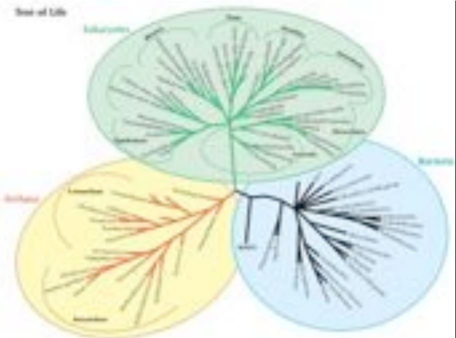
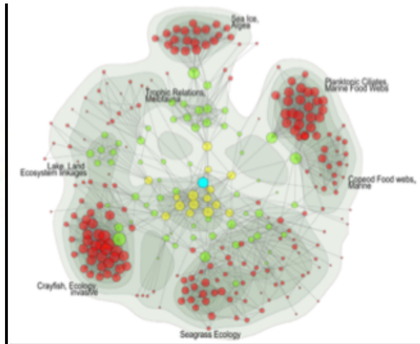
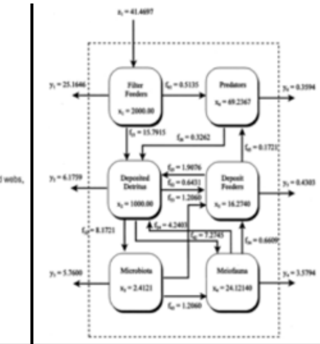
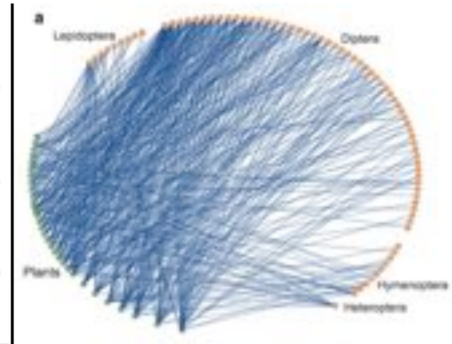


Ecological Network Analysis: Example Applications

Stuart R. Borrett[1,2,3]

1. Department of Biology and Marine Biology, University of North Carolina Wilmington
2. Center for Marine Science, University of North Carolina Wilmington
3. Duke Network Analysis Center, Social Science Research Institute, Duke University

Systems Ecology and Ecoinformatics Laboratory

@ University of North Carolina Wilmington

ISEM 2019,,Salzburg, Austria

Dominance of Indirect Effects

Hypothesis

Indirect flows dominate direct flows in ecosystems

Higashi & Patten 1989

Indirect > Direct   Indirect / Direct > 1

Consequences

Alter species roles and who controls resources

Hidden relationships

Impact assessment and management implications

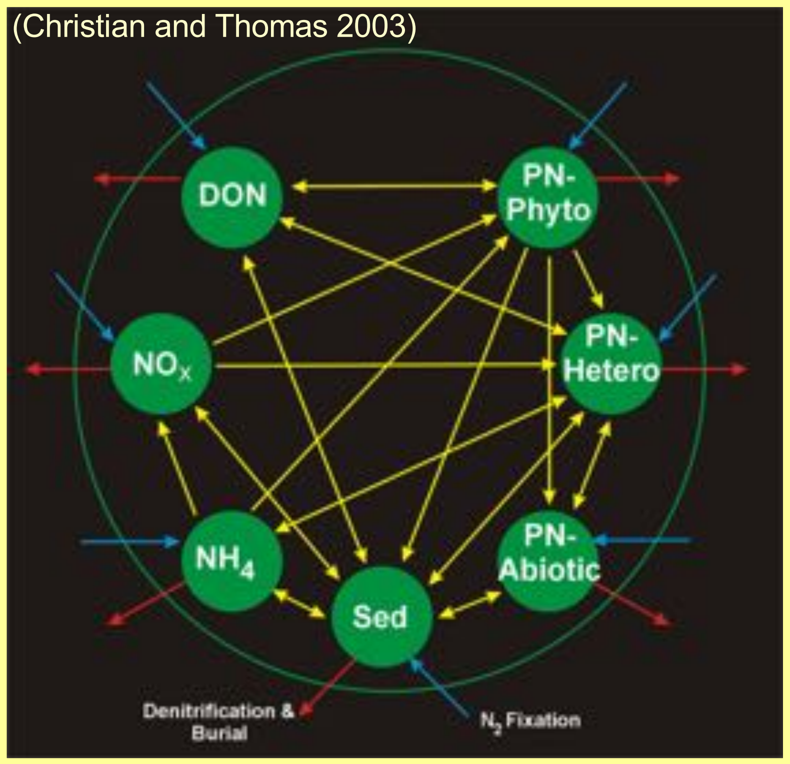
Conservation

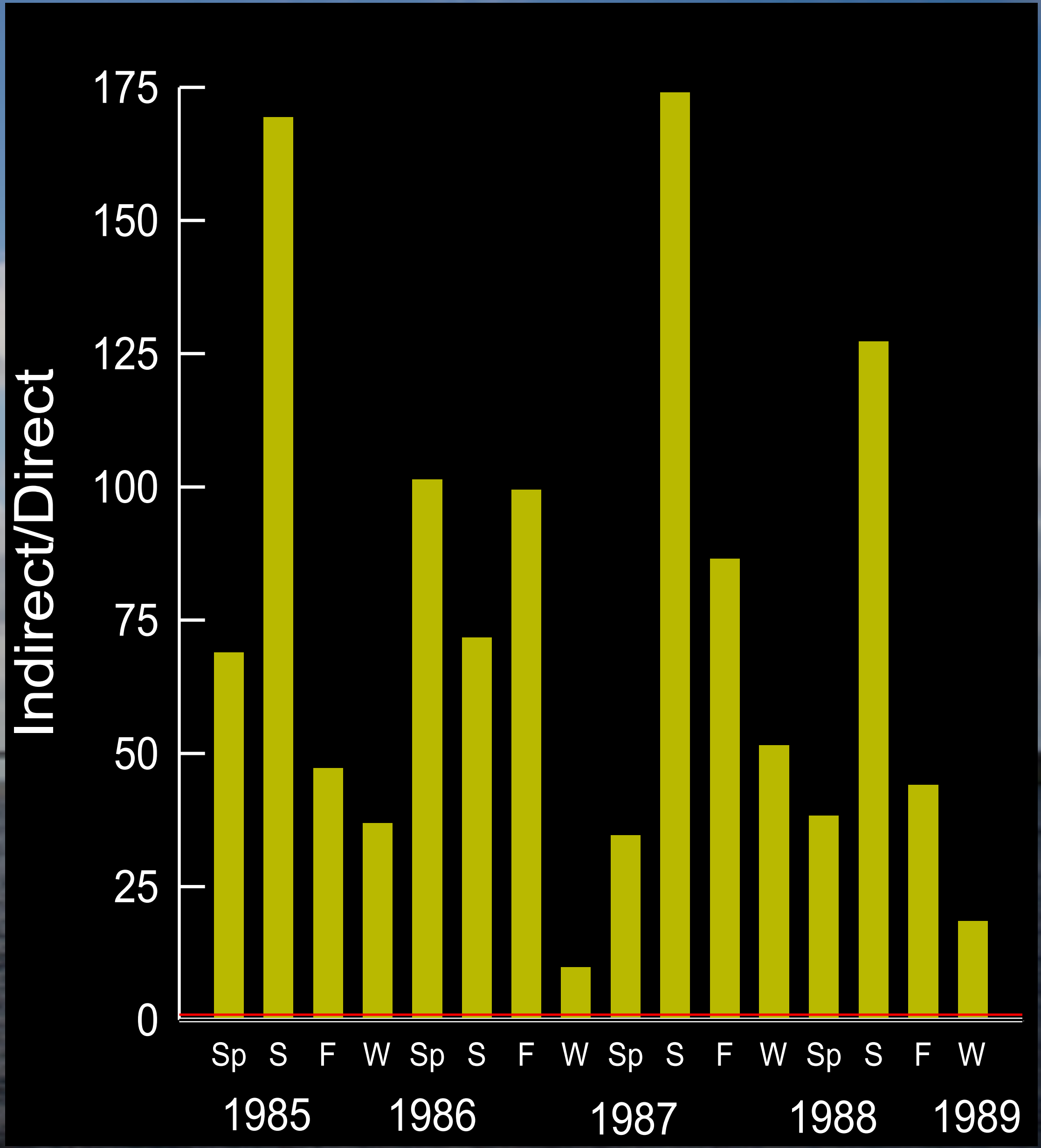
Borrett et al., 2006. Indirect effects and distributed control in ecosystems: temporal variation of indirect effects in a seven-compartment model of nitrogen flow in the Neuse River Estuary, USA—time series analysis. Ecological Modelling, 194(1-3), pp.178-188.

