

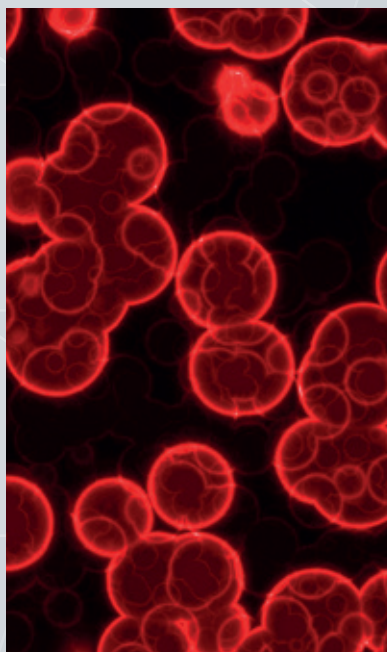
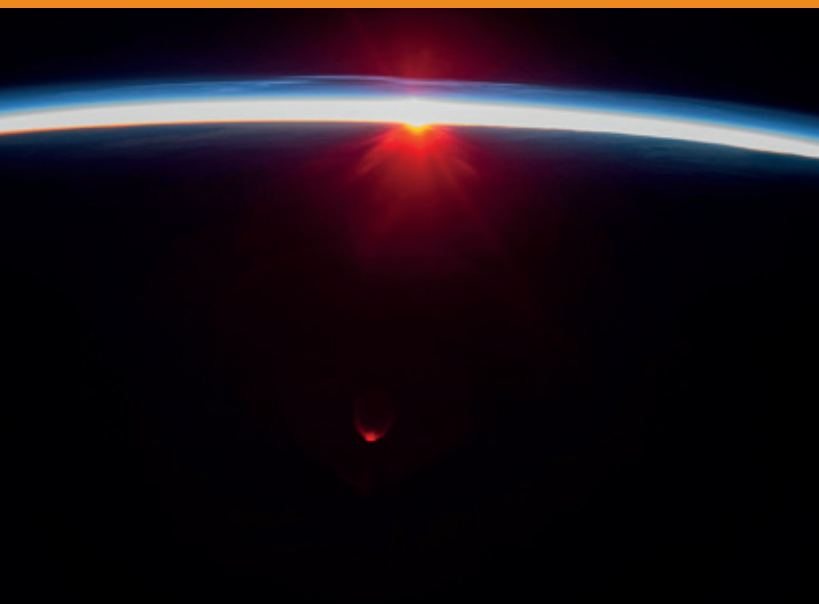


GLOBAL ECONOMIC DYNAMICS AND THE BIOSPHERE

THE ROYAL SWEDISH ACADEMY OF SCIENCES

The Erling-Persson Family Academy Programme

REPORT 2017



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INTRODUCTION

This annual report of the Global Economic Dynamics and the Biosphere programme (GEDB) describes its work in 2017. The five-year Erling-Persson Family Academy Programme at the Royal Swedish Academy of Sciences focuses on the economic dynamics of global change in a biosphere context and its implications for a sustainable future.

The programme was set up to conduct interdisciplinary research that integrates social, economic and ecological dimensions, perspectives and data to explore scientific frontiers that lie at the nexus between these areas. GEDB performs rigorous high-impact scientific work of relevance for, and in collaboration with, practice, policy, business and society as a whole. The emphasis of the programme is on science for change.

The focus and achievements of GEDB so far have been of a highly emergent and innovative nature, combining methods and disciplines across hitherto largely unexplored domains to develop sustainability science. This differs from most other academic efforts in a number of ways, for example by:

- Connecting knowledge and competencies of researchers from disciplines that seldom interact
- Combining whole areas of work that have previously been performed separately
- Enabling new forms of collaboration between science, practice and business for human wellbeing and biosphere stewardship.

The outcome is novel and surprising research findings, the emergence of unexplored areas and new fields of research, and informed collaborative platforms engaging central actors in society and business in solving problems and challenges of great relevance for actions towards sustainability.

These new discoveries and collaborations across diverse fields and actors that GEDB has achieved so far would not have been possible without the flexible funding provided by the Erling-Persson Family Foundation.

AIMS AND VISIONS

- To create a platform for interdisciplinary collaboration on the challenges of global change and sustainability, with specific focus on how local-to-global, cross-scale interactions affect human wellbeing and the sustainable use of natural resources and ecosystems.
- To facilitate and promote collaboration between early career economists and scientists with other backgrounds, focusing on sustainability science.
- To combine diverse knowledge systems and experiences, and conduct research for a broader understanding of the preconditions and opportunities for sustainable societal development in the new global context.

RESEARCH ACHIEVEMENTS AND ACTIVITIES

(Macro)economy and the biosphere

This theme furthers cutting-edge work on economic models which recognise that the economic system is embedded in – and dependent on – the biosphere. The latest developments within economic theory are integrated with methods used in sustainability science, to create economic models that do not focus solely on the threat of climate change, but include many more environmental factors and their dynamics. As these types of integrated assessment models (IAMs) are typically used in government decisions and for policy development, improving their ability to capture multiple environmental phenomena is essential.

Economic modelling and sustainability

Work under this topic has proceeded within three primary domains. The first has explored the relationship between energy availability and global macro-economic patterns concerning the short- and long term development of countries. Two papers have been submitted for review. A study produced in collaboration between GEDB researcher Johan Gars and Conny Olovsson at Sveriges Riksbank, which is under review at *Journal of Economic Theory*, considers the importance of availability and affordability of oil for explaining patterns of economic growth over time and across different countries. Their results offer an explanation as to why certain countries grow more quickly than others (a phenomenon known as “the great divergence”). Since the oil price is determined on a world market, richer countries push the price up, leading to poorer

countries being excluded from technical advances dependent on oil use. In a wider context these results show that access to energy is an important factor lifting countries out of poverty.

A second paper by the same authors, under review at *International Economic Review*, shows that globally observed patterns in how countries’ business cycles are correlated (e.g. GDP, consumption, employment and investment) can be explained by the fact that oil is traded on a world market and by the transmission of oil supply and technology shocks through this world market.

