the understated aspect of fisheries and coastal management. *Hum. Organ.* 66, 426–437. doi: 10.17730/humo.66.4.a836621h2k5x46m2
- Jentoft, S., and Chuenpagdee, R. (2009). Fisheries and coastal governance as a wicked problem. *Mar. Policy* 33, 553–560. doi: 10.1016/j.marpol.2008.12.002
- Kachergis, E. J., Knapp, C. N., Fernandez-Gimenez, M. E., Ritten, J. P., Pritchett, J. G., Parsons, J., et al. (2013). Tools for resilience management: multidisciplinary development of state-and-transition models for northwest Colorado. *Ecol. Soc.* 18:39. doi: 10.5751/ES-05805-180439
- Kooiman, J., Baavinck, M., Chuenpagdee, R., Mahon, R., and Pullin, R. (2008). Interactive governance and governability: an introduction. *J. Transdisc. Environ. Stud.* 7, 1–11.
- Lebel, L., Anderies, J. M., Campbell, B., Folke, C., Hatfield-Dodds, S., Hughes, T. P., et al. (2006). Governance and the capacity to manage resilience in regional social-ecological systems. *Ecol. Soc.* 11:19. doi: 10.5751/ES-01606-110119
- Maru, Y. T., Stafford Smith, M., Sparrow, A., Pinho, P. F., and Dube, O. P. (2014). A linked vulnerability and resilience framework for adaptation pathways in remote disadvantaged communities. *Global Environ. Change* 28, 337–350. doi: 10.1016/j.gloenvcha.2013.12.007
- Miñarro, S., Navarrete Forero, G., Reuter, H., and van Putten, I. E. (2016). The role of patron client relations on the fishing behaviour of artisanal fishermen in the Spermonde Archipelago (Indonesia). *Mar. Policy* 69, 73–83. doi: 10.1016/j.marpol.2016.04.006
- Moore, A. (2016). Anthropocene anthropology: reconceptualizing contemporary global change. *J. R. Anthropol. Inst.* 22, 27–46. doi: 10.1111/1467-9655.12332
- Nyström, M., Norström, A., Blenckner, T., la Torre-Castro, M., Eklöf, J. S., Folke, C., et al. (2012). Confronting feedbacks of degraded marine ecosystems. *Ecosystems* 15, 695–710. doi: 10.1007/s10021-012-9530-6
- O'Brien, K., and Barnett, J. (2013). Global environmental change and human security. *Annu. Rev. Environ. Resour.* 38, 370–391. doi: 10.1146/annurev-environ-032112-100655
- O'Brien, K., Hayward, B., and Berkes, F. (2009). Rethinking social contracts: building resilience in a changing climate. *Ecol. Soc.* 14:12.
- Olsson, L., Jerneck, A., Thoren, H., Persson, J., and O'Byrne, D. (2015). Why resilience is unappealing to social science: theoretical and empirical investigations of the scientific use of resilience. *Sci. Adv.* 1:e1400217. doi: 10.1126/sciadv.1400217
- Olsson, P., Folke, C., and Berkes, F. (2004). Adaptive co-management for building resilience in social-ecological systems. *Environ. Manag.* 34, 75–90. doi: 10.1007/s00267-003-0101-7
- Olsson, P., Galaz, V., and Boonstra, W. J. (2014). Sustainability transformations: a resilience perspective. *Ecol. Soc.* 19:1. doi: 10.5751/ES-06799-190401
- Plass-Johnson, J. G., Teichberg, M., Bednarz, V. N., Gärdes, A., Heiden, J. P., Lukman, M., et al. (2018). Spatio-temporal patterns in the coral reef communities of the spermonde archipelago, 2012–2014, II: fish assemblages display structured variation related to benthic condition. *Front. Mar. Sci.* 5:36. doi: 10.3389/fmars.2018.00036
- Plass-Johnson, J. G., Schwieder, H., Heiden, J., Weiland, L., Wild, C., Jompa, J., et al. (2015). A recent outbreak of crown-of-thorns starfish (*Acanthaster planci*) in the Spermonde Archipelago, Indonesia. *Reg. Environ. Change* 15, 1157–1162. doi: 10.1007/s10113-015-0821-2