Temporal Dynamics in the Neuse

N Cycling Model

(Christian and Thomas 2003)



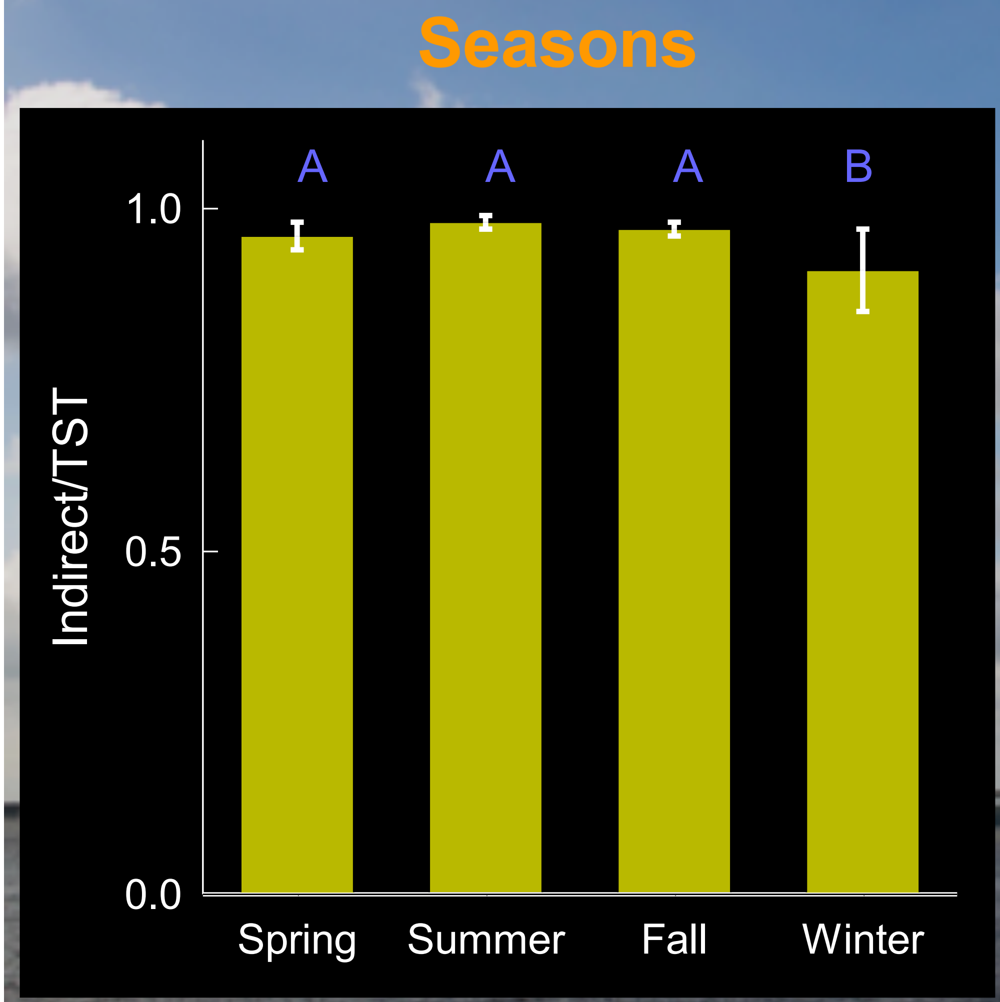


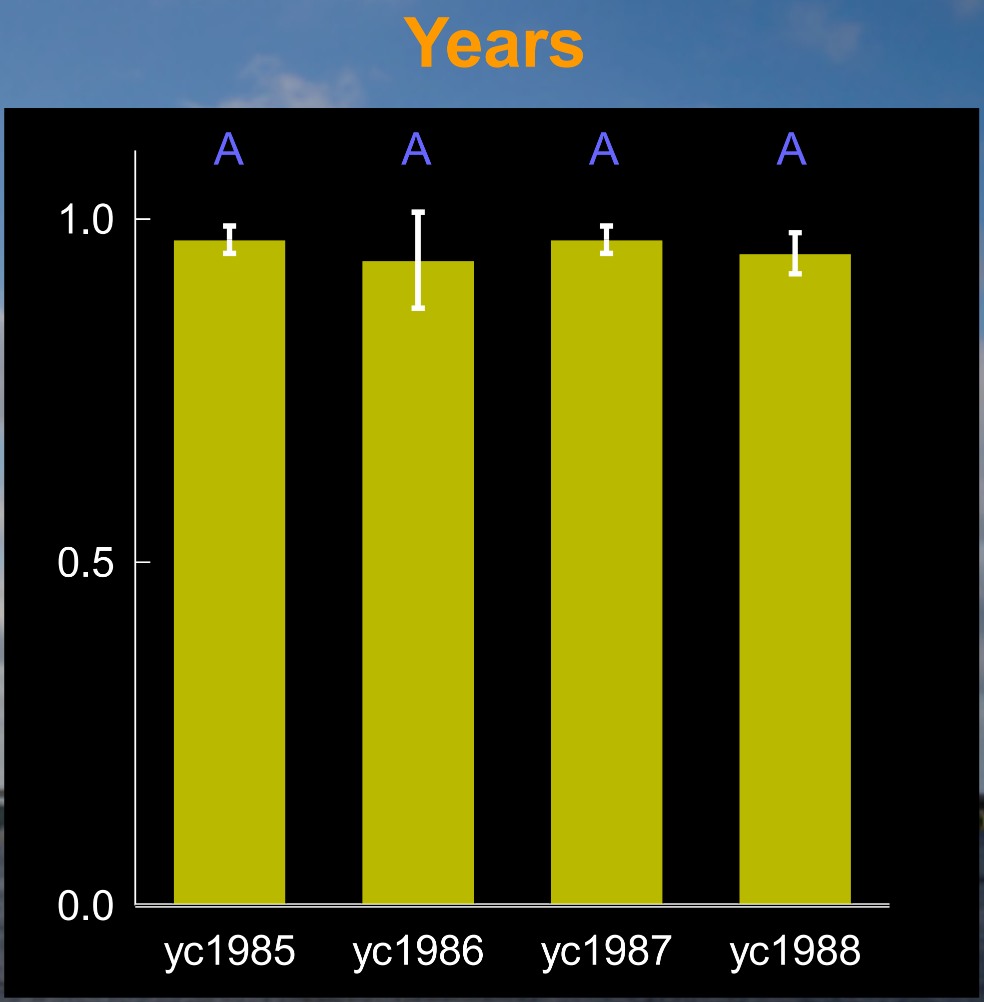
Indirect Flows Dominate (I>D)

Borrett et al. 2006

Temporal Dynamics in the Neuse

Indirect Effects





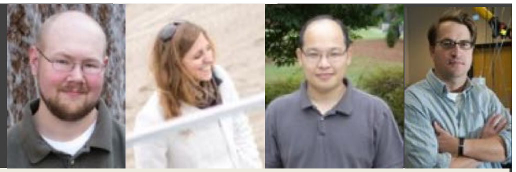
Little Temporal Variation

Stable organization driven by internal processes

Borrett et al. 2006

Cape Fear River Estuary

Hines et al. 2012, 2015



Watershed: 23,734 km^2

River: 325 km

Estuary: 56 km

Black water = high CDOM

Ecosystem Services

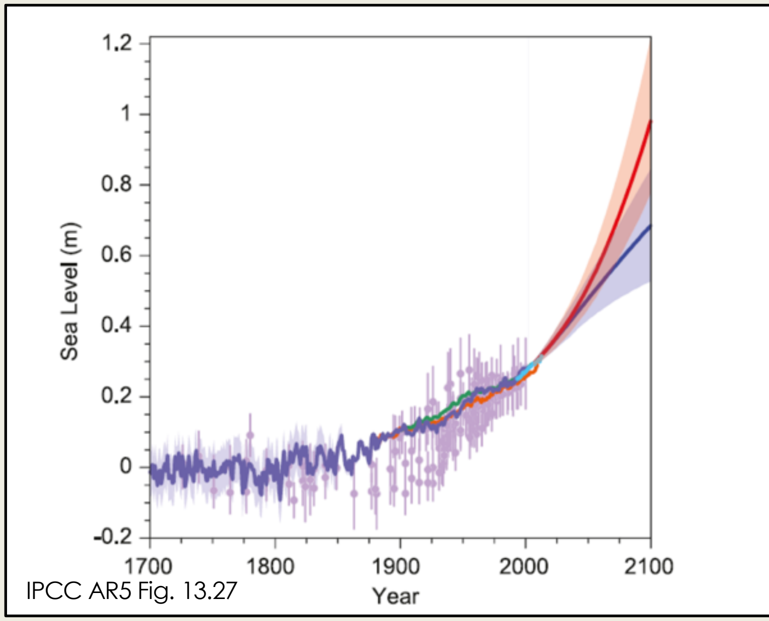
Fisheries

Recreation & Tourism

Nutrient Removal

Changes in the Estuary

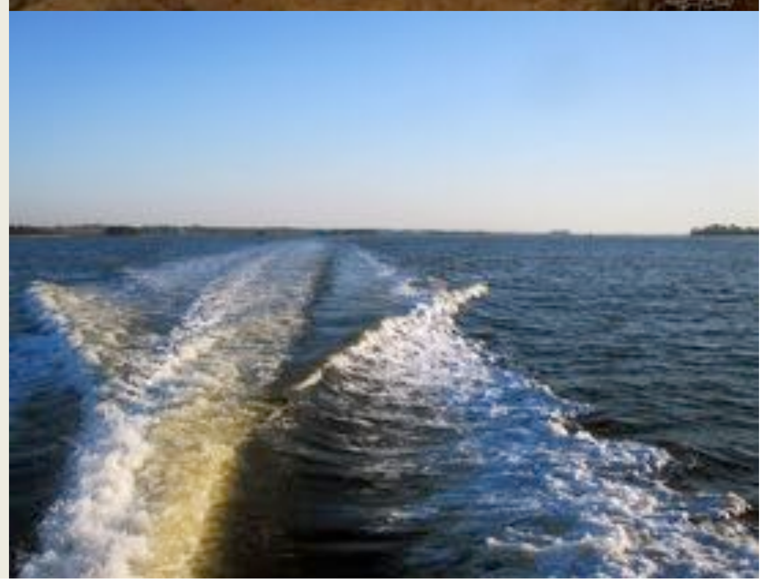
Sea level rise



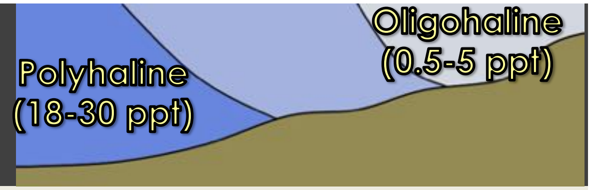
Dredging

Seawater intrusion

Compare Nitrogen Cycle



Hypotheses



When compared to the polyhaline site, ….

H_1: Coupled **nitrification**-**denitrification** will be higher at the oligohaline site

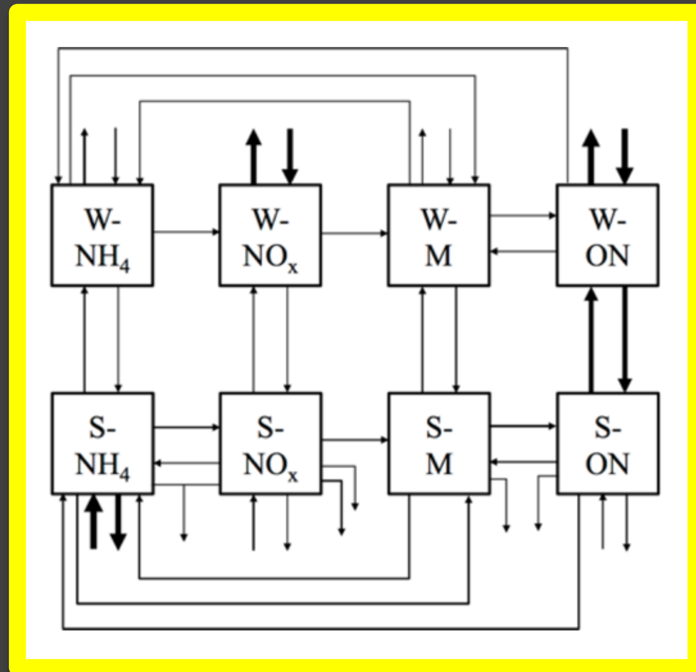
H_2: Coupled **nitrification**-**anammox** will be higher at the oligohaline site

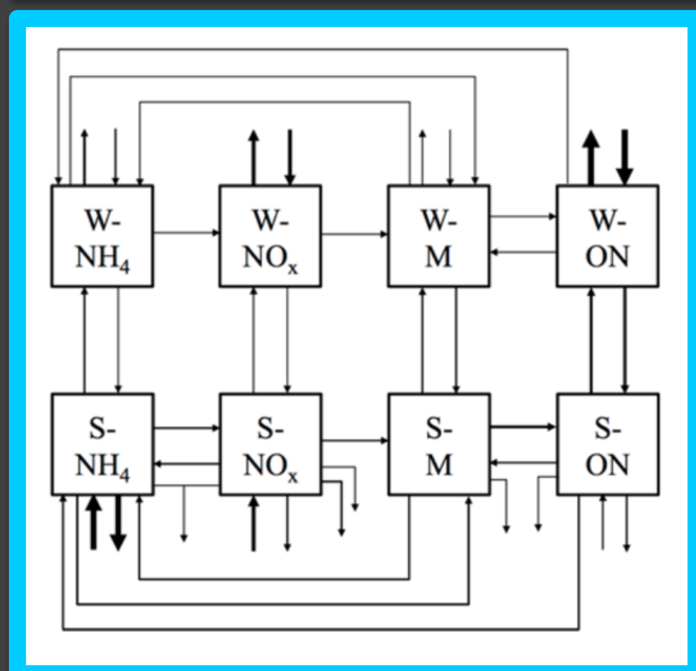
H_3: Coupled **DNRA**-**anammox** will be lower at the oligohaline site

H_4: Microbial **nitrogen removal capacity** will be **higher in the oligohaline** sites

Hines et al. 2015

Network Models & Analysis





Ecosystem
Network
Analysis

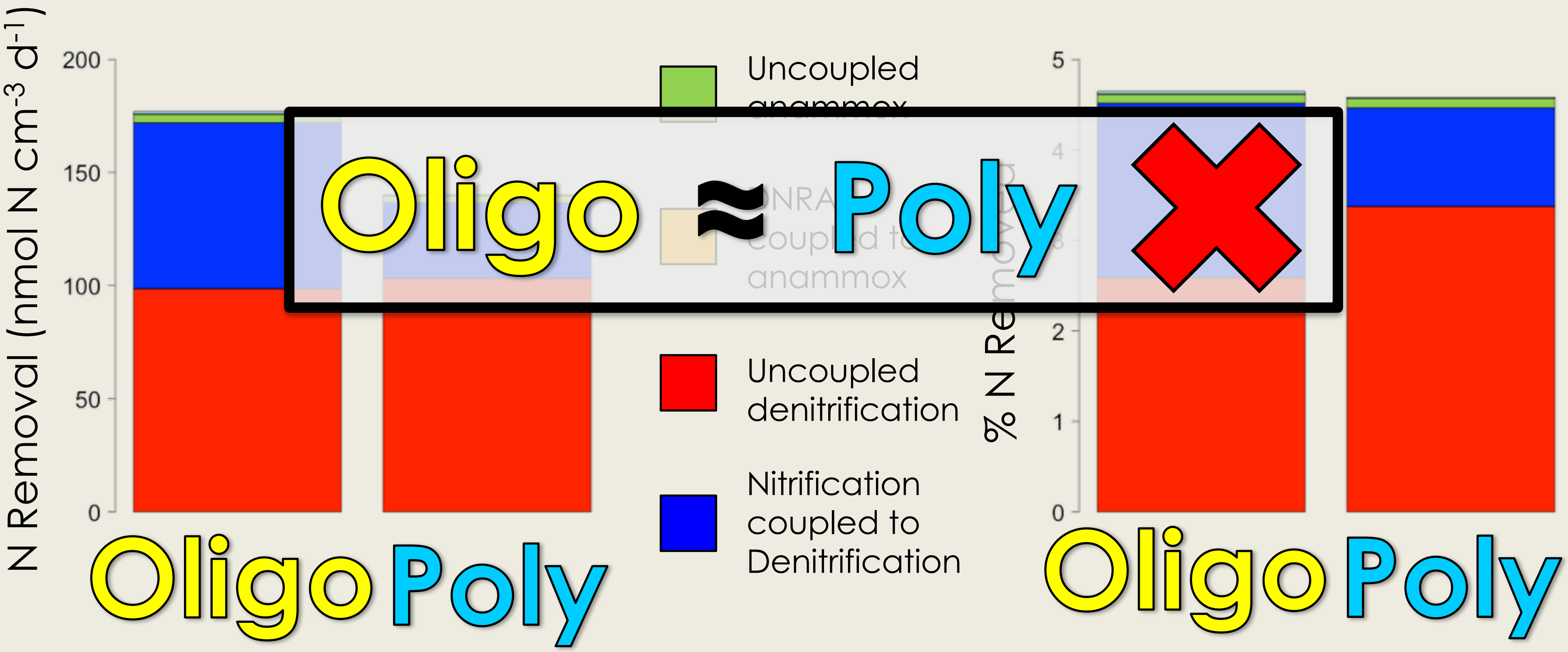
Environ Analysis

Patten et al. 1976;
Patten 1982, 1983

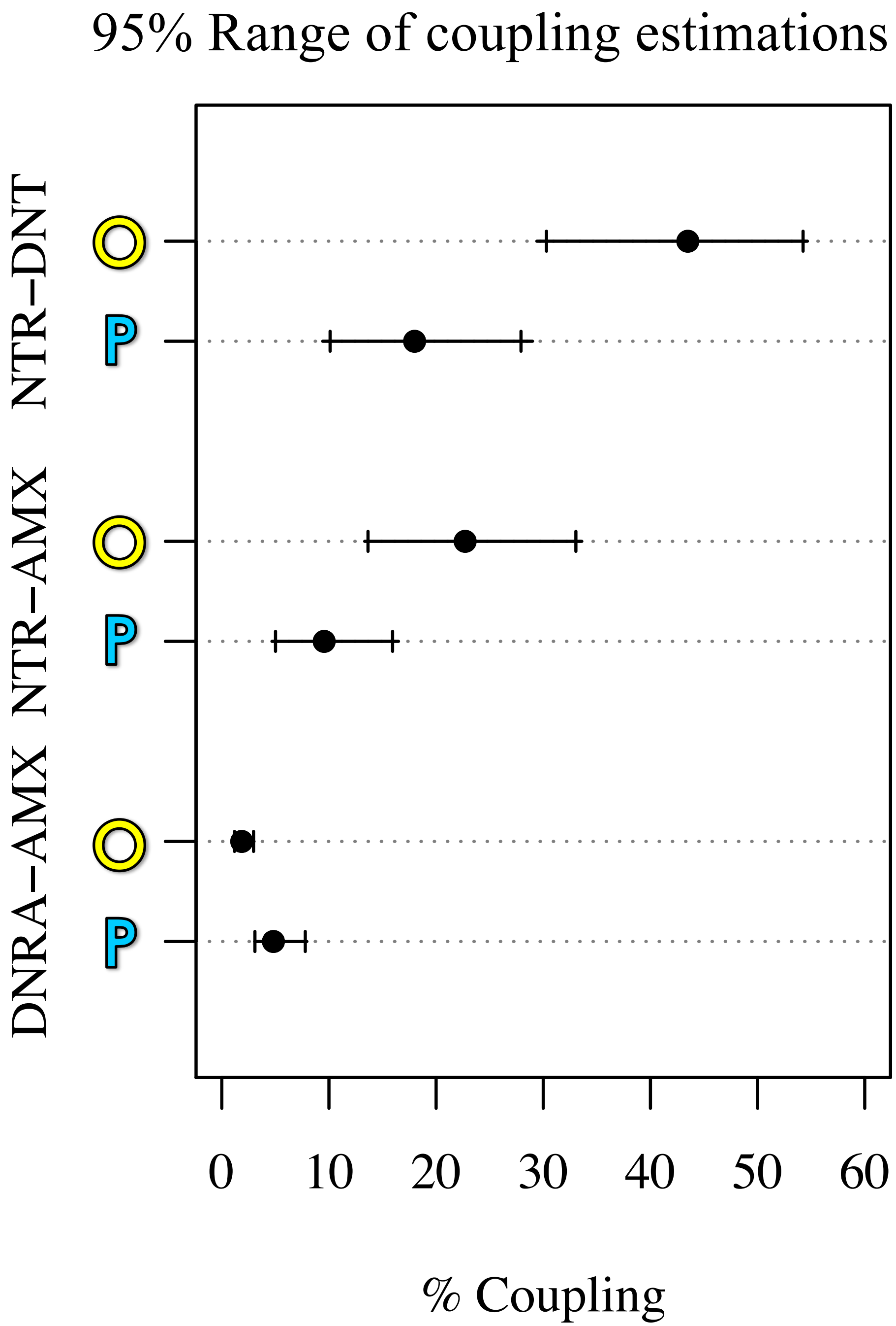
Estimate
N Removal
% Coupling

Hypothesis Testing

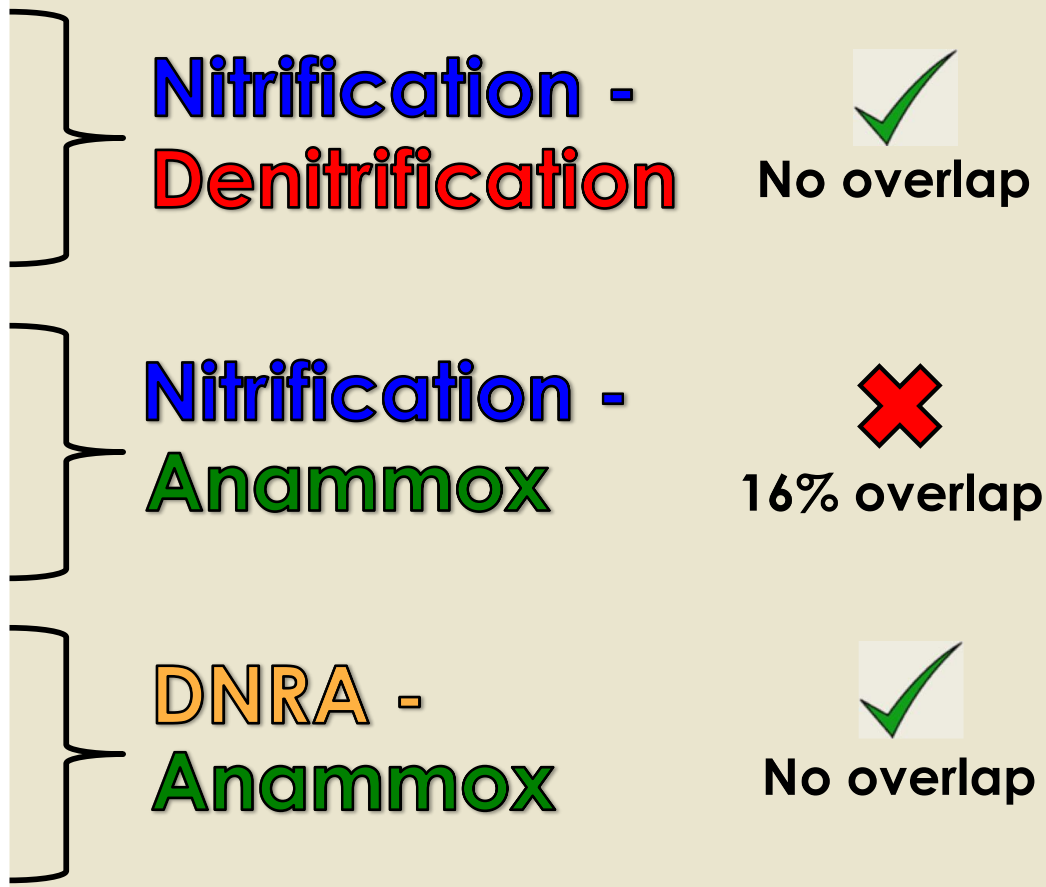
H_4: Microbial **nitrogen removal capacity** will be higher in the oligohaline portion of the estuary compared to polyhaline sites



