Reaching reference conditions in the WFD: Is the concept still valid under climate change?

Lessons from coastal systems

Daniel J. Conley[1], Carlos M. Duarte[2],
Jacob Carstensen[3], and María Sánchez-Camacho[1]

1. Marie Curie Chair, GeoBiosphere Centre, Lund University, Sweden
2. IMEDEA, CSIC, University of Illes Balears, Spain
3. National Environmental Research Institute, Aarhus University, Denmark

Introduction

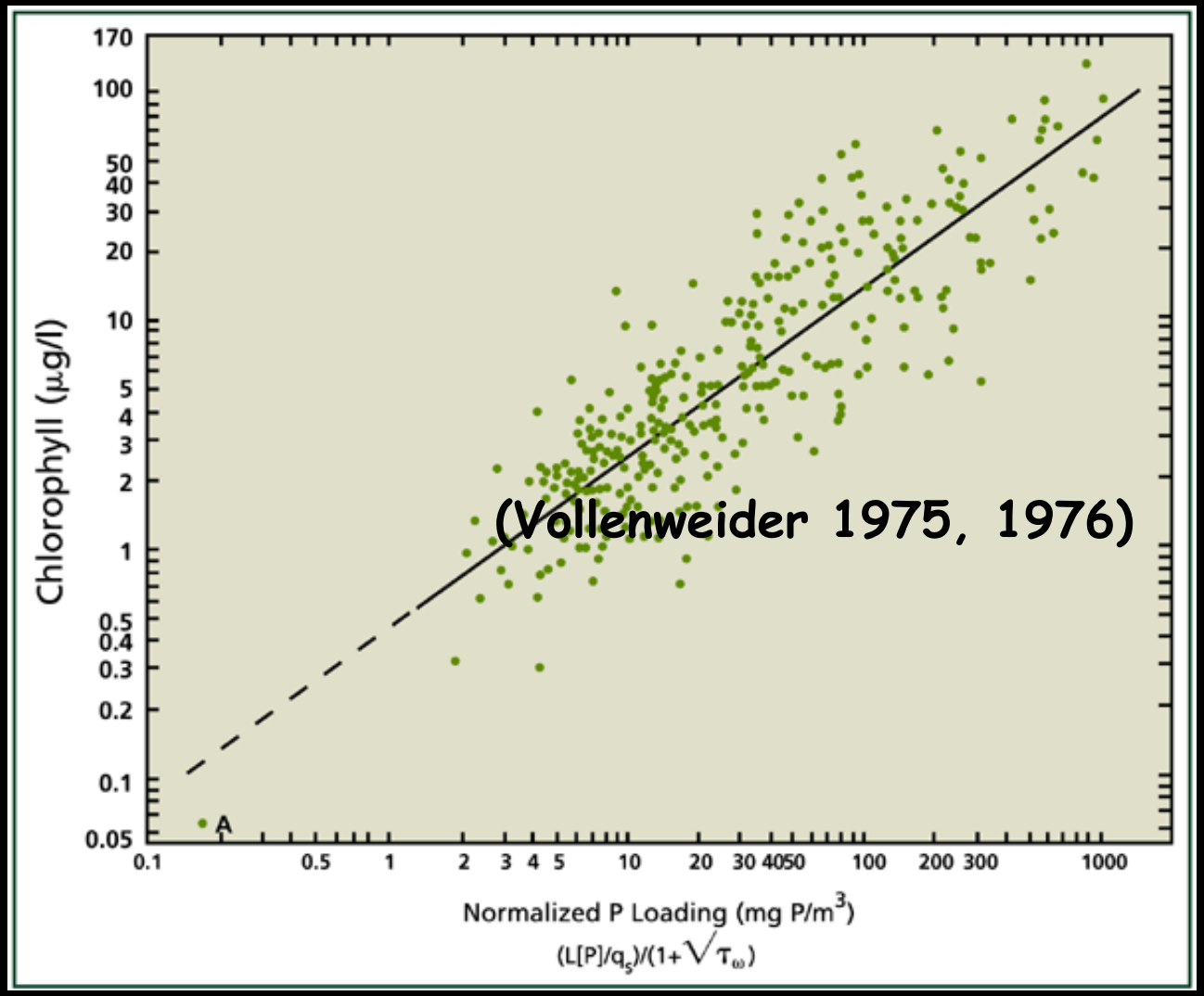
Control of nutrient inputs to coastal marine ecosystems
- fewer examples of “oligotrophication”

Evaluate nutrient reductions in coastal marine ecosystems using trajectories (nutrients vs response over time)