Another topic centres on macro-economic effects on international trade. For example, as the volatility of agricultural production is expected to increase with climate change, it is important to evaluate to what extent international trade can be used to mitigate the effects of agricultural production shocks. Results from this research contained in a paper submitted to *European Review of Agricultural Economics* show that there is room for improving trade as a coping mechanism, an important mitigation strategy in a more uncertain future climate.

Third, work is underway to map the economic connections between the different “planetary boundaries”, a set of nine processes that are critical to the functioning of the Earth system. More specifically, Johan Gars and collaborators Gustav Engström and Chandra Kiran have developed a model incorporating important market linkages between economic activities that affect the planetary boundaries, in order to study how economic policies aimed at reducing the pressure on one boundary affect the other boundaries. An important finding is

SUSTAINABLE DEVELOPMENT GOALS



The UN Sustainable Development Goals. GEDB researchers are investigating how national economies can contribute to fulfilling these goals.

that a small set of policies (such as a carbon tax and a policy that prevents land conversion) can reduce the pressure on almost all the planetary boundaries. This shows that, while the task of constructing fully optimal policies dealing with the planetary boundaries is very complex, a small set of policies can go a long way. Work is now underway to explore the trade-offs between these types of policies and those aiming to ensure global food security.

Sustainable Development Goals and a safe and just operating space for humanity

Peter Sjøgaard Jørgensen has continued his postdoctoral work on assessing the social-ecological performance of national economies in a world interconnected by trade, transport and travel. Multiple ongoing collaborations have been initiated with the Norwegian University of Science and Technology (NTNU) and the World Conservation Monitoring Centre (WCMC), including time series analysis of the effect of national economies on the planetary boundaries and their contribution to the UN Sustainable Development Goals, based on the countries' environmental footprints. These projects will be advanced in 2018 through visits to NTNU in Trondheim and WCMC in Cambridge. A comparative analysis of territorial and global accounting frameworks to measure countries' performance was presented at the Resilience 2017 conference and a paper is in the final stages of sensitivity testing before submission. The work has revealed that, when production outside national borders is fully included in a country's consumption footprint, high-income countries use more resources to achieve the same amount of societal well-being progress than they did two decades ago.

Marine resource trade and its effects on social-ecological systems

This research theme examines how existing and emergent markets affect the functioning of marine social-ecological systems at different scales. It looks at the economic, social and environmental components of fisheries and aquaculture production systems. Transitioning to sustainable fisheries and seafood production will involve changes in how seafood is produced, but equally important are the types and volumes of species demanded by markets, and how these market choices can help support more sustainable seafood production and consumption. Understanding how such a transformation can be achieved requires a focus on the production of seafood and the market system, and on the supply chains connecting production and consumption. Below are some examples of research that uncovers important aspects for sustainable production, marketing and consumption, in a world of changing climate and increasingly globalised trade.

Seafood trade and sustainable supply chains

Fisheries Improvement Projects (FIPs) is an approach to improve sustainability in fisheries by enlisting market actors, like retailers, suppliers and processors, and the capture sector to work together for improved governance. The number of FIPs has grown dramatically in the past decade and they are becoming a key feature of the fisheries governance landscape around the world. However, lack of a systematic overview of



Salmon cages in northern Norway. GEDB researchers have studied the challenges for aquaculture production in a warmer Arctic.

their mode of operation hampers the ability to assess how well they are working, what the challenges are and where opportunities lie for the future.

The long-term collaboration and dialogue fostered between researchers and fisheries industry actors (such as the Sustainable Fisheries Partnership) through the GEDB programme is now paying off. An important output is the first comprehensive analysis of FIPs, which describes the working process of these initiatives (submitted to the journal *Fish and Fisheries*). This analysis provides a solid empirical basis from which to continue the collaboration on how FIPs can contribute to a global transition to more socially and environmentally sustainable fisheries.

Fisheries production and sustainable social-ecological marine systems

Large-scale changes in the Arctic marine food web can be expected in the next 40–100 years. In a review in the journal *Ambio* of state-of-the-art knowledge about climate impacts on Arctic seafood production, a team led by Max Troell concluded that Arctic fisheries already experience high variability and that climate change will further amplify these. This means more changes in species dynamics in fish stocks and marine ecosystems, and associated governance challenges. Furthermore, changes in water temperature, sea level, water current and salinity are drivers most likely to challenge the aquaculture industry to adapt to the new reality.

The future of marine protein production through aquaculture

In a comment in the journal *Nature Ecology & Evolution*, Max Troell and co-authors Patrik Henriksson and Malin Jonell elaborate on the potential for future marine aquaculture (mariculture) development. Considering existing and emerging challenges facing food production on land, the incentives for expansion of food production into the oceans is large. They explain that feed availability and feed costs will prevent further expansion of mariculture long before any ocean space limitations are reached. Current aquaculture production of fish in off-shore ocean systems requires high-quality protein feeds, based on fish resources and, increasingly, agriculture crops such as soy, making aquaculture production dependent on both aquatic and terrestrial ecosystems. The potential for marine aquaculture is also affected by climate change through both temperature increases and ocean acidification.

Activities

- * The Stockholm Dialogue: Advancing the Seafood Business for Ocean Stewardship (SeaBOS) Initiative, organised by SRC, the Beijer Institute and GEDB at the Royal Swedish Academy of Sciences, Stockholm, Sweden, 15–16 May. Read more under Communication and Impact.
- * *Fish Futures – sustainable seafood to support the SDGs*. A competence forum co-organised by Van Holt and Troell at the 2017 EAT Forum in Stockholm 12–13 June. This dialogue was an initial step in discussing the role seafood can play in improving human and planetary health.

- * *The Global Oceans and the Future of Humanity*. GEDB co-organised a half-day seminar at the Royal Swedish Academy of Sciences on 28 November with Volvo Environment Prize laureate 2017, Professor Rashid Sumaila and others. Read more under Communication and Impact.
- * A scoping workshop was hosted by GEDB on 7–9 December to explore China’s role in the future global seafood system. As one of the largest seafood producers and consumers in the world, China’s choices in terms of how and where it sources its seafood, and in what it produces and consumes, will have implications for seafood availability and economic opportunities for other nations for years to come. The workshop brought together leading experts on Chinese policy, fisheries and aquaculture production, and trade and consumer behaviour from around the world, including University of Technology Sydney, University of Wollongong, WorldFish, Stanford University, University of Washington, University of British Columbia and Shanghai Ocean University.
- * GEDB staff took part in a science/art collaboration with Beckmans College of Design and the design company Svenskt Tenn, resulting in the exhibition *Transformation* in Stockholm 16–29 January 2018. Read more under Communication and Impact.