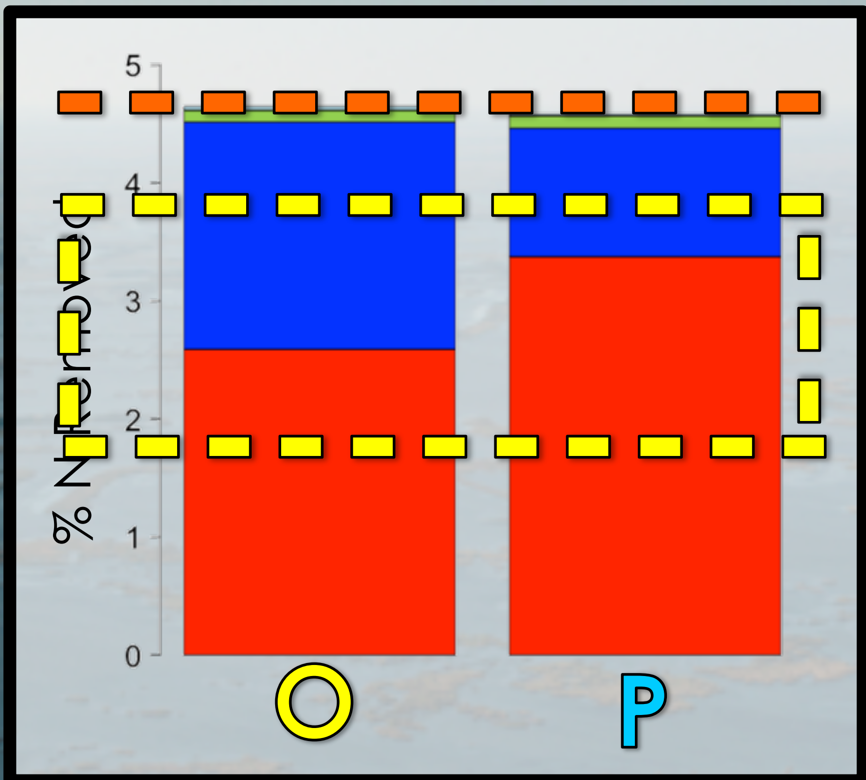
Inference Under Uncertainty



Linear Inverse Modeling
10,000 Plausible Models



Conclusions



Little change in microbial N_2 production capacity

May **alter the pathways** that contribute to N_2 production

http://farm3.staticflickr.com/

Control Analysis

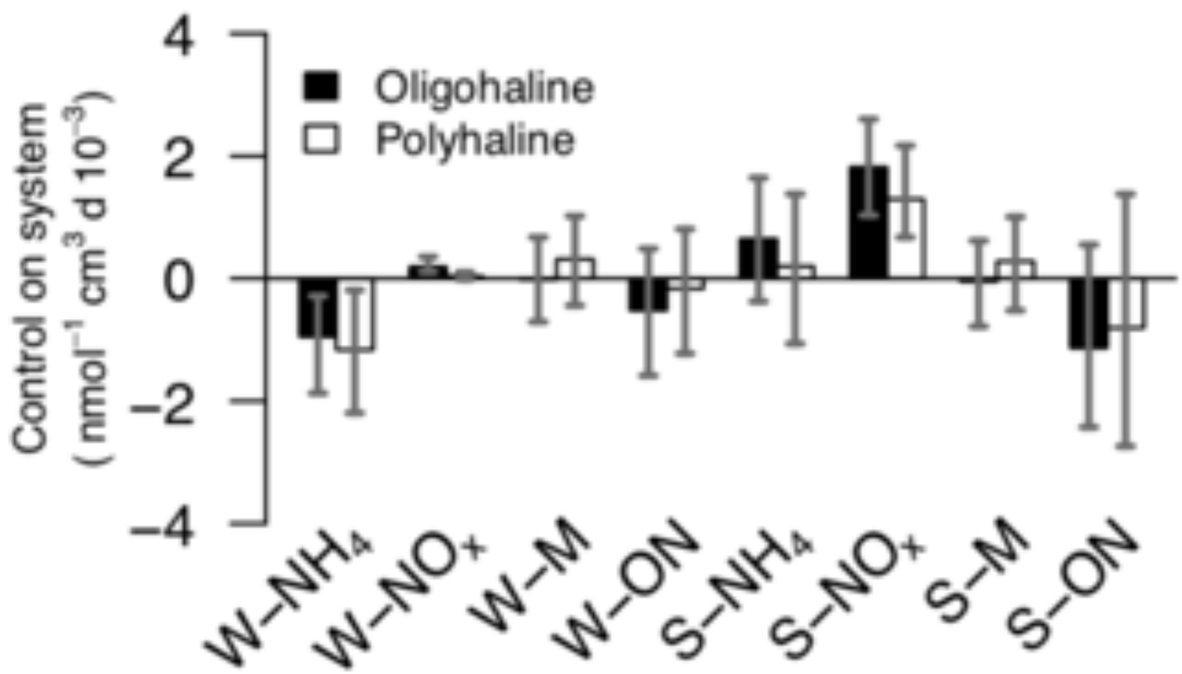
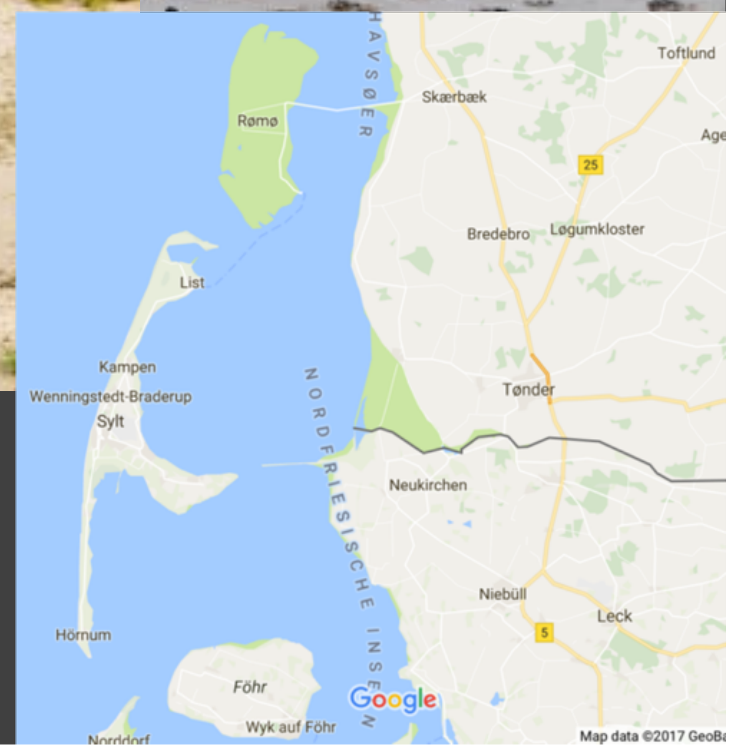


Fig. 3. Comparison of SC vectors ($\vec{sc}$) for the oligohaline (black) and polyhaline (white) networks. Gray error bars show 95% distribution of system control values for the 10,000 plausible models produced by the uncertainty analysis for each site. Positive values indicate that a component exerts control on the system, while negative values indicate that this component is controlled by the system. Note that all values have have been multiplied by 10^3.

Hines et al. 2016. Ecol Eng

Seasonal dynamics and functioning of the Sylt-Rømø Bight, Northern Wadden Sea

Camille de la Vega[1]*, Sabine Horn[1], Dan Baird[2], David Hines[3], Stuart Borret[3,4], Lasse Jensen[5], Philipp Schwemmer[6], Ragnhild Asmus[1], Ursula Siebert[7], Harald Asmus[1]

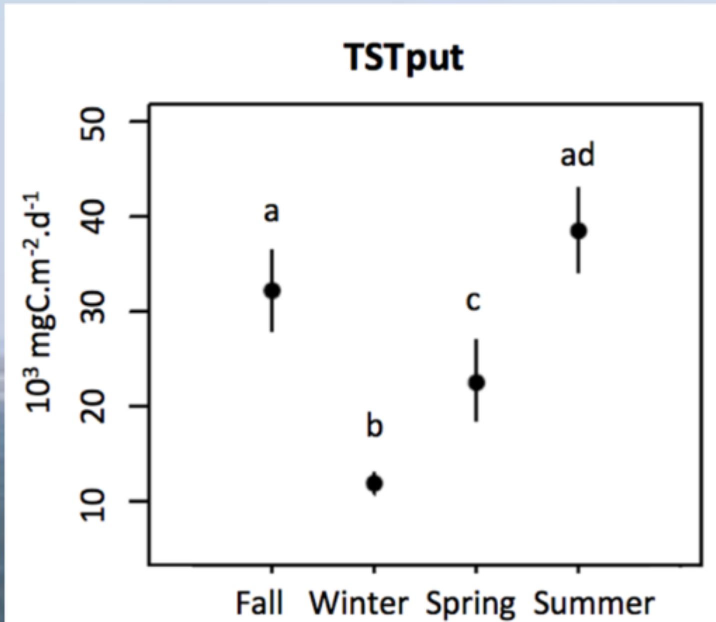


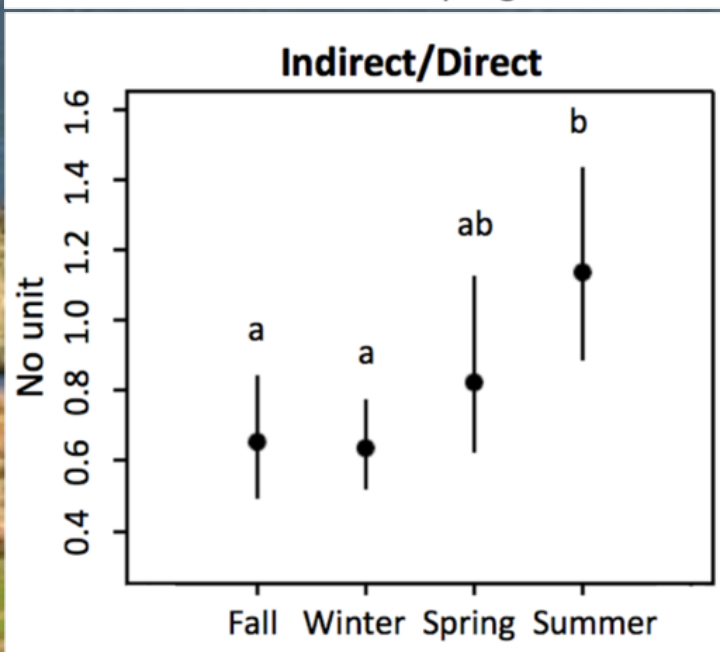
Seasonal ecosystem variability
Impact of migratory waterfowl

2018. Estuarine, Coastal and Shelf Science 203, 100-118

Seasonal dynamics and functioning of the Sylt-Rømø Bight, Northern Wadden Sea

Camille de la Vega[1]*, Sabine Horn[1], Dan Baird[2], David Hines[3], Stuart Borret[3,4], Lasse Jensen[5], Philipp Schwemmer[6], Ragnhild Asmus[1], Ursula Siebert[7], Harald Asmus[1]





TST shows a seasonal cycle

Indirect < Direct !!!

Some 95% CI includes 1.0

De la Vega et a;l. 2018

Bibliometric Review of ENA

2010 – 2016

Guiding Questions

Key **topics**?

Ecosystem types, questions, applications, methods

Structure of **scientific collaboration**?

Borrett, S.R., Sheble, L., Moody, J. and Anway, E.C., 2018. Bibliometric review of ecological network analysis: 2010–2016. Ecological Modelling, 382, pp.63-82.

Bibliometric Approach

Given: publications are core of scientific production

Approach: **INFER** the field from publication records

Search

- ISI Web of Science & Scopus (2010–2016)

  TS = ("Ecological Network Analysis" OR
  "Network Environ Analysis" OR
  "Ecosystem Network Analysis")

- Exclusion Phrases

  TS = ("Business Ecosystems Network Analysis" OR
  "molecular ecological network analysis")

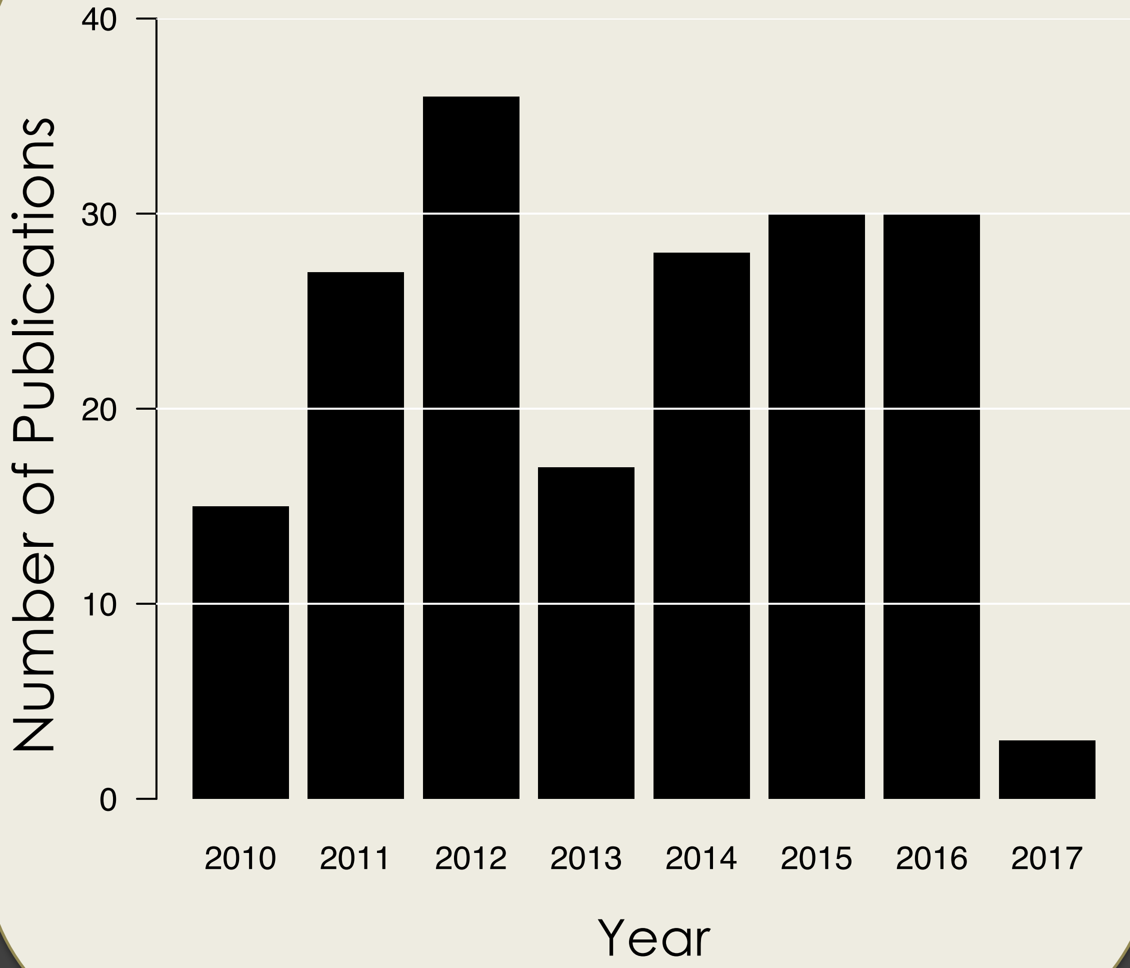
Construct network models: terms & coauthorship

Apply Network Analysis (SAS, Pajek, UCINet, R)