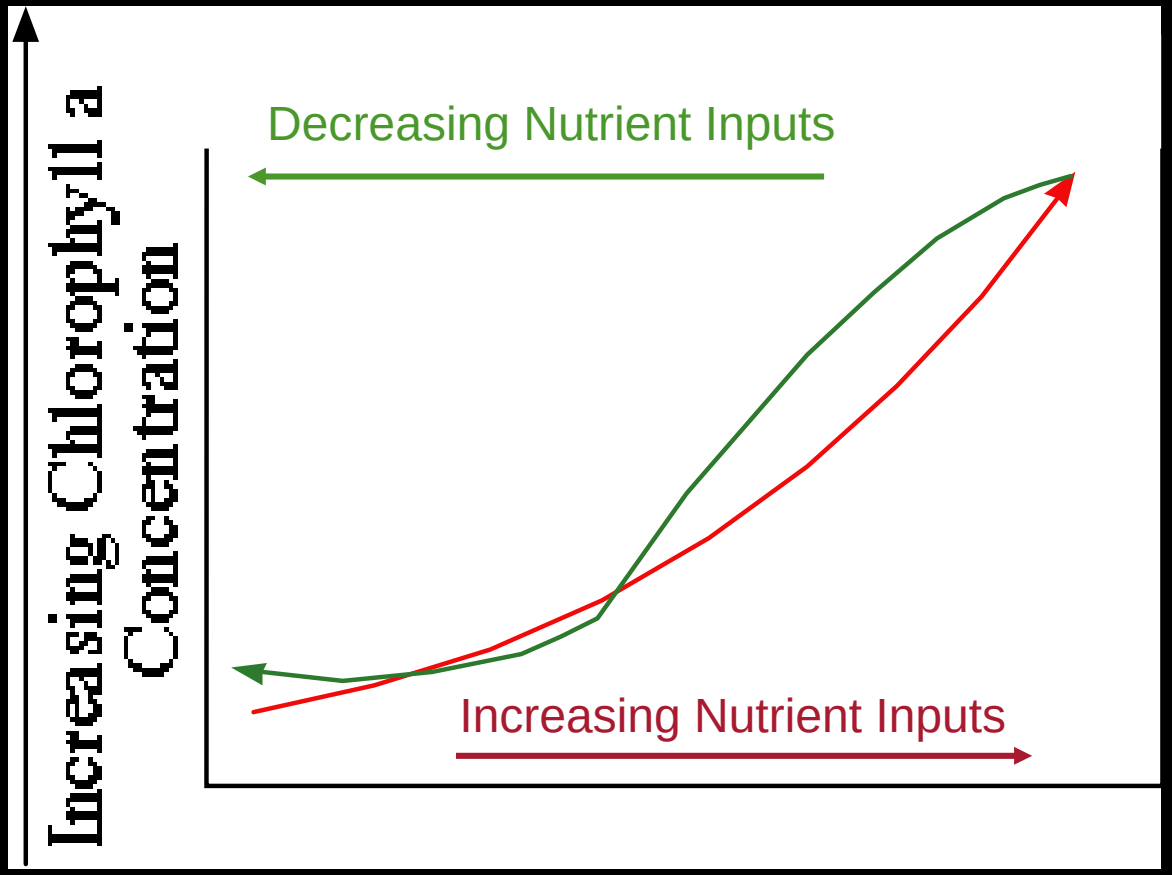
Influence of climate and human activities in the anthropocene

Inclusion of shifting baselines into meeting reference values

The evidence for the role of nutrients: A general relationship between chlorophyll a and nutrient inputs



The expectation:



Nutrient reductions can lead to

Coastal Oligotrophication

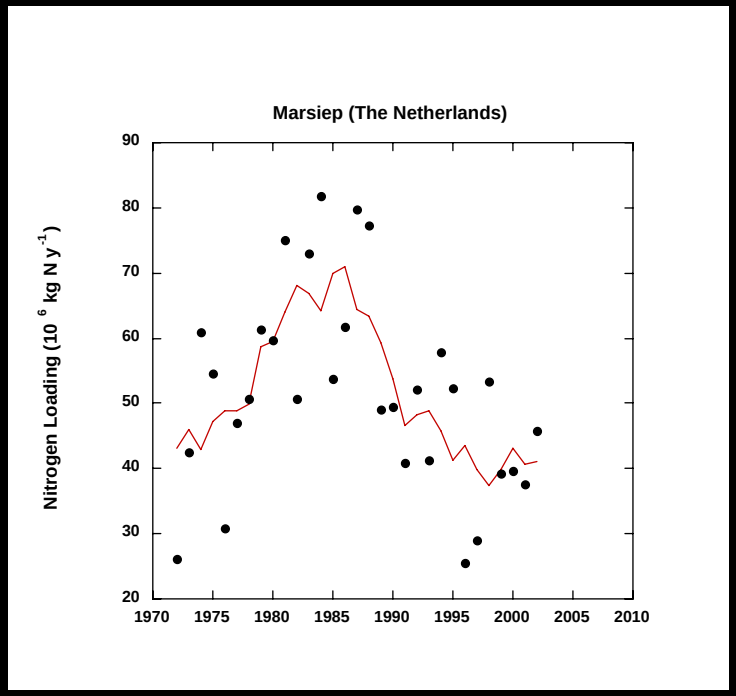
Where does oligotrophication stop?