Links between biosphere dynamics and the financial system

Since its inception, this theme has undergone dramatic development. It started in 2014 with an intellectual exploration of how the interaction between financial systems and the biosphere could be manifested and possible implications of this for human and planetary health in the future. Since then, it has moved from conducting seminar series aimed at bridging the gap between finance and sustainability scholars to conducting transdisciplinary empirical research.

As such, this theme has gone from an idea and explicit strategies for cross-pollination between fields of research to the emergence of an entirely novel academic field and ways of conceptualising and empirically investigating links between the financial sector and the biosphere.

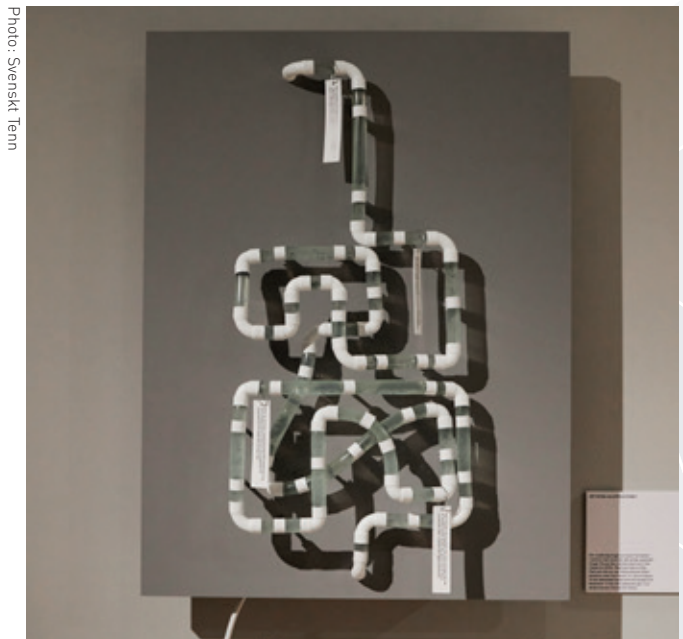


Photo: Svenskt Tenn
For the exhibition *Transformation*, student Jonathan Jervelind at Beckmans College of Design created this tube system, illustrating how ocean plastic pollution finds its way into human bodies. Read more under Communication and Impact.

Earth System Finance – how financial actors shape the Earth system

Under this topic, we explored and mapped the links between investors and key stabilising elements of the Earth climate system (such as the Amazon rain forest). As part of our science for change, we have also started to engage the financial sector in a constructive dialogue around our findings. The preliminary analysis of these efforts fed into a funding proposal “Earth System Finance – new approaches to finance and sustainability” for a 2-year project to Sweden’s innovation agency Vinnova, to complement the GEDB efforts so far. The application was successful and the three key partners are Stockholm Resilience Centre, Future Earth and UNEP Financial Initiative.

During the course of the year, we also initiated fruitful collaborations with Prof. Bert Scholtens (University of St Andrews and University of Groningen) and Jan Fichtner (University of Amsterdam). Both bring valuable perspectives from the banking and finance fields and broaden the interdisciplinarity of the team at GEDB.

During 2017, the research focus was expanded beyond the initial sectors considered in the pilot project (Amazon soya and beef, boreal forest in Russia and Canada). Additional areas now include timber exploitation in Brazil and Borneo; oil, gas and mineral extraction in boreal forests; and the global production of phosphorus- and nitrogen-based fertilisers.

To achieve this, the team was expanded in September by hiring Amar Causevic, who holds a Masters in International Economics and Energy, Resources & Environment from Paul H. Nitze School of Advanced International Studies (SAIS) at Johns Hopkins University.

Tax havens, international financial flows and global sustainability

Launched in spring 2016, this research effort was initiated to address the effect of tax havens on the biosphere. The study explores how offshore jurisdictions subsidise environmental degradation and reduce transparency at a scale that has implications for the resilience of the Earth system. This work has borne fruit and a paper has now been accepted and is due to be published in *Nature Ecology and Evolution* in 2018.

Human-biosphere interactions and financial crises

This project is examining general patterns in human-biosphere interactions in the period leading up to, during and immediately after financial crises, using a base of five financial crises; the 2008 great recession, the Euro crisis, the 2001 Dot-com bubble, the 1997 South-East Asia crisis and the 1991 real-estate bubble in Japan. PhD student Ami Golland will lead the work on linking a financial instability model with models central to the fields of sustainability and resilience.

Activities

- * A dialogue was held on 5–6 June for the project Earth System Finance: New perspectives on financial markets (described above). International financial experts were invited to offer insights from their industry, under Chatham House rules. Read more under Communication and Impact.
- * Within the Earth System Finance project, work on a report communicating academic findings to a non-academic audience has been initiated, as has work to produce a short animated film highlighting key messages for outreach to a wider public.
- * *The interaction between environmental and financial performance*, a seminar by Bert Scholtens (University of St Andrews), invited by GEDB, was held in Stockholm on 25 January.
- * *Finance and the Biosphere: Understanding the “Big Three”*, a seminar with Dr Jan Fichtner (CORPNET), organised by GEDB, was held in Stockholm on 14 February.



Photo: Fredrik Andersson/They Are Here

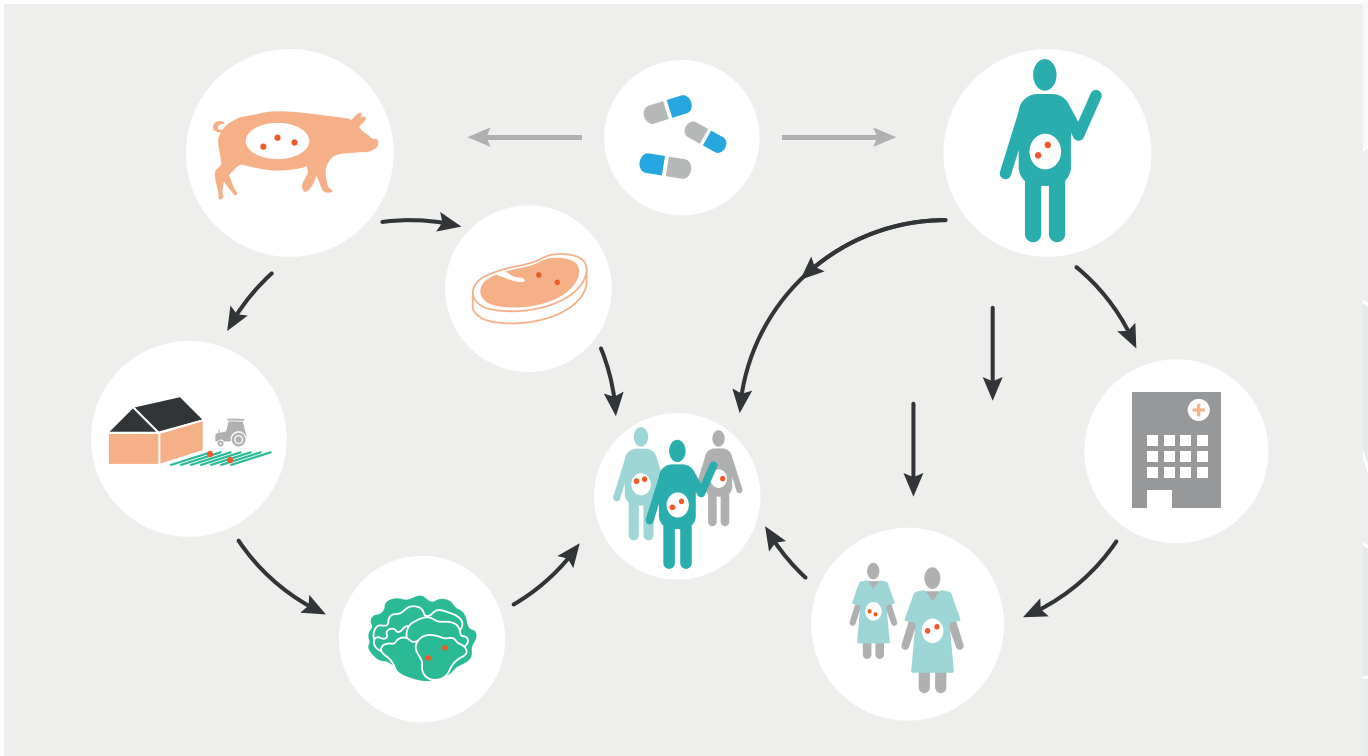
Discussions during the art event *The People Behind the Financial System*.

- * *The People Behind the Financial System*, an artwork which GEDB co-financed and in which GEDB researchers took part, took place in Stockholm 25 November. Read more under Communication and Impact.

Cross-cutting themes: Cross-scale dynamics and Systems transformation

During the course of the GEDB programme, two additional cross-cutting themes have emerged: Cross-scale dynamics and Systems transformation, initially highlighted in the Progress Report 2013–2015. The former can be seen as a red thread running through much of the ongoing work, both as an explicit research focus with targeted analysis such as in the Marine trade and Financial markets themes, and also more implicitly through the macroeconomic models employed in the (Macro)economy and the Biosphere theme.

The Systems transformation theme has developed through the recurring focus of several research efforts on factors that bolster or impede transformative change in a system, and the role of governance in microbial drug use in food production for halting antimicrobial resistance.



Resistant microbes spread through society from person to person, in communities or in hospital. They also develop and spread from antibiotic use in meat production and can be passed on in undercooked meat or poorly washed vegetables from farms where animal manure is used as fertiliser.

SOURCE: RETHINK

Cross-scale dynamics

Work on global seafood trade and its effects on local populations of resource users and ecosystems continues. In collaboration with behavioural economist Therese Lindahl of the Beijer Institute, we have developed economic field experiments to examine the behaviour of small-scale fishers in response to changing global market prices. The experiments are innovative in multiple ways. Participants receive actual monetary rewards based on the decisions they make connected to resource extraction. Multiple assessments are performed of fishers' individual risk taking, which has implications for their fishing behaviour. Both these methodological features are anchored in the fishers' everyday reality, which increases the reliability of results. The study aims to empirically test fishers' fishing responses to globally changing prices and how that may affect fish stocks. Thus, it provides a way of rigorously examining cross-scale dynamics, and acting upon the results.

Systems transformation

Fighting antimicrobial resistance

Antimicrobial resistance, enhanced by overuse of antibiotics and other microbial drugs, is a serious problem for global public health, as it threatens the effective prevention and treatment of a range of infections. The overuse stems from both the human health sector and agriculture, through the use of pesticides and antibiotics to promote growth and prevent disease in livestock.

The project Living with resistance (www.sesync.org/project/living-with-resistance), co-led by Peter Søgaaard Jørgensen, held its last workshop in 2017. This work establishes antibiotic and pesticide resistance as global challenges to environmental sustainability. It emphasises that resistance is a change in the composition of the living environment, which undermines the operating space afforded by these technologies. A series of five papers, each outlining different challenges, will comprise a focus section in *Nature Sustainability*, due for publication in 2018.

Collaborations emerging from this SESYNC-funded work have also resulted in multiple outputs. The first is a policy paper in the journal *PLoS Medicine* proposing a systemic indicator framework to measure progress in addressing antimicrobial resistance (AMR). This framework is being considered by the WHO in the process of developing new AMR indicators.

A second output provides an overview of the dominant policy frames in the AMR discourse showing that security, development and medicine are the main domains of discussion, and that biosphere-based policy frames are almost completely lacking.

A third study reviews existing evidence to show that, by making microorganisms that are susceptible to antibiotics thrive, humans are provided with a regulating ecosystem service that keeps resistant organisms at low numbers. Consequently,



Vegetable market in Rajasthan, India. GEDB contributed to the EAT Lancet Commission focusing on diets that support health and environmentally sustainable food production.

a change toward a pro-microbial approach that maximises the broad array of ecosystem services humans receive from microorganisms is urgently needed.