Feature Analysis

Publications

Publication Rate



Sources

60 unique sources
centralization = 94%

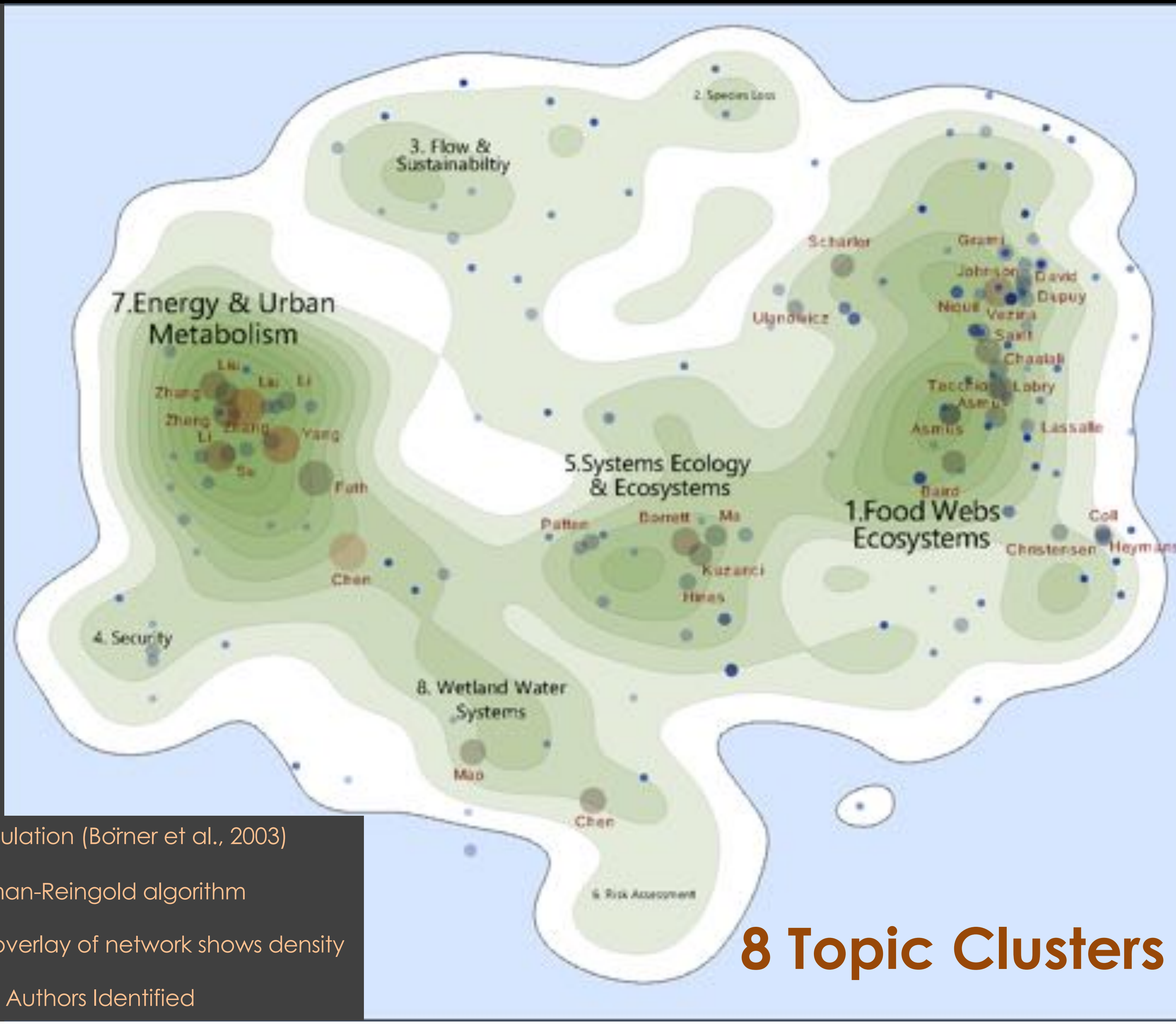
Top Journals	
Ecological Modelling	22%
Ecological Indicators	5%
Estuarine Coast Shelf Sci	4%
J Cleaner Production	4%
Environ Sci Tech	4%
Applied Energy	3%
Mar Ecol Prog Ser	3%
Sci Total Environ	3%

n = 186

26 pubs yr^{-1} (± 2.7 SD)

ENA Topics

Node = Publication, Edge = co-term similarity



tf-idf formulation (Bőrner et al., 2003)

Fruchterman-Reingold algorithm

Contour overlay of network shows density

Common Authors Identified

ENA Topic Clusters (1/2)

Food Webs & Ecosystems (n = 55)

Key terms: food web, trophic, estuary, biomass, flow

Examples

- Assessing coastal/marine food webs
  - Sylt-Rømø (Baird, 2012; Baird et al., 2012, 2011)
  - Baltic Sea (Tomczak et al., 2013)
  - Humboldt Current (Neira et al. 2014)
  - SA Open-Closed Estuaries (Scharler 2012)
- Indicator use – Good Ecosystem Status (Bocci et al., 2016; Brigolin et al., 2014; Chaalali et al., 2015)
- Assess negative impacts of toxin (Taffi et al. 2014, 2015)

Energy & Urban Metabolism (n = 46)

Key terms: energy, metabolism, utility, economic sectors, relationships

Examples

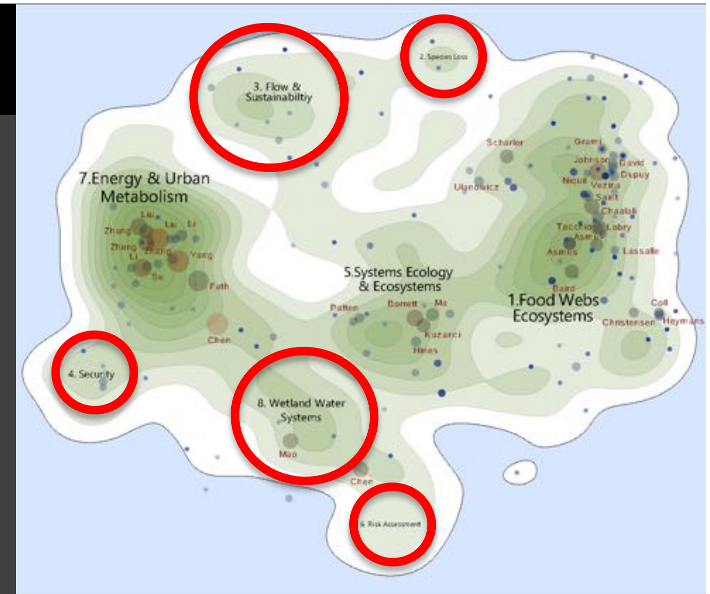
- Assess Urban Metabolism (Chen and Chen, 2015; Liu et al., 2011, Zhang et al., 2016)
- Compare Socio-Economic Systems (Zhang et al., 2016d)
- Success of Eco-Industrial Parks (Lu et al., 2015, 2012, Zhang et al., 2015a, 2015b)

Systems Ecology & Ecosystems (n = 26)

Systems Theory, Environs, General ecosystem properties (Indirect Effects)
(Borrett et al., 2010; Ma and Kazanci, 2013; Yong Min et al., 2011; Salas and Borrett, 2011)

Software: NCNA (Min et al., 2011) , EcoNet (Schramski et al., 2011), enaR (Borrett and Lau, 2014)

ENA Topic Clusters (2/2)



Flow, Sustainability (n = 22)

Theory, Method Development, Applications

Key terms: sustainability, performance, indicators, information, diversity

Example Applications

- Resiliency of the Heiha River Basin (Kharrazi et al. 2016)
- Crop & Livestock System, N flow perspective (Stark et al. 2016)
- Industrial System Design, Industrial Parks as Ecosystem (Layton et al. 2016)

Wetlands & Water Systems (n = 19)

Physical water exchanges in wetlands (e.g. Baiyangdian Basin) (Mao et al., 2015, 2010; Yang and Mao, 2011)
Virtual water trade (Fang and Chen, 2015; Mao and Yang, 2012; Yang et al., 2012)
Energy-water nexus (Duan and Chen, 2017; Wang and Chen, 2016; Yan and Chen, 2016)

Risk Assessment (n = 8)

Energy Security, supply, stability (n = 7)

Species Loss (Rate, Remove, Lake; n = 4)

Summary of Key Findings

Development of ENA

New analyses & metrics (describe system state)
Software tools – model construction, analysis
Methods for sensitivity & uncertainty analyses
Indicator – empirical testing (Luong et al. 2014), comparative

Diverse applications of ENA

Food Webs (marine)
Urban, Socio–Economic
Creative applications

Growing fastest