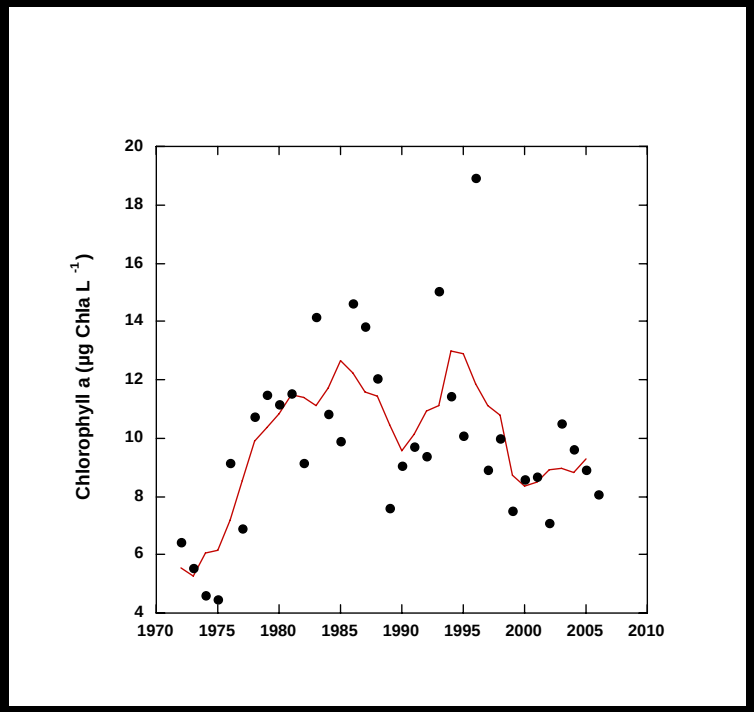
(nutrients are required to maintain system productivity)

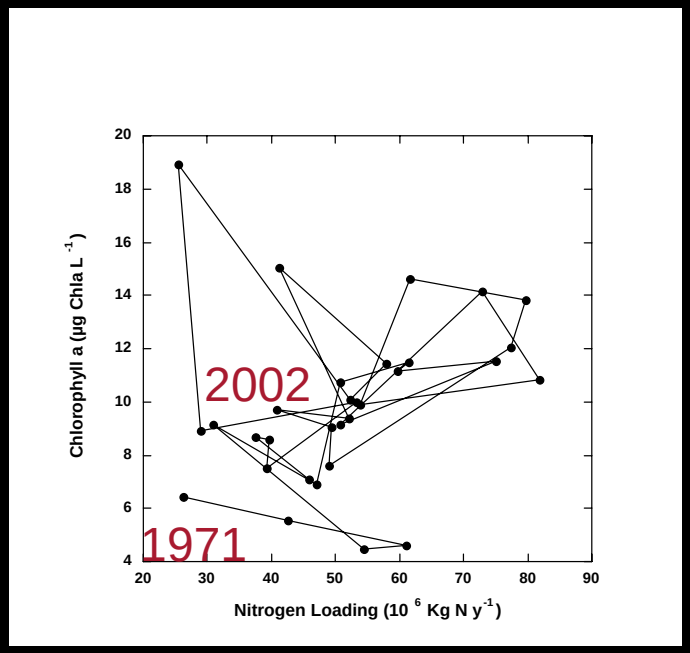
Water Framework Directive (EU): "*reference values*"

The reference condition is a description of the biological quality elements that exist, or would exist, at high status, that is, with no, or very minor disturbance from human activities

Can we reach reference conditions?



