Imagine living on sunshine...
Symbiosis key to reef productivity

Most reef-building corals contain photosynthetic micro-algae (dinoflagellates)

These algae are called zooxanthellae, or "zoox", and live inside the corals’ transparent tissues.
Coral Reefs

Benefitting and learning from one of the planet’s most important and complex ecosystems

Fredrik Moberg
fredrik@albaeco.com
Twitter: FredrikMoberg

albaeco

Stockholm Resilience Centre
Sustainability Science for Biosphere Stewardship

Stockholm University
Coral Reefs

Benefitting and learning from one of the planet’s most important and complex ecosystems

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Gulf of Thailand 1995
Greetings from the tropics
Greetings from the tropics
Inspiration...
Inspiration...
Inspiration...
Inspiration...
Growing cement like a coral

6 % of all CO₂ emissions from cement

Innovation inspired by corals creates a cement substitute that binds CO₂
45 minutes. Three things.
Three things…

1. Coral reefs are important: ecological wonders and provide livelihoods for hundreds of millions

2. Unfortunately they are also vulnerable and threatened

3. But we can save them and learn a lot from them as systems
I. Coral reefs are important
Rest Coral reefs

Marine species
A food web of a coral reef
Amazing diversity of form and colour
Reef growth

Sediment
Coral rubble
Algae
Three main types of reefs

- *Fringing reef*
- *Barrier reef*
- *Atoll*

Oceanic Reefs and Darwin's Theory of Atoll Formation
655 million people live within 100 km of coral reefs

75% of these (424 million) live in "developing countries"
What's in it for us?

<table>
<thead>
<tr>
<th>Goods</th>
<th>Ecological services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewable resources</td>
<td></td>
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<tr>
<td>Sea food products</td>
<td>Shoreline protection</td>
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<tr>
<td>Raw materials and medicines</td>
<td>Build up of land</td>
</tr>
<tr>
<td>Other raw materials (e.g. seaweed)</td>
<td>Promoting growth of mangroves and seagrass beds</td>
</tr>
<tr>
<td>Curio and jewellery</td>
<td></td>
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<tr>
<td>Live fish and coral collected for aquarium trade</td>
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**Table 2. Goods and ecological services of coral reef ecosystems**

*This article identifies ecological goods and services of coral reef ecosystems, with a special emphasis on how they are generated. Goods are divided into renewable resources and non-renewable. Ecological services are classified into physical structure services, biotic services, and socio-economic services. A review of economic valuation studies reveals that only a few of the goods and services of reefs have been captured. We synthesize current understanding of the relationships between ecological services and human groups of species and ecologically communities of coral reefs in different regions of the world. The consequences of human impacts on coral reefs are also discussed, including loss of resilience, or buffer capacity. Such loss may impair the capacity for recovery of coral reefs, and as a consequence the quality and quantity of their delivery of ecological goods and services. Conserving the capacity of reefs to generate essential services requires that they are managed as components of a larger landscape of which human activities are seen as integrated parts.*

**Analysis**

**Ecological goods and services of coral reef ecosystems**

Fredrik Moberg ***, Carl Folke **

**Abstract**

This article identifies ecological goods and services of coral reef ecosystems, with a special emphasis on how they are generated. Goods are divided into renewable resources and non-renewable. Ecological services are classified into physical structure services, biotic services, and socio-economic services. A review of economic valuation studies reveals that only a few of the goods and services of reefs have been captured. We synthesize current understanding of the relationships between ecological services and human groups of species and ecologically communities of coral reefs in different regions of the world. The consequences of human impacts on coral reefs are also discussed, including loss of resilience, or buffer capacity. Such loss may impair the capacity for recovery of coral reefs, and as a consequence the quality and quantity of their delivery of ecological goods and services. Conserving the capacity of reefs to generate essential services requires that they are managed as components of a larger landscape of which human activities are seen as integrated parts.
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<td>Information services</td>
</tr>
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<td>Social and cultural services</td>
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Source: adapted from Moborg and Folke (1999)
172 billion dollar per year...

Value per hectare and year:

- Food, commodities, ornaments: $1100
- Climate control, storm protection, waste and water treatment: $26,000
- Cultural services (recreation/tourism): $88,700
- Conservation of genetic diversity: $13,500

Total: ecosystem services of coral reefs have an average annual value of $172,000,000,000
2. There are threats and reefs are sensitive...
“Our environmental crisis is multi-faceted, pervasive and very serious. Coral reefs are particularly hard hit, and stand a real chance of being the first ecosystem ever eliminated by humanity”

Peter F. Sale, 2011
Planetary Boundaries
A safe operating space for humanity

What makes a coral reef thrive?

- Clear and clean water
- Temperature: about 25 degrees
- Currents that benefit them
- A solid foundation
- Not too much nutrients
- Salinity: 23 - 42 permille
- Sustainable fishing
Yes, people can be good for reefs!