- Plass-Johnson, J. G., Taylor, M. H., Husain, A. A., Teichberg, M. C., and Ferse, S. C. (2016). Non-random variability in functional composition of coral reef fish communities along an environmental gradient. *PLoS ONE* 11:e0154014. doi: 10.1371/journal.pone.0154014
- Quinlan, A. E., Berbes-Blazquez, M., Haider, J., and Peterson, G. (2015). Measuring and assessing resilience: broadening understanding through multiple disciplinary perspectives. *J. Appl. Ecol.* 53, 677–687. doi: 10.1111/1365-2664.12550
- Rockström, J., Will Steffen, W., Noone, K., Persson, A., Chapin, F. S. III., Lambin, E. F., et al. (2009). A safe operating space for humanity. *Nature* 461, 472–475. doi: 10.1038/461472a
- Sawall, Y., Jompa, J., Litaay, M., Maddusila, A., and Richter, C. (2013). Coral recruitment and potential recovery of eutrophied and blast fishing impacted reefs in Spermonde Archipelago, Indonesia. *Mar. Pollut. Bull.* 74, 374–382. doi: 10.1016/j.marpolbul.2013.06.022
- Scholten, J., Stephen, J., and Menon, A. (2013). Between the devil and the not-so-deep blue sea. Asymmetrical power in the Indo-Sri Lankan fisheries conflict. *The Broker Online*.
- Teichberg, M., Wild, C., Bednarz, V. N., Kegler, H. F., Lukman, M., Gärdes, A. A., et al. (2018) Spatio-temporal patterns in coral reef communities of the spermonde archipelago, 2012–2014, I: comprehensive reef monitoring of water and benthic indicators reflect changes in reef health. *Front. Mar. Sci.* 5:33. doi: 10.3389/fmars.2018.00033
- Tredgold, T. (1818). *Elementary Principles of Carpentry*. London: William Clowes and Sons.
- Troell, M., Naylor, R. L., Metian, M., Beveridge, M., Tyedmers, P. H., Folke, C., et al. (2014). Does aquaculture add resilience to the global food system? *Proc. Natl. Acad. Sci. U.S.A.* 111, 13257–13263. doi: 10.1073/pnas.1404067111
- UN Development Programme (UNDP) (2014). *Human Development Report 2014. Sustaining Human Progress: Reducing Vulnerabilities and Building Resilience*. New York, NY.
- Walker, B., Carpenter, S., Anderies, J., Abel, N., Cumming, G. S., Janssen, M., et al. (2002). Resilience management in social-ecological systems: a working hypothesis for a participatory approach. *Conserv. Ecol.* 6:14. doi: 10.5751/ES-00356-060114
- Walker, B. H., Gunderson, L. H., Kinzig, A. P., Folke, C., Carpenter, S. R., and Schultz, L. (2006). A handful of heuristics and some propositions for understanding resilience in social-ecological systems. *Ecol. Soc.* 11:13. doi: 10.5751/ES-01530-110113
- Walker, B., Holling, C. S., Carpenter, S. R., and Kinzig, A. (2004). Resilience, adaptability and transformability in social-ecological systems. *Ecol. Soc.* 9:5. doi: 10.5751/ES-00650-090205
- Westley, F., Olsson, P., Folke, C., Homer-Dixon, T., Vredenburg, H., Loorbach, D., et al. (2011). Tipping toward sustainability: emerging pathways of transformation. *AMBIO* 40. doi: 10.1007/s13280-011-0186-9
- Westley, F. R., Tjornbo, O., Schultz, L., Olsson, P., Folke, C., Crona, B., et al. (2013). A theory of transformative agency in linked social-ecological systems. *Ecol. Soc.* 18:27. doi: 10.5751/ES-05072-180327

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Copyright © 2018 Glaser, Plass-Johnson, Ferse, Neil, Satari, Teichberg and Reuter. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.