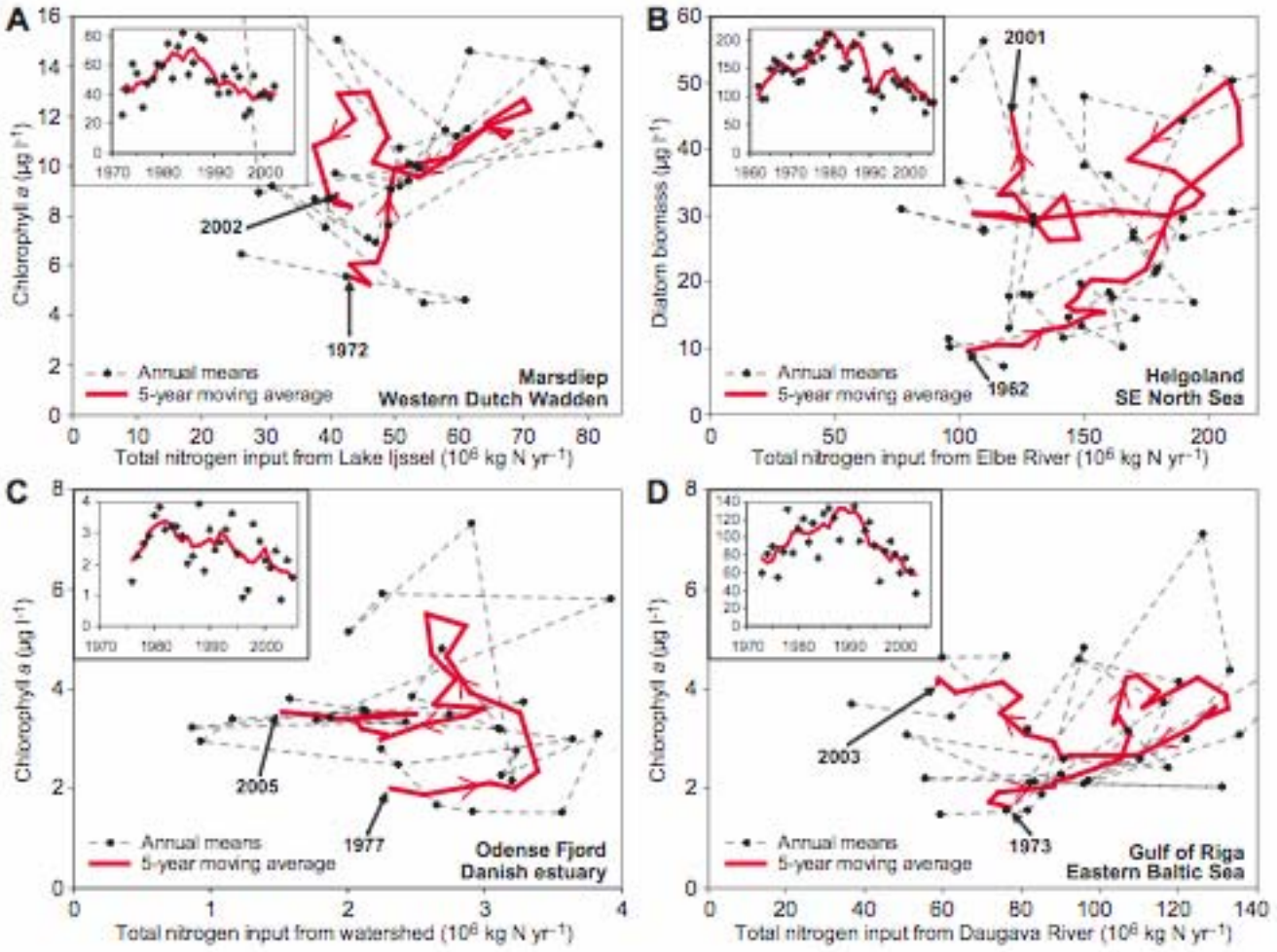




Data from de Jonge (1997), Pätsch and Lenhart (2004), and www.waterbase.nl

Complex trajectories, No return to the expected, lower Chl a, values following nutrient reductions

Trajectories for 4 coastal marine ecosytems (Marsdiep, Helgoland, Odense Fjord, Gulf of Riga)



GAM Models to smooth trajectories

Convoluted trajectories do not return to starting point

Ad hoc explanations

- Switch from N to P limitation
- Switch to light limitation
- Internal loading
- etc

The perils of reference values

- With thousands of years of landscape use in Europe it is far from trivial to assess in the 1990's what was the "undisturbed" status of coastal ecosystems
- Even if we could establish those, all other conditions (e.g. climate, land use, pCO_2, water quality, species assemblages, etc.) were not the same as they are today. Can we expect coastal ecosystems to revert to those "*reference*" status of the past under the different conditions of today's biosphere?
- Failure to reach "reference" conditions may lead to frustration

A DIFFERENT WORLD FROM THAT IN 1990's:

No Powerpoint, No Mobile phones, No www, No Starbucks, No Play Station, No iPOD's, No Cowboy Presidents

No Kyoto(1997) , Brand New CBD (1992), No US Harmful Algal Bloom and Hypoxia Research and Control Act (1998), No €'s, Globalization was not such a key issue.

We were 500 million fewer people; 1,300 Tg N have been released in Fertilizer, and 65,000 km^3 of freshwater have been used, Aquaculture production was 20 million Ton lower.

Atmospheric pCO_2 was about 20 ppm lower than present, global T about 0.2 ºC lower, record global T broken in 2006, record hurricane season broken in 2005, nearly 2,000 species have disappeared, sea level is 25 mm higher, and about 15 % of global seagrass cover, coral reefs, salt-marshes and mangrove forest cover has been lost.

And nearly 4,000 papers on coastal eutrophication have been published (Nixon, in press).

A different world…

What else continues to change?

- CO_2 is increasing globally: increased CO_2 will lead to increased photosynthetic rates by, often, CO_2 limited marine vegetation (enhanced eutrophication effects?).

- The oceans will acidify further, impacting on calcifying organisms

- T is rising: increased respiration rate, increased hypoxia, increased species shift and opportunities for invasives.

- The water cycle will continue to change.