- Survey found 15 "bright spots", reefs with a lot more fish than expected based on human and natural pressures
- These "surprisingly resilient" reefs had strong local involvement and ownership rights that allow people to develop creative solutions to manage reef fisheries beyond expectations

Cinner and others, 2016, Nature
7 key insights from resilience science

1. Maintain diversity
2. Manage connectivity
3. Work with nature - not against it
4. Tighten feedback loops
5. Build social capital (trust)
6. Encourage innovation
7. Make nature’s services visible
Connectivity is key to reef resilience

Tay and others, 2012. *Aquatic Biology*
A whiter shade of pale...
Threats to reef health

- Climate change
- Ocean acidification
- Destructive fishing methods
- Overfishing
- Tourism
- Nutrient pollution
- Coral mining
- Sedimentation
Symbiotic relationship
sugars, lipids and oxygen

Protection, nutrients and carbon dioxide

zooxanthellae (microalgae)
coral polyps

Stressed by unusually high water temperatures

GLOBAL
Climate change
Trade
Pollution from land
Nutrient and sediment run-off from land

LOCAL
Ocean acidification
Fishing pressure
Coral reef tipping points due to loss of resilience

Coral reef tipping points due to loss of resilience
Coral reef tipping points due to loss of resilience
3. We can save them - and learn a lot from them
"I have a dream"!

"I have a nightmare"
The great barrier reef
The not-so-great barrier reef?
I showed the results of aerial surveys of bleaching on the Great Barrier Reef to my students, and then we wept.

NORTHERN SECTOR
522 reefs surveyed
81% severely bleached
<1% not bleached

CENTRAL SECTOR
226 reefs surveyed
33% severely bleached
10% not bleached

SOUTHERN SECTOR
163 reefs surveyed
1% severely bleached
25% not bleached
NOOOO! This is SO WRONG to write off the #GreatBarrierReef - We can & must save it, and reef tourism jobs - Article is full of misinformation

Outside Magazine @outsidemagazine
The Great Barrier Reef of Australia passed away in 2016 after a long illness. It was 25 million years old: bit.ly/2dOl1um #RIP
Five positive trends!
New research shows reefs more resilient than previously thought

Obituaries for coral reefs may be premature, study finds

Author
John Pandolfi
Professor, School of Biological Sciences at The University of Queensland

Disclosure statement
John Pandolfi receives funding from the Australian Research Council, including the ARC Centre of Excellence for Coral Reef Studies.

Coral reefs are the poster child for the damage people are doing to the world’s oceans. Overfishing, pollution and declining water quality have all taken their toll on reefs around the world. Perhaps the most famous example is Australia’s Great Barrier Reef, where half of the coral cover has disappeared over the past three decades.
Guiding coral reef futures in the Anthropocene

In the Anthropocene, changes in the Earth have led to the decline of many marine species and ecosystems due to human activities, including climate change, overfishing, pollution, and widespread coral reef bleaching. Over the past few decades, our understanding of the scale and speed of change has grown. It is clear that human activities are impacting the health of the ocean, and that these impacts are likely to continue and even increase in the coming decades.

Figure 3. The safe operating spaces, zones of uncertainty, and zones of high risk of the key drivers of change on coral reefs: (1) fishing, (2) water quality, and (3) anthropogenic climate change (i.e., mass bleaching and ocean acidification).
Better systems understanding
#3 Public awareness and action
CORAL GUARDIANS is an initiative highlighting successful Coral Reef stewardship around the world.

We do this through integrated science and music events where individuals from all walks of life can meet and discuss constructive solutions for coral reefs and the people who depend on them.

Our goal is to let successful initiatives have an impact beyond the local scale and contribute to mutual learning globally.

EVENTS

Stockholm 2011
The first CORAL GUARDIANS activity was a benefit concert on October 14,

Philippines 2012
“Saving Our Seas” was a combined concert and seminar continuation of

Zanzibar 2013
Good energy at the first meeting for CORAL GUARDIANS ZANZIBAR at

Hawaii 2014
In November, Coral Guardians visited Hawaii and met with scientists,
#4 Increased political will
Paris, December 2015

Nations Unies
Conférence sur les Changements Climatiques 2015

COP21/CMP11

Paris, France
#5 Innovations and tech
Biomimicry: learn from nature and minimize use of resources and energy

- Create robots and drones by mimicking insects, birds etc
- Paint boats with colour that mimics skin of sharks and reduce friction and save energy
- Construct solar cells by mimicking plant photosynthesis
- Farm like a prairie without pesticides and artificial fertilizers
What can we learn from this?
A coral reef runs on solar energy and all "wastes" are recycled
Industrial ecology in Kalundborg
From linear flows to circular economy

Source: W. McDonough and M. Braungart
Principles of Nature vs principles of industrial manufacturing

Natural processes:
• Use as little energy as possible
• No waste
• Conduct chemistry in water
• Use small subset of elements obtained nearby

Industrial manufacturing processes:
• Use “heat, beat, and treat” methods and cocktail of chemicals
• Extracted from all corners of the Earth
7 ways to contribute to coral reef conservation and sustainable use

1. Think about what you eat; avoid shark fin soup and scampi
2. Be a responsible tourist (hotel, transport, diving)
3. Support an organisation that works with coral reef conservation
4. Save energy and promote renewable energy production
5. Engage politically / influence your politicians
6. Educate others, spread the message
7. Use your entrepreneurial skills!
Twitter summary

#CoralReefs are increasingly threatened by climate change etc. But not too late to save and learn from them, says @FredrikMoberg #LEAP2017
Thanx!