Submitted: 30 January 2018

Title: Scale mismatches in ecological research and management: consequences and solutions through data management

Short title: Scale mismatch in ecology

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Project Summary

Numerous, long-term ecological monitoring programs exist yet the data are not always collected at the scales(s) necessary to identify and understand the relevant processes driving observed patterns. Moreover, the lack of a unifying standard makes it difficult to aggregate and integrate multiple datasets *post hoc*. These "mismatches" between observation and process as well as between independent datasets make it challenging to develop effective management policy or predict future transitions in a changing global climate. This project aims to identify the scope of these issues and develop solutions that bridge the gap between monitoring programs and research efforts. We propose a series of workshops with these specific goals:

1. identify how research questions about global ecological change are affected by mismatches with the sscale of extant datasets
2. develop a standardized framework for data integration to enable interoperability among multiple datasets and guidelines for model development
3. create recommendations for prioritizing current and future monitoring programs and for establishing adaptive management/monitoring practices

Proposed Start and End Dates: January 2019—August 2020 with 1 five-day and 2 four-day workshops at the Powell Center.

Proposed Data Release Date (or before): May 2020

Total Requested Budget: $172,121.50 (Year 1: $85,984.38; Year 2 $84,337.13)

Is this a resubmission? No

Conflicts of Interest with Reviewers: Craig R. Allen serves on the Powell Center SAB.

Keywords: ecosystems

1 Problem Statement

The scales at which we monitor and manage ecological systems do not always align with the scales at which ecological feedbacks and processes (hereafter processes) operate. Mismatches between our observations and the processes we aim to understand can lead to ineffective or counterproductive management and policy decisions (Lee 1993, Folke et al. 1998, Cumming et al. 2006), unexpected responses of faunal populations to intervention (e.g., Chundawat et al. 2016), and overexploitation or harvest of natural resources (e.g., Lee 1993). We refer to the misalignment between ecological (or physical) scale and social (or management) scales as 'scale mismatch' (Levin 1992, Cumming et al. 2006). Such mismatches can occur along one or several axes simultaneously, including spatial (wrong physical size and/or extent), temporal (wrong sampling frequency and/or extent), or even taxonomic (wrong taxonomic rank) dimensions. For example, ecosystem dynamics often operate on larger spatial (or longer temporal) scales than any single monitoring program or management area can capture, and management decisions often occur at spatial (temporal) scales that are smaller (quicker) than assessments or models provide, requiring strict assumptions of constancy or problematic downscaling methods. As we navigate the 'