

# Supporting Information

Schultz et al. 10.1073/pnas.1406493112

## SI Text

**Methods.** The three case studies were originally investigated by the authors of this paper, using literature reviews, interviews, surveys, social network analyses, participatory observations in meetings, and field observations (1–8). The comparison was made in three steps. First, we compared existing insights from the three cases, looking for common features as well as differences between governance arrangements, visions, and goals of the respective initiatives, and potential effects on natural capital. Based on this analysis, we decided to focus on investigating and comparing effects of adaptive governance on natural capital and on the capacity to deal with new challenges. Second, we engaged in a number of follow-up research activities of each case, focused on investigating trends in natural capital and responses to new challenges. Methods included additional interviews with key informants, targeted questions to individuals with specific knowledge of parts of these issues, and an extensive literature review. The review focused on scientific documentation in the peer review literature. Material for KV was not as published in the primary literature, and the sources to support the findings of this case study are summarized below. Third, the new findings were compared with a specific focus on untangling the effects of the adaptive governance initiatives from other influential variables.

### Adaptive Governance of Natural Capital in Kristianstads Vattenrike.

Kristianstads Vattenrike Biosphere Reserve is coordinated by a municipal organization, the Biosphere Office. This organization monitors and documents changes in the ecosystems and keeps track of research and inventories of relevance to the biosphere reserve through a continuously updated literature list on their official website (9). The activities of the organization are documented in annual reports and on their blog. These supporting materials provide details about the developments in the area since 2005.

The biological and cultural values of Kristianstads Vattenrike are described in detail in the application to become a biosphere reserve from 2005, a document that has been reviewed by a large group of stakeholders and endorsed by the Swedish government and UNESCO (10). The initial focus in 1989 on restoring wet grasslands expanded in preparation for the biosphere reserve application, to include 10 landscape themes, including sandy grasslands, coastal areas, and ground water, all combining the three biosphere reserve functions of conservation, development, and learning (10). The list of threatened species found in the biosphere reserve is updated yearly, based on observations in the area. The list from 2015 encompasses 775 of the nationally red-listed species (11)—23 of these species are globally red-listed, 16 are listed in the EU habitat directive, and 43 are listed in the EU bird directive.

A thorough mapping of wet grasslands under active management shows that they increased from 1,222 ha in 1989 to 1,660 ha in 2008 (12). This trend seems to have continued. For example, according to an annual report of the biosphere office, 42 ha of wetland were restored along Vinneå River during 2012, with the aim of reducing eutrophication, increasing flood protection, enhancing aesthetic values, and providing habitat for associated organisms. In the same project, spawning grounds were restored along the river, to enhance production of fish and to support red-listed mussels who need fish as hosts during larvae stages. The restoration was done together with college students, thus supporting environmental education (13). This multifunctional approach is indicative to many of the projects currently underway

in all of the themes, including restoration of habitats, inventories of species and management practices, facilitating dialogue and collaboration between stakeholders, improving access to recreational ecosystem services, and providing educational support (9).

According to the official webpage of Kristianstads Vattenrike (9), there are now 29 nature reserves in the area, and follow-up interviews indicate that more than half of these reserves result from the adaptive governance work by the biosphere office staff. Several of the reserves are situated close to the city, and secure ecosystem services that would most likely have been lost to urban expansion in the absence of an adaptive governance platform for biodiversity conservation.

According to yearly inventories of bird populations, coordinated by Hans Cronert at the biosphere office and analyzed in a published report by the biosphere office, wading bird populations increased between 1990 and 1997, along with the restoration of habitats, but then some of the species have rapidly decreased between 1997 and 2009 (14). In a later report, Cronert summarizes the suggested reasons for this decline, including deterioration of nesting grounds caused by geese grazing, increasing predation by fox and birds of prey, dry springs causing wet ponds to dry up earlier, and an extreme flood event in 2007, which killed a lot of vegetation (15). Cronert concludes that more research is needed to establish causes and potential management responses (15). Experimentation with different interventions is currently underway to increase populations and increase knowledge about underlying causes for the decline.

In response to the brownification, Sven-Erik Magnusson at the biosphere office contacted several researchers to apply for funding from the Swedish Environmental Protection Agency (EPA) to assess drivers behind deteriorating water quality, mapping effects on ecosystem services, and actors involved in management and use of these services, and a participatory resilience assessment of the whole drainage basin of the River Helgeå. The 3-y project proposal was granted funding in 2013 (16). The biosphere reserve coordinator also wrote an open letter to the environmental minister urging for action because brownification is a general trend in rivers and lakes of Southern Sweden. In April 2014, the Swedish Agency for marine and water management announced that they would invest 15.7 million SEK (2.4 million USD) in improving the water quality of the River Helgeå mainly through wetland restoration in upstream forest areas (17).

### Influence of the Studied Adaptive Governance Cases on Policy and Practice in Other Regions.

Kristianstads Vattenrike has inspired the designation of four new biosphere reserves in Sweden (18). Furthermore, KV is used as a showcase in several guiding documents from the Swedish EPA on implementing the ecosystem approach, enhancing local participation and dialogue, and analyzing ecosystem services (18–20). Swedish government policy documents use experiences from KV to illustrate how the value of ecosystem services can be visualized and taken into account in decision making and practical resource management (21). KV has also been highlighted in analogous EU reports as a successful example of social innovation (22). Internationally, KV was one of the first areas encompassing a city that was designated as a biosphere reserve under the UNESCO Man and the Biosphere program, opening up for urban biosphere reserves. In addition, their innovative approach to integrate conservation, development, and learning in all projects, instead of spatial zonation in core, buffer, and transition areas, has inspired the development of guidelines at

the global level of the program. As a case study within the Millennium Ecosystem Assessment (23), it has influenced a range of other local initiatives in the world.

The Great Barrier Reef Marine park authority played a major role in the emergence of the concept of Marine Spatial Planning (MSP) and how it has spread globally (24). The rezoning of the GBR, and the Representative Areas Program, became an early demonstration site of how MSP could be designed and implemented. More specifically, it provided an example of a workable model of ecosystem-based management through MSP at a seascape scale that addressed simultaneously both the human dimension and the ecosystem dimension. Specific individuals that had been involved in the rezoning of the GBR were highly influential in creating an informal international network that helped the diffusion of MSP worldwide, as well as in establishing the MSP initiative of the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO). Because of their experience of managing large-scale social-ecological systems and designing institutional architectures for multiple-use marine planning systems, these individuals have also been involved in developing the Coral Triangle Initiative (25). This initiative is an international agreement and partnership for ecosystem-based management of coastal and marine resources in a large-scale marine ecosystem at the confluence of the Indian Ocean and the Western Pacific.

The Southern Ocean initiative generated a range of sanctioning mechanisms that have been used in other places. Informal sanctioning mechanisms used by environmental NGOs and the licensed fishing industry includes “naming and shaming” campaigns (26, 27). Formal policy tools agreed on by governments and aimed to evaluate compliance and sanction noncompliance include the development of a Catch Documentation Scheme,

adopted in 2000, to improve the traceability of fish products (28) and an “IUU vessel list” (where IUU means “illegal, unreported, and unregulated”), adopted in 2003 (vessels registered on this list are not able to obtain a license for quotas and are not received in port in any of the member states). Both the catch documentation scheme and the IUU vessel list have been critical tools for success within CCAMLR (5, 6). Interestingly, several other regional fisheries management organizations have subsequently mimicked the policy tools and practices of CCAMLR. The Intergovernmental Commission for the Conservation of Atlantic Tuna established a catch documentation scheme in 2007 and is also considering an electronic scheme as currently in practice in CCAMLR (29). The Commission for the Conservation of Southern Bluefin Tuna established a similar scheme in 2010, and discussions to establish this tool have also taken place in the Western and Central Pacific Fisheries Commission (WCPFC). A range of regional fisheries management organizations also currently use IUU vessel lists, including the WCPFC (from 2009), the South East Atlantic Fisheries Organization, from 2007, the North East Atlantic Fisheries Commission, from 2005, the Indian Ocean Tuna Commission, from 2011, and the Inter-American Tropical Tuna Commission, from 2005. These vessel lists have also recently been combined (by a nonstate actor) in a global list on the Internet. Part of the reason for the widespread implementation of policy tools similar to CCAMLR may be the widespread media and policy attention that illegal fishing in this area received, and the emphasis on the success of CCAMLR in globally widespread reports developed by the Organisation for Economic Co-operation and Development (OECD) (30) and the Ministerial-led High Seas Task Force (26).

- Olsson P, Folke C, Hahn T (2004) Social-ecological transformation for ecosystem management: The development of adaptive co-management of a wetland landscape in southern Sweden. *Ecol Soc* 9(4):2.
- Hahn T, Olsson P, Folke C, Johansson K (2006) Trust-building, knowledge generation and organizational innovations: The role of a bridging organization for adaptive co-management of a wetland landscape around Kristianstad, Sweden. *Hum Ecol* 34(4): 573–592.
- Schultz L, Folke C, Olsson P (2007) Enhancing ecosystem management through social-ecological inventories: Lessons from Kristianstads Vattenrike, Sweden. *Environ Conserv* 34(2):140–152.
- Olsson P, Folke C, Hughes TP (2008) Navigating the transition to ecosystem-based management of the Great Barrier Reef, Australia. *Proc Natl Acad Sci USA* 105(28):9489–9494.
- Österblom H, Bodin Ö (2012) Global cooperation among diverse organizations to reduce illegal fishing in the Southern Ocean. *Conserv Biol* 26(4):638–648.
- Österblom H, Sumaila UR (2011) Toothfish crises, actor diversity and the emergence of compliance mechanisms in the Southern Ocean. *Glob Environ Change* 21(3):972–982.
- Österblom H, Sumaila UR, Bodin Ö, Hentati Sundberg J, Press AJ (2010) Adapting to regional enforcement: Fishing down the governance index. *PLoS ONE* 5(9):e12832.
- Bodin T, Österblom H (2013) International fisheries regime effectiveness: Activities and resources of key actors in the Southern Ocean. *Glob Environ Change* 23(5):948–956.
- Anonymous (2014) Official website of Kristianstad. Available at [www.vattenriket.kristianstad.se/](http://www.vattenriket.kristianstad.se/). Accessed May 14, 2014.
- Magnusson S-E, Magntorn K, Wallsten E, Cronert H, Thelass M (2005) *Kristianstads Vattenrike Biosphere Reserve Nomination Form* (Municipality of Kristianstad, Kristianstad, Sweden). Swedish.
- Anonymous (2015) *Nationellt Rödlistade Arter [National Red-Listed Species]* (Kristianstads Vattenrike, Kristianstad, Sweden). Swedish.
- Oveson P (2009) Markhävdkartering 2008 hävdstillståndet på betesmarker och slåtterängar inom nedre Helgeåns våtmarksområde i Kristianstads Vattenrike [Mapping of traditional agricultural land use 2008: Status of grazed and mowed pastures within the wetland area of Lower Helgeå River basin]. *Vattenriket i Fokus* (Kristianstads Vattenrike, Kristianstad, Sweden). Swedish.
- Anonymous (2013) *Biosfärområde Kristianstad Vattenrike: Verksamheten år 2013 [Biosphere Reserve Kristianstads Vattenrike: Annual Report of 2013]* (Kristianstads Vattenrike, Kristianstad, Sweden). Swedish.
- Cronert H (2010) Strandängsfåglar längs nedre Helgeån i Kristianstads Vattenrike 2009: Med jämförelser bakåt i tiden [Birds on the wet grasslands along the lower Helgeå River in Kristianstads Vattenrike: With historical comparisons]. *Anser* 49(2): 79–94. Swedish.
- Cronert H (2014) Strandängsfåglar i Vattenriket: Häckfågelkarteringar och simultanräkningar. *Spoven* 1:1–19.
- SEPA (2013) *Värdet av Ekosystemtjänster [The Value of Ecosystem Services]* (Swedish Environmental Protection Agency), press release. Available at [www.naturvardsverket.se/Miljoarbete-i-samhallet/Miljoarbete-i-Sverige/Forskning/forskning-for-miljomalen/Vardet-av-ekosystemtjanster/](http://www.naturvardsverket.se/Miljoarbete-i-samhallet/Miljoarbete-i-Sverige/Forskning/forskning-for-miljomalen/Vardet-av-ekosystemtjanster/). Accessed May 14, 2014. Swedish.