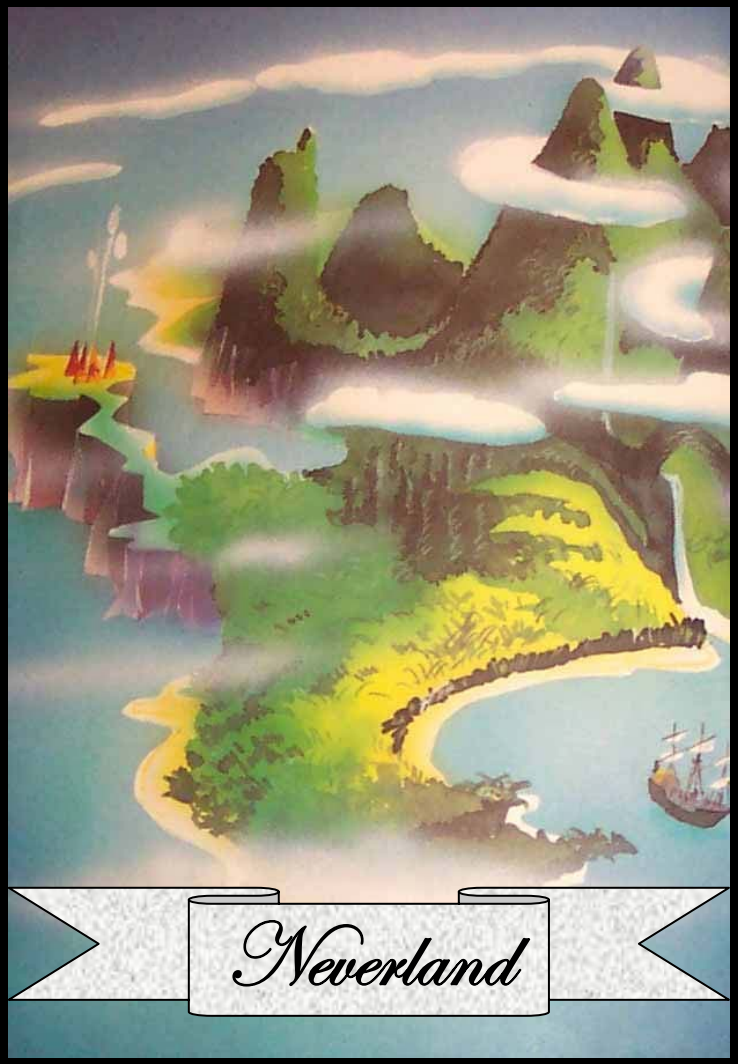
- More species will be driven extinct or decimated (biodiversity).

- Desertification is expanding.

- Society, demography, technology and consumption patterns are changing (including Presidents).

Jeppesen et al. 2005. Lake responses to reduced nutrient loading - an analysis of contemporary long-term data from 35 case studies. *Freshwater Biology* **50:** 1747-1771.

“Recovery of lakes after nutrient loading reduction may be confounded by concomitant environmental changes such as global warming.”



J.M. Barrie, author of the celebrated children novel and play Peter Pan and Wendy conceived an island, **Neverland**, where everything remained perpetually unchanged.

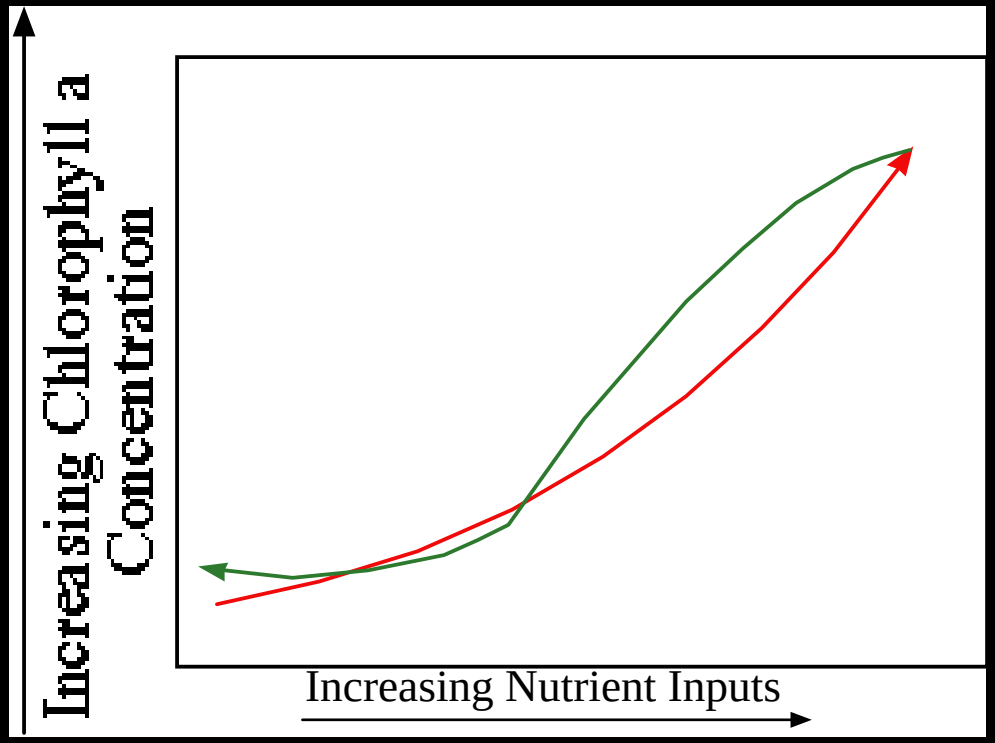
The expectation that coastal (any?) ecosystems can be returned to an idealized pristine or past reference status by virtue of reducing direct human pressures is as likely as the existence of Neverland