Transforming to healthy diets from sustainable food systems

Nearly one billion people in the world lack sufficient food, and most of the world consumes a poor-quality diet, contributing enormously to premature death and morbidity. Simultaneously, food systems are profoundly and non-sustainably stressing the ecosystems on which they depend. If diets and modes of food production are not transformed in the next few decades, humanity will face a planet where several of the planetary boundaries, such as greenhouse gas emissions, nitrogen and phosphorus flows, water and land use, are crossed. GEDB researchers Beatrice Crona and Max Troell were part of the scientific team behind the *EAT Lancet Commission on Healthy Diets from Sustainable Food Systems: Our Food in the Anthropocene*. The EAT Lancet Commission consists of 20 world-renowned scientists and it is co-chaired by Walter Willett, Harvard University, and Johan Rockström, Stockholm Resilience Centre. The report will be launched in 2018. Its aim is to advance the development of quantitative targets for two elements of food systems: diets that support health and environmentally sustainable food production. It will also provide a framework for a 'Great Food Transformation'.

Activities

- * *Living with Resistance: Social-ecological Governance of Resistance Evolution*. Two workshops organised by GEDB researcher Peter Søgaaard Jørgensen in cooperation with SESYNC at University of Maryland, USA, in April and September 2017.
- * *Cold turkey: Transformation to a less antimicrobial planet and Social-ecological transformations for sustainability*. Sessions organised by GEDB together with REACT at the Resilience 2017 conference in Stockholm on 20–23 August [see Appendix].
- * *REACT – antibiotic resistance*. Symposium organised by GEDB and Stockholm Resilience Centre in Stockholm on 13 January.

COMMUNICATION AND IMPACT



Sweden's deputy Prime Minister Isabella Lövin and Professor Jane Lubchenco, former US presidential advisor and part of the GEDB advisory committee, at the SeaBOS Stockholm Dialogue in May.

SeaBOS – Seafood Business for Ocean Stewardship

The second keystone dialogue, the Stockholm Dialogue *Advancing the Seafood Business for Ocean Stewardship Initiative*, was hosted at the Royal Swedish Academy of Sciences by GEDB, the Beijer Institute and Stockholm Resilience Centre in May 2017. The dialogue is part of the initiative *SeaBOS – Seafood Business for Ocean Stewardship*, a collaboration between researchers and ten of the world's largest seafood companies, formed with the ambition to lead a global transformation towards sustainable and healthy oceans.

Based on the statement from the first dialogue in 2016, action was agreed upon to improve transparency and traceability; to reduce illegal, unreported and unregulated fishing; to put an end to slavery in the supply chains; and to reduce antibiotic use in aquaculture, greenhouse gas emissions and plastic pollution. HRH Crown Princess Victoria of Sweden and Sweden's deputy Prime Minister Isabella Lövin participated in the meeting.

In addition, the SeaBOS initiative was presented at the UN Oceans conference in New York in June 2017. The initiative also received the Sweden Impact Award 2017 in the category Social Sciences and Humanities, citing the "synergy between world-class research and societal impact" as a key motivation.

The keystone actors' process is initiated and operated by researchers at Stockholm Resilience Centre, GEDB and the Beijer Institute, through the interim SeaBOS secretariat.

A scientific article, *Emergence of a global science-business initiative for ocean stewardship*, led by Henrik Österblom, Stockholm Resilience Centre and with Carl Folke and Jean-Baptiste Jouffray as co-authors, describing the initiative and the processes was published in August in *Proceedings of the National Academy of Sciences, USA (PNAS)*.

Read more about the SeaBOS initiative, the dialogues and statements at [www.http://keystonedialogues.earth/](http://keystonedialogues.earth/).

Art and science collaboration for the oceans

With the keystone dialogues as a starting point, an exhibition was created by students at Beckmans College of Design to raise awareness about the state of the oceans.

GEDB staff and colleagues from the Beijer Institute and SRC gave introductory lectures and provided background readings and tuition to the students throughout a five-week course, starting in early December, on different aspects of fishing and aquaculture production and its effects on the global oceans.

The project inspired 16 very diverse works providing visual, emotional and humoristic entry points to the subject. These included a kitchen aid that removes plastics from the food we eat, a futuristic news broadcast showing genetically modified fish used to fight eutrophication, carrier bags in a textile made from "ghost nets" (fishing nets left or lost at sea) and a cookery book with information and recipes for sustainable seafood.



Speakers at the seminar *The Global Ocean and the Future of Humanity* with HRH Crown Princess Victoria of Sweden (centre). From left: Carl Folke, Rashid Sumaila, Beatrice Crona and Maria van Berlekom (Sida).

The exhibition *Transformation* was created in collaboration with the design company Svenskt Tenn and shown in its store in central Stockholm on 16–29 January 2018. Participating from GEDB were Beatrice Crona, Jean-Baptiste Jouffray, Agneta Sundin and Max Troell.

Biosphere Finance – A sector dialogue on the links between financial markets and climate stability

A two-day dialogue was held on 5–6 June 2017 for the project “Earth System Finance: New perspectives on financial markets and sustainability” at the Royal Swedish Academy of Sciences. International financial experts from different industries, ranging from pension funds to investment banks and credit rating agencies, were invited to offer insights from their industry, under Chatham House rules.

Participants provided feedback on a pilot study, undertaken by GEDB researchers, about the potential role of the financial sector for avoiding reaching global tipping points, which may otherwise precipitate climate change in an abrupt and unpredictable manner. Ways to scale up and communicate this research were also discussed, in an effort to create a long-term impact on the practices of the financial sector. All participants showed tremendous interest in the issue of tipping elements in the Earth system, a complementary approach to the conventional approach of reducing greenhouse gas emissions. A second dialogue, with an expanded set of financial actors, will be organised in the City of London in March 2018.

This is a collaborative effort between the academic team at GEDB and our partners Future Earth and UN Environment Finance Initiative.

The Global Ocean and the Future of Humanity

The Volvo Environment Prize laureate 2017 was Professor Rashid Sumaila, who has dedicated his career to promoting sustainable use of fisheries and ocean resources. GEDB co-organised a half-day seminar at the Royal Swedish Academy of Sciences on 28 November in honour of Prof Sumaila, who was the main speaker. He and other speakers explored pathways to ensure that the ocean can continue to provide for humanity, while also protecting its intrinsic values and the structure and function of ecosystems. Furthermore, they discussed how improved use of the oceans can provide benefits from these global commons, in a fair way, to citizens of all nations. Executive director Beatrice Crona and Director Carl Folke gave presentations and took part in the subsequent panel discussion. The seminar was honoured by the presence of HRH Crown Princess Victoria of Sweden and it was well attended by representatives from government, political parties and NGOs, as well as scientists and students.

The People Behind the Financial System

GEDB contributed financial and research resources to the artwork and performance, *The People Behind the Financial System: Sweden*, by London-based artist duo They Are Here (www.theyarehere.net), which took place in Stockholm on 25 November. The work comprised informal encounters between 20 individuals working in the Swedish financial sector and attendees from the wider

public. These 20 representatives ranged from a former Member of the European Parliament and bank CEO to a venture capitalist, algorithm coder and banknote engraver. Over a two-hour period, attendees were invited to engage in ten conversations of their choice, each lasting 10 minutes. The People Behind The Financial System sought to instigate an open environment of idea exchange, democratising the specialist knowledge and hidden transactions that affect us all.

The event reached full capacity with the maximum of 50 attendees, including local residents, members of the arts community and others curious to learn more about the financial system.

Audio recordings were made with a selection of the finance workers and these will be edited and distributed in autumn 2018, extending the reach of the project. They Are Here will also give a talk about the project in autumn 2018 at the Stockholm School of Economics.

NETWORKS AND INTERNATIONAL COLLABORATIONS

Much of the work under GEDB is conducted in collaboration with researchers at various international universities and institutes, many of which are exemplified in the text. Below we highlight a few, focusing primarily on institutional collaborations.

Stockholm Resilience Centre (SRC) and the Beijer Institute of Ecological Economics. There are strong links between GEDB and both SRC and the Beijer Institute, exemplified through ongoing collaborations and co-publications throughout this report.

Future Earth. Future Earth is a key partner in the project to explore links between the financial systems and the biosphere.

Early Career Researchers Network of Networks. Peter Søggaard Jørgensen organised the Future Earth online conference *Early career perspectives on Future Earth* (14–18 August) in partnership with Future Earth, INTECOL, INNGE, Early Career Researchers Network of Networks, PECS and Stockholm Resilience Centre.

ReAct. A global network dedicated to the problem of antibiotic resistance. Members have backgrounds ranging from global



GEDB researcher Peter Søggaard Jørgensen presenting at the conference *Resilience 2017*.

health, microbiology and healthcare professionals to journalists and communication experts. Collaborations were initiated to introduce biosphere-literate approaches for dealing with the issue of antibiotic resistance.

Stockholm School of Economics. The GEDB project *Human-biosphere interactions and financial crises* is a part of Mistra Financial System Programme, hosted by the Mistra Center for Sustainable Markets (MISUM) at the Stockholm School of Economics.

Sustainable Fisheries Partnership. An ongoing collaboration to evaluate data on Fisheries Improvement Projects, to understand which supply chain strategies lead to more sustainable use of marine resources in specific cultural/political contexts.

UNEP Finance Initiative and Principles for Responsible Investment. UNEP FI is a member of the Vinnova-funded project to extend the Earth System Finance work stream during 2017, and PRI is a more recent collaborator in getting the science of Biosphere Finance communicated to the financial industry.

APPENDIX

STAFF:

Director	Carl Folke
Executive Director	Beatrice Crona
Senior Academy Researchers	Max Troell Tracy Van Holt
Early Career Academy Researchers	Gustav Engström Johan Gars Joshua Stoll Peter Søggaard Jørgensen James Watson
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Visiting Professor	James Wilen
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Communications Officer	Agneta Sundin
Finance and HR Administration	Sofia-Kristin Kokinelis

ADVISORY BOARD:

GEDB has an advisory board comprising a list of prominent academics. The role of the advisory board is to advise on strategically important research directions and decisions, and to provide guidance, suggestions, contacts and networks for collaboration. From time to time, members of the advisory board are also invited to participate in specific research endeavours in the form of working groups/workshops designed with a specific thematic focus.

Advisory board members:

Neil Adger	University of Exeter
Scott Barrett	Columbia University
Steve Carpenter	University of Wisconsin
Jane Lubchenco	Oregon State University
Bonnie McCay	Rutgers University
Stephen Polasky	University of Minnesota

FUNDING:

Core funding by the Erling-Persson Family Foundation. Additional funding was also received in 2017 from the Swedish research council Formas, the Swedish Foundation for Strategic Environmental Research Mistra, Sweden's innovation agency Vinnova and Anna-Greta and Holger Crafoord Foundation.

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BOOK CHAPTERS:

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- Folke, C. 2017. The biosphere foundation and sustainability: A reflection. In: Kessler, E. and A. Karlqvist (eds.) *Environmental Reality: Rethinking the Options, The 12th Royal Colloquium, Rosersberg's Palace, Sweden, May 23–25, 2016*.
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OTHER:

- Crona, B. and M. Troell (eds) with support from M. Jonell and J.-B. Jouffray. 2017. *Trade, People and Ecosystems*. Background Brief, the Stockholm Dialogue.
- Troell, M. and M. Jonell (eds) with support from P. Henriksson. 2017. *Seafood for Human and Planetary Health*. Background Brief, the Stockholm Dialogue.
- Crona, B. Background paper to round table discussion on transdisciplinary science. Arranged by Swedish Science Council Vetenskapsrådet and the Young Academy of Sweden, Stockholm, Sweden, 19 October.

JOURNAL ARTICLES IN PRESS:

- Gars, J. and D. Spiro. 2018. Trade and the risk of renewable resource collapse. *Journal of the Association of Environmental and Resource Economists*. In press.
- Tittensor, D.P., et al. (including J.R. Watson). A protocol for the intercomparison of marine fishery and ecosystem models: FishMIP v1.0. *Geoscientific Model Development*. In press.
- Van Holt, T., W. Weisman, S. Käll and B. Crona. Dominant narratives in seafood sustainability based on media reports. *Ecology and Conservation Biology*. In press.

Villarino, E., J-R. Watson et al. Large-scale ocean connectivity and planktonic body size. *Nature Communications*. In press.

Wedding, L.M., J. Lecky, J.M. Gove, H.R. Walecka, M.K. Donovan, G.J. Williams, J.-B. Jouffray et al. Advancing the integration of spatial data to map human and natural drivers on coral reefs. *PLOS ONE*. In press.

WORK IN PROGRESS:

Crona, B.I., S. Käll and T. Van Holt, A global systematic review of Fisheries Improvement Project development and working process. In preparation.

Galaz, V., B. Crona, A. Dauriach, J.-B. Jouffray and H. Österblom. Tax havens and global sustainability. *Nature Ecology and Evolution*. In review.

Galaz, V., B. Crona, A. Dauriach, B. Scholtens and W. Steffen. Sleeping financial giants: Financial actors and non-linear changes in the Earth's climate system. *Frontiers in Ecology and the Environment*. In review.

Kininmonth, S., T. Blenckner, S. Niiranen, J.R. Watson, A. Orio, M. Casini, S. Neuenfeldt, V. Bartolino and M. Hansson. Is biotope information the missing link in coastal fisheries management? *Fish and Fisheries*. In review.

McManus, L.C., J.R. Watson, V.V. Vasconcelos and S.A. Levin. Nonlinear dynamics of coral-algae systems and their recruitment dependent resilience. *Theoretical Ecology*. In review.

Siegel, D.A., J.R. Watson, R.D. Simons, S. Mitarai and J.C. McWilliams. Characterizing particle transit time metrics in a coastal ocean network. *Journal of Geophysical Research*. In review.

Spijkers, J., T. Morrison, R. Blasiak, G. Cumming, M. Osborne, J.R. Watson and H. Österblom. Marine fisheries and future ocean conflict. *Fish and Fisheries*. In review.

Søgaard Jørgensen, P. et al. Governing global dynamics of resistance evolution: Pathways for sustainable development. *Science* special issue on Resistance Evolution. In review.

Thompson, D., J. Kleypas, F. Castruccio, E. Curchitser, M.L. Pinsky, B. Jonsson and J.R. Watson. Variability in physical barriers to coral larval dispersal: do currents shape biodiversity? *Progress in Oceanography*. In review.

Tilman, A., S.A. Levin and J.R. Watson. Risk aversion and revenue sharing agreements can lead to cooperative self-regulation. *Proceedings of the Royal Society Interface*. In review.

Van Holt, T., B. Crona and S. Käll. Fishery Improvement Projects – a way to transform towards sustainable fisheries? In preparation.

Watson, J.R., E.F. Fuller, F. Castruccio and J. Samhuri. Fishermen follow fine-scale physical ocean features for finance. *Frontiers in Marine Science*. In review.

Living with resistance project (a group of authors including Søgaard Jørgensen, P.): Preservation of treatment opportunity as a core element of environmental sustainability in the Anthropocene. Invited Focus section for *Nature Sustainability* with several papers including the following suggested titles submitted for consideration in January 2018:

- i) Promoting antibiotic and pesticide susceptibility to preserve an Anthropocene operating space.
- ii) Global trends in the pressure, state and impacts of antibiotic and pesticide resistance.
- iii) De-escalating resistance evolution in pursuit of a safe and equitable operating space.
- iv) A global analysis of efforts to de-escalate long-term trends in antibiotic resistance.

SELECTED ACTIVITIES FEATURING GEDB RESEARCH:

REACT – antibiotic resistance. Symposium organised by Stockholm Resilience Centre in Stockholm on 13 January. Organiser (Søgaard Jørgensen), presenter: *AMRs in Aquaculture* (Troell).

The interaction between environmental and financial performance. Seminar by Bert Scholtens (University of St Andrews), invited by GEDB, in Stockholm on 25 January (Crona).

Symposium: Sustainable consumption – how do we do it? at Stockholm School of Economics in Stockholm on 25 January. Panel member and presentation: *New approaches to sustainable finance* (Galaz).

Green bonds. Meeting hosted by SEB Bank and Swedish International Development Cooperation Agency Sida in Stockholm on 9 February. Participant (Galaz).

Finance and the Biosphere: Understanding the "Big Three". Seminar with Dr Jan Fichtner (CORPNET) organised by GEDB in Stockholm on 14 February (Crona and Galaz).

Sustainable Finance. Panel discussion at screening of the documentary "The Borneo Case" at Stockholm School of Economics in Stockholm on 10 March. Panel member (Galaz).

AP-fondernas etikråd (AP Pensionfund's ethics council) celebrating 10 years 2007–2017. Seminar with Al Gore, hosted by Mistra in Stockholm on 20 March. Participant (Galaz).

Workshops: Living with Resistance: Social-ecological Governance of Resistance Evolution. Two workshops organised by GEDB in cooperation with SESYNC at University of Maryland, USA, in April and September 2017 (Søgaard Jørgensen).

High-level workshop on EU High Level Group Innovation Policy Management at the Nordic Embassies in Berlin, Germany, on 4–5 May. Participant and presentation: *Challenges and opportunities in the biosphere economy: Innovation as pathway to resilience* (Galaz).

THE STOCKHOLM DIALOGUE: ADVANCING THE SEAFOOD BUSINESS FOR OCEAN STEWARDSHIP (SEABOS) INITIATIVE, Keystone Dialogues. Organised by Stockholm Resilience Centre in collaboration with the Beijer Institute and GEDB at the Royal Swedish Academy of Sciences in Stockholm on 15–16 May.

GEDB co-organisers: (Crona, Folke, Jouffray, Troell)

Presentations:

Trade, people and ecosystems (Crona).

Ocean stewardship – the grand challenge (Folke, with Johan Rockström, Stockholm Resilience Centre)

Summary of the "keystone actors" process (Jouffray, with Henrik Österblom, Stockholm Resilience Centre).

Seafood for Human and Planetary Health (Troell).

Swedish Institute for Global Health Transformation (SIGHT) Inception Workshop in Stockholm on 1–2 June. Presentations (Crona and Folke).

Earth system finance – First engagement meeting. Workshop organised by GEDB and Future Earth in Stockholm on 5–6 June (Crona and Galaz).

Stockholm Seminar, Economics, complexity, and nonequilibrium with Prof Brian Arthur at Royal Swedish Academy of Sciences in Stockholm on 8 June. Co-organiser (Galaz and Sundin).

EAT Competence Forum: Fish Futures – sustainable seafood to support the SDGs, in Stockholm on 12–13 June, Organiser/presenter: *The role of seafood for improving human and planetary health* (Troell).

Workshop: Features of a resilient global food system in Stockholm. Arranged by Stockholm Resilience Centre and Stanford University in Saltsjöbaden, Sweden on 14–16 June. Presenter: *Resilient systems* (Troell).

EAERE 23d Annual Conference in Athens, Greece, on 1 July. Presentation: *Measuring the impact of agricultural production shocks on international trade flows* (Gars).

Early career perspectives on Future Earth: Ecology and civilization. Global online conference organised by GEDB in collaboration with Future Earth, INTECOL and INNGE on 14–18 August. Head organiser (Søgaard Jørgensen).

RESILIENCE 2017 – RESILIENCE FRONTIERS FOR GLOBAL SUSTAINABILITY. Conference hosted by Stockholm Resilience Centre, Resilience Alliance and the Beijer Institute in Stockholm on 20–23 August.

Plenary speaker (Folke).

Theme key note presentation: *Connectivity and cross-scale dynamics in the Anthropocene* (Crona).

Presentations:

Social-ecological analysis for critical sustainability challenges: Some examples and reflections (Crona).

Big Money, Big Change – exploring the links between big finance and large-scale environmental change (Galaz).

Earth system finance (Galaz).

Innovations within the financial sector to support and finance biodiversity conservation and ecosystem services (Golland).

Ecosystem services in the Anthropocene: Policy integration and insurance value (Hahn).

Disentangling the role of human and natural drivers of multiple reef regimes (Jouffray).

The blue acceleration: Racing for the ocean to secure global human support (Jouffray).

Trade and narratives of social-ecological change in the Anthropocene (Søgaard Jørgensen).

Session organisers:

Cold turkey: Transformation to a less antimicrobial planet. Contributed to session Social-ecological transformations for sustainability (Søgaard Jørgensen).

One tightly knit global family – Teleconnected social-ecological dynamics of the Anthropocene (Crona and Søgaard Jørgensen).

The Stockholm Act, sustainability week at the House of Culture (Kulturhuset) in Stockholm on 21–27 August. Panellist in session: *The overview effect – how does the perspective from space affect our relationship to planet Earth?* (Folke).

25th anniversary celebrations of H.M. the King's Royal Colloquium's in Stockholm on 6 September. Participant (Folke).

Connecting and protecting out seas, symposium organised by Prince Albert II of Monaco Foundation and the Swedish Embassy, Paris, in Monaco on 12–14 October. Co-organiser and panel discussant, *Future of seafood* (Folke and Troell).

NTNU Sustainability Science Conference in Trondheim on 18–20 October. Plenary lecture: *Transitions to biosphere resilience* (Folke).

Livsmedelsforum 2017. Conference organised by Aktuell Hållbarhet Konferens in Malmö, Sweden, on 19 October. Keynote speaker (Crona).

Sustainable investments and Swedish pension funds. Workshop hosted by all Swedish AP Pension funds in Stockholm on 19 October. Participant (Galaz).

Workshop: *Scenario analysis for nutrition-sensitive aquaculture*, at SESYNC (National Center for Socio-Ecological Synthesis), Annapolis, USA, on 24–26 October, Participant (Troell).

10th WIOMSA Scientific Symposium in Dar el Salaam, Tanzania, on 30 October–4 November. Panel Chair: *Mariculture development: Types, systems and lesson learnt* (Troell).

PECS Conference – Place-based transdisciplinary research for global sustainability, in Oaxaca, Mexico, on 7–10 November.

Keynote lecture: *Tax Havens and Global Sustainability* (Galaz).

Chair of speed talk session: *Governance and community-level natural resource management*.

Presentation: *Emergence of a global science-business initiative for ocean stewardship* (Jouffray).

Hållbarhet och socialt ansvar, historiskt och i framtiden. (Sustainability and social responsibility, now and in the future). Seminar to celebrate the 100th Anniversary of food retail corporation ICA, organised by Centre for Business History in Stockholm on 14 November. Presentation: *Runda midjor och sprängda planetgränser – hur kom vi hit och vad gör vi nu? [Bulging waistlines and fractured boundaries– how did we get here and what do we do now?]* (Crona).

Joint staff day for Bolin Centre and Stockholm Resilience Centre in Stockholm on 15 November. Presentation: *Links between finance and climate dynamics* (Galaz).

The Global Ocean and the Future of Humanity. Half-day seminar organised by GEDB in collaboration with the Beijer Institute and Volvo Environment Prize, Royal Swedish Academy of Sciences, in Stockholm on 28 November. Presentation: *GLOCAL – cross-scale understanding as a prerequisite for seafood sustainability* (Crona). Organisers (Folke and Sundin).

Conference: Politics of the Earth: Renewing research, renewing action. Sciences Po Paris, Paris, France, on 4–5 December. Keynote speech: *A panorama of research on politics of the Earth* (Galaz).

China's role in the global seafood future. Workshop arranged by GEDB at the Royal Swedish Academy of Sciences in Stockholm on 7–9 December (Crona, Troell, Wassénus).

Rachel Carson Distinguished Lecture, at Michigan State University, East Lansing, USA, on 13 December. Invited lecturer: *Social-ecological systems, resilience thinking, and sustainability: Reconnecting development to the biosphere* (Folke).

RIHN 12th International Symposium Trans-scale Solutions for Sustainability in Kyoto, Japan, on 19–21 December. Presentation: *Taking Social Responses to "Tipping" Points Seriously – Challenges and Opportunities* (Galaz).

AWARDS AND RECOGNITIONS:

Elected member of AcademiaNet, nominated by the Swedish Research Council Vetenskapsrådet (Crona).

Elected SIGHT fellow, 2017, by Swedish Institute for Global Health Transformation (SIGHT) (Crona).


Elected member of the U.S. National Academy of Sciences (Folke).

The 2017 Gunnerus Award in Sustainability Science, Trondheim (Folke).

Honorary Doctor of Science, Michigan State University, East Lansing, USA (Folke).

NEW FUNDING:

Resilience: Comparative assessment of social-ecological resilience and transformability to limit AMR in one health systems. From JPIAMR through Swedish Research Council Vetenskapsrådet. Grant SEK 9 million (of which SEK 3 million to GEDB) for 2018–2022 (Søgaard Jørgensen, coordinator, and Troell).



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