- Anonymous (2014) *Miljoner till Skånska Vattenprojekt [Millions to Scanian Water Projects]* (Länsstyrelsen i Skåne län), press release. Available at [www.lansstyrelsen.se/skane/Sv/nyheter/2014/Pages/miljoner-till-skanska-vattenprojekt.aspx](http://www.lansstyrelsen.se/skane/Sv/nyheter/2014/Pages/miljoner-till-skanska-vattenprojekt.aspx). Accessed May 14, 2014. Swedish.
- SEPA (2008) *Ekosystemansatsen: En Väg Mot Bevarande och Hållbart Nyttjande av Naturresurser [The Ecosystem Approach: A Road to Conservation and Sustainable Use of Natural Resources]* (Swedish Environmental Protection Agency, Stockholm). Swedish.
- SEPA (2003) *Lokal Förankring av Naturvård Genom Deltagande och Dialog [Local Anchoring of Nature Conservation Through Participation and Dialogue]* (Swedish Environmental Protection Agency, Stockholm). Swedish.
- SEPA (2009) *Ekosystemtjänstanlys i Kristianstads Vattenrike: Pilotstudie strandängar [Ecosystem Assessment of Kristianstads Vattenrike: A Pilot Study of Wet Grasslands]* (Swedish Environmental Protection Agency, Stockholm). Swedish.
- SOU (2013) *Synliggöra Värdet av Ekosystemtjänster: Åtgärder för Välfärd Genom Biologisk Mångfald och Ekosystemtjänster [Making the Value of Ecosystem Services Visible: Interventions for Welfare Through Biodiversity and Ecosystem Services]* (Swedish Government Offices, Stockholm). Swedish.
- Anonymous (2014) *Science for Environment Policy In-depth Report: Social Innovation and the Environment* (University of the West of England, Bristol, United Kingdom), report produced for the European Commission DG Environment.
- MEA (2005) *Ecosystems and Human Well-Being: Synthesis* (Island Press, Washington, DC).
- Merrie A, Olsson P (2014) An innovation and agency perspective on the emergence and spread of Marine Spatial Planning. *Mar Policy* 44:366–374.
- Rosen F, Olsson P (2012) Institutional entrepreneurs, global networks, and the emergence of international institutions for ecosystem-based management: The Coral Triangle Initiative. *Mar Policy* 38:195–204.
- High Seas Task Force (2006) *Closing the Net: Stopping Illegal Fishing on the High Seas* (Governments of Australia, Canada, Chile, Namibia, New Zealand, and the United Kingdom, WWF, IUCN and the Earth Institute at Columbia University).
- Fallon LD, Kriwoken LK (2004) International influence of an Australian non-government organization in the protection of Patagonian toothfish. *Ocean Dev Int Law* 35(3):221–226.
- Agnew DJ (2000) The illegal and unregulated fishery for toothfish in the southern Ocean, and the CCAMLR catch documentation scheme. *Mar Policy* 24(5):361–374.
- FAO-COFI (2008) *Harmonization of Catch Documentation Schemes*, paper to the Committee on Fisheries, Sub-Committee on Fish Trade, Eleventh Session, Bremen, Germany, June 2–6, 2008 (FAO, Quebec City, QC, Canada).
- OECD (2004) *Fish Piracy: Combating Illegal, Unreported and Unregulated Fishing* (Organisation for Economic Co-Operation and Development, Paris).