Eutrophication is part of Global Change

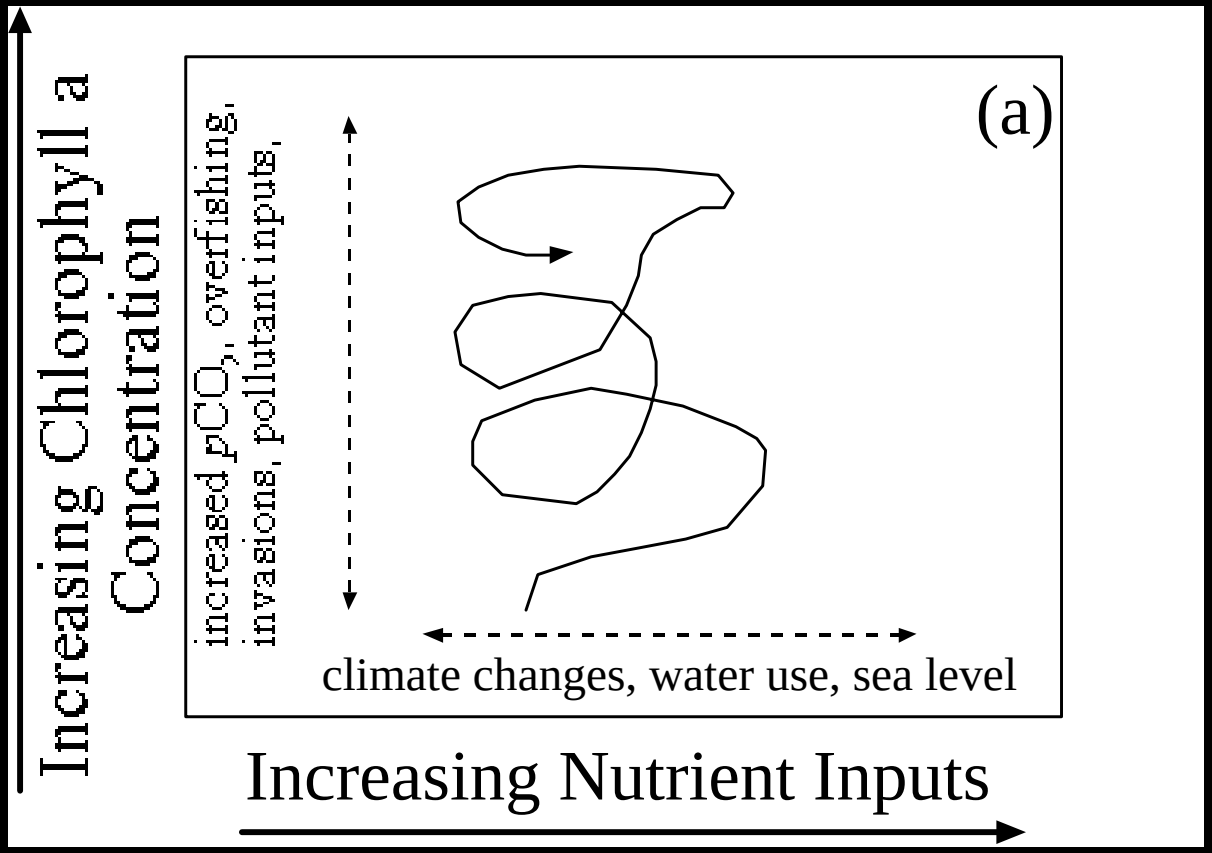
Eutrophication is a phenomenon of the Anthropocene, and eutrophication research, which addresses major alterations of elemental cycles by humans, should be brought up to the Earth System Science perspective, where its interactions with climate change, biodiversity changes, etc. can be best addressed.

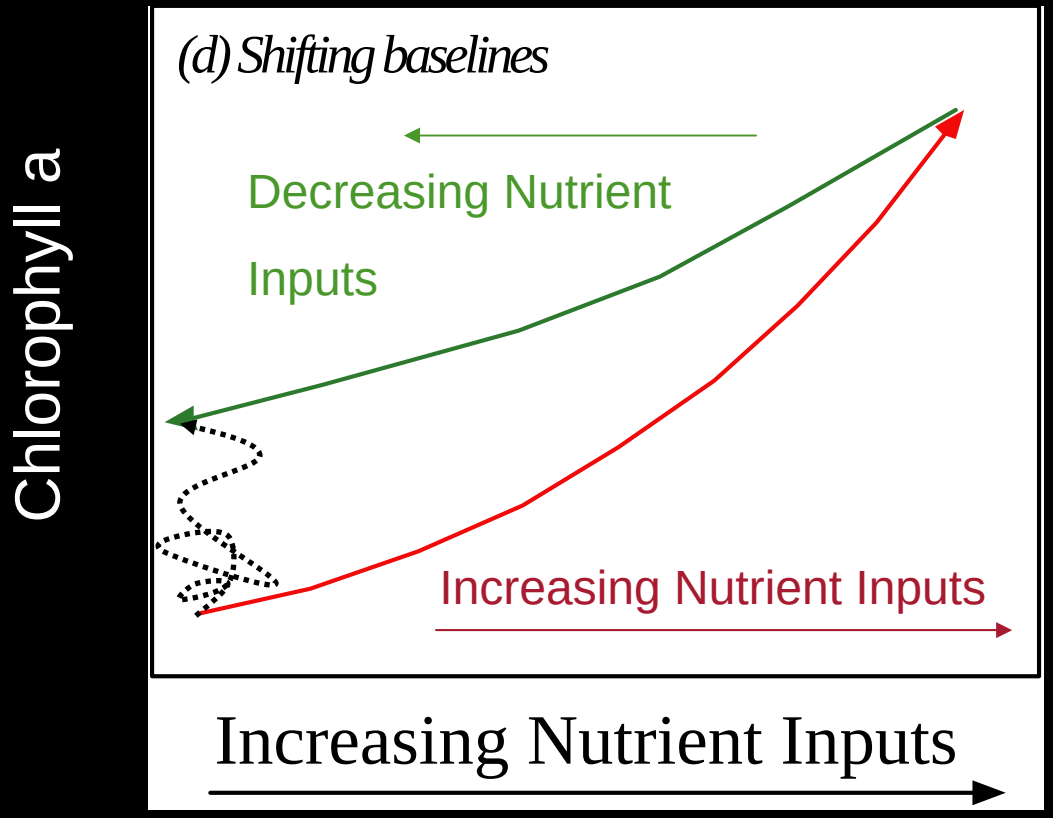
The Anthropocene

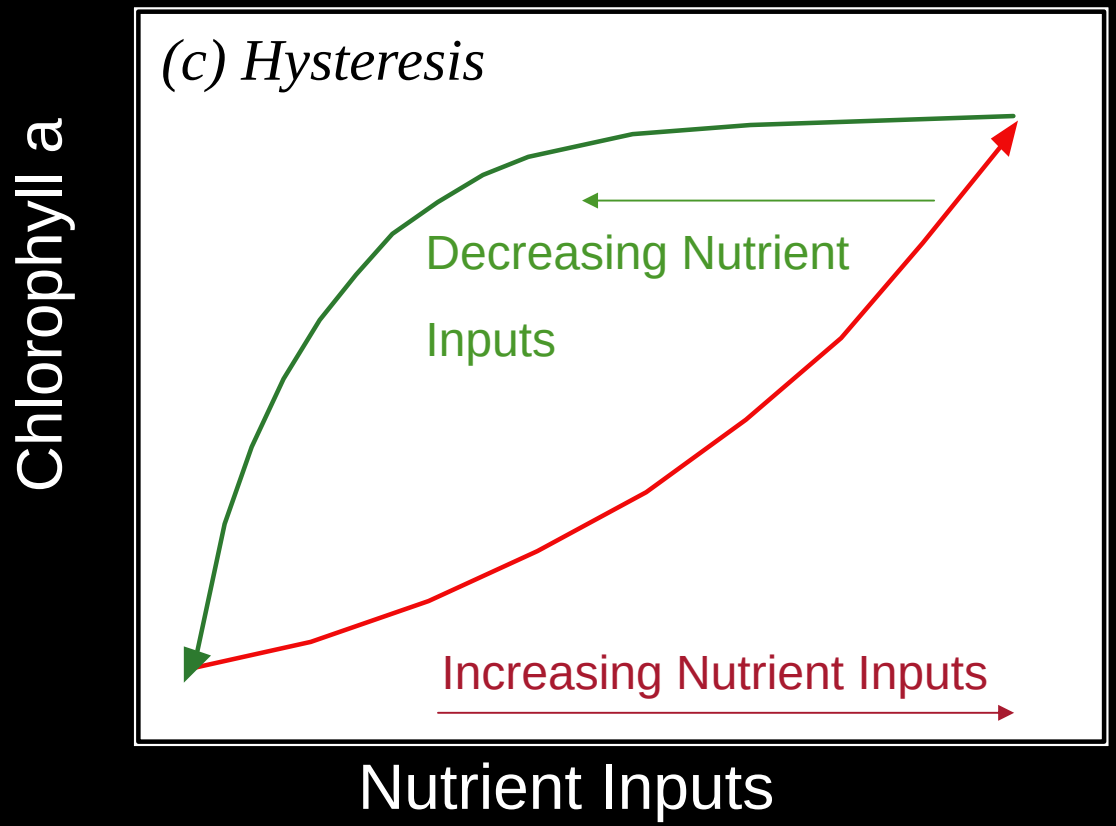
The Neverland Paradigm

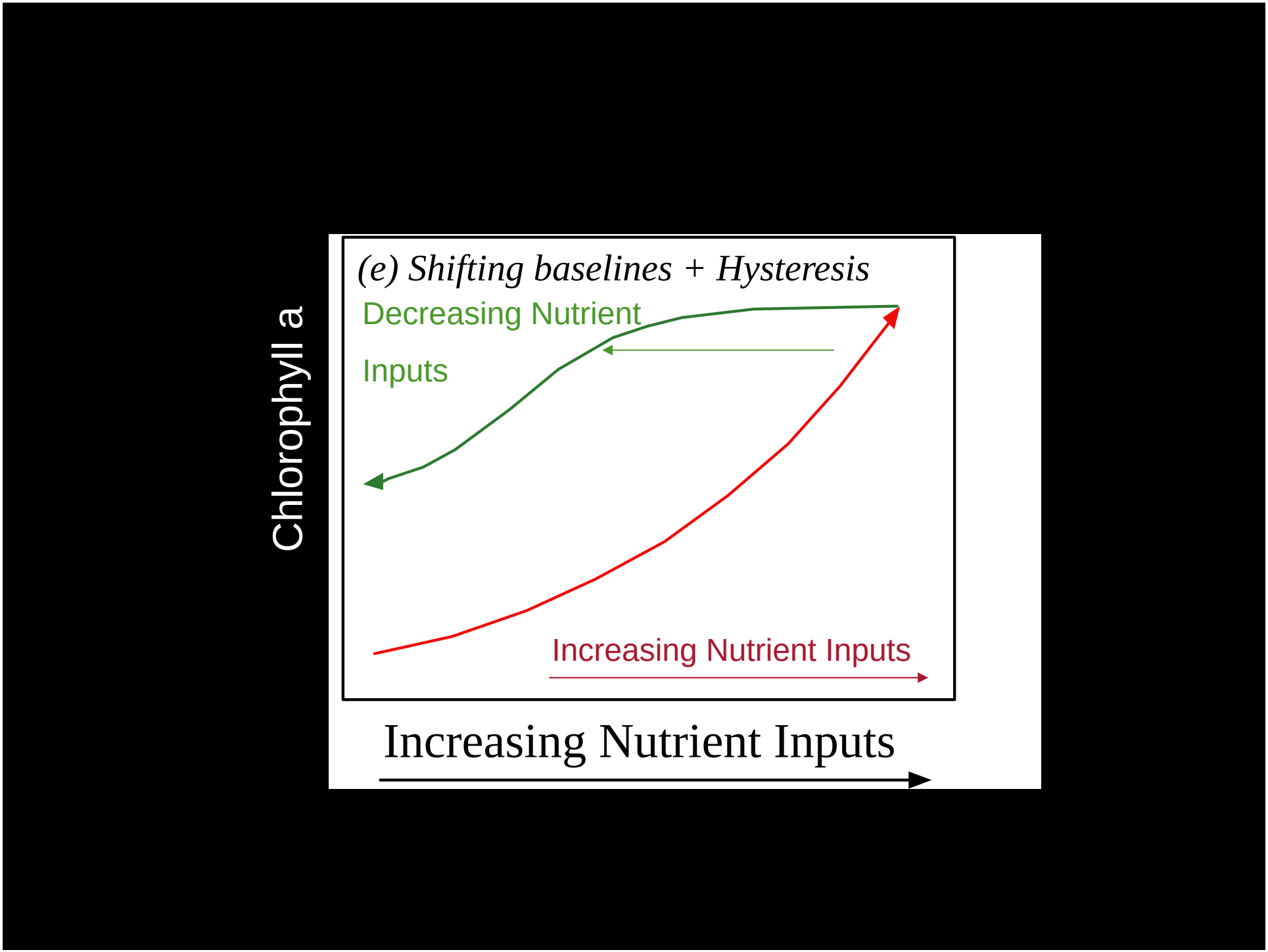


Ecosystem Trajectories Reflect Multiple Concurrent Changes
"Reference Values" are Dynamic




(d) Shifting baselines
Decreasing Nutrient
Inputs
Increasing Nutrient Inputs
Chlorophyll a
Increasing Nutrient Inputs


(c) Hysteresis
Chlorophyll a
Decreasing Nutrient Inputs
Increasing Nutrient Inputs
Nutrient Inputs


Chlorophyll a
(e) Shifting baselines + Hysteresis
Decreasing Nutrient
Inputs
Increasing Nutrient Inputs
Increasing Nutrient Inputs

Conclusions

- The expectation that eutrophication can be reverted back to reference values by reducing nutrient inputs is naive - oligotrophication is not occurring to the expected extent.
- Reduced nutrient inputs has prevented further eutrophication, reduced damage and vulnerabilities and improved some indicators of ecosystem health.
- Our science must progress to reach the capacity to forecast the trajectories of ecosystems subject to multiple, simultaneous pressures and changes.
- Our targets should perhaps focus on restoring ecosystem functionality and resilience, and reduce vulnerabilities, instead of specific, desirable past status, abandoning the “Neverland” dream.
- Ecology and restoration science must, as Wendy, grow to face change.

Thank You!