**Table S1. A comparison of scope, history, and actors involved in adaptive governance of Kristianstads Vattenrike, Great Barrier Reef, and Southern Ocean**

Key aspects for comparison	Kristianstads Vattenrike	Great Barrier Reef	Southern Ocean
Guiding vision	To maintain, develop, and support sustainable use of the cultural and natural values in Kristianstads Vattenrike	To ensure that all human uses of the Park are ecologically sustainable and that the ecosystem's natural functions, especially resilience, are maintained	To preserve the waters surrounding the Antarctic continent for peaceful purposes only and to prevent their becoming the scene or object of international discord
Area and type of focal ecosystem	1,040 km <sup>2</sup> of cultural landscapes: wet and sandy grasslands, lakes, rivers, deciduous forests, coastal region, urban green areas	345,000 km <sup>2</sup> of coral reef: 70 different habitats (30 reef and 40 nonreef)	20,327,000 km <sup>2</sup> of ocean
Ecosystem services in focus	Supporting (habitat for more than 700 nationally red-listed species); cultural (recreational, aesthetic, educational, heritage); regulating (flood regulation, water purification); provisioning (food, fresh water)	Supporting (habitat for 600 types of corals, >100 species of jellyfish, 3,000 varieties of molluscs, 1,625 types of fish, 133 varieties of sharks and rays, and >30 species of whales and dolphins); cultural (world heritage, indigenous hunting, tourism, recreation); regulating (storm protection); provisioning (seafood, medicines, aquarium fish)	Supporting (benthic habitats); cultural (pristine ecosystems to be conserved for the benefit of mankind, including charismatic seabirds); provisioning (fish stocks)
Levels of governance (primary level of bridging organization in bold)	Submunicipal (landowners and associations), <b>municipal</b> (Kristianstad), regional (Skåne County), national (Swedish EPA), international (UNESCO MAB)	Local (communities and associations), state (Queensland), <b>national</b> (GBRMPPA), international (UNESCO WH)	Subnational (fish industries and environmental NGOs); national (several member states within CCAMLR and <b>International</b> (CCAMLR and other international organizations)
Actor groups involved	State actors, resource users, conservation NGOs, academic institutions, local associations, landowners	State actors, resource users, conservation NGOs, academic institutions, local associations, indigenous groups	State actors, resource users, conservation NGOs, academic institutions
Milestones	1975 Ramsar designation, 1989 launch of a new municipal organization for ecosystem-based management, 2005 designated UNESCO biosphere reserve, 2010 Naturum inaugurated	1975 The Great Barrier Reef Marine Park Act enacted, 1976 The Great Barrier Reef Marine Park Authority established, 1981 designated UNESCO World Heritage Site, 2004 new zoning passed into law	1983 CAMLR Convention, 2000 establishment of a catch documentation scheme, 2003 establishment of vessel IUU list
Refs.	(1–3)	(4, 5)	(6–11)

MAB, Man and the Biosphere Programme; UNESCO WH, United Nations Educational, Scientific and Cultural Organization World Heritage.

- Hahn T, Olsson P, Folke C, Johansson K (2006) Trust-building, knowledge generation and organizational innovations: The role of a bridging organization for adaptive comanagement of a wetland landscape around Kristianstad, Sweden. *Hum Ecol* 34(4):573–592.
- Schultz L, Folke C, Olsson P (2007) Enhancing ecosystem management through social-ecological inventories: Lessons from Kristianstads Vattenrike, Sweden. *Environ Conserv* 34(2): 140–152.
- Olsson P, Folke C, Hahn T (2004) Social-ecological transformation for ecosystem management: The development of adaptive co-management of a wetland landscape in southern Sweden. *Ecol Soc* 9(4):2.
- Olsson P, Folke C, Hughes TP (2008) Navigating the transition to ecosystem-based management of the Great Barrier Reef, Australia. *Proc Natl Acad Sci USA* 105(28):9489–9494.
- Merrie A, Olsson P (2014) An innovation and agency perspective on the emergence and spread of Marine Spatial Planning. *Mar Policy* 44:366–374.
- Bodin Ö, Österblom H (2013) International fisheries regime effectiveness: Activities and resources of key actors in the Southern Ocean. *Global Environ Change* 23(5):948–956.
- Österblom H, Bodin Ö (2012) Global cooperation among diverse organizations to reduce illegal fishing in the Southern Ocean. *Conserv Biol* 26(4):638–648.
- Österblom H, Sumaila UR (2011) Toothfish crises, actor diversity and the emergence of compliance mechanisms in the Southern Ocean. *Glob Environ Change* 21(3):972–982.
- Österblom H, Sumaila UR, Bodin Ö, Hentati Sundberg J, Press AJ (2010) Adapting to regional enforcement: fishing down the governance index. *PLoS ONE* 5(9):e12832.
- Österblom H, Constable A, Fukumi S (2011) Illegal fishing and the organized crime analogy. *Trends Ecol Evol* 26(6):261–262.
- Österblom H, Folke C (2013) Emergence of global adaptive governance for stewardship of regional marine resources. *Ecol Soc* 18(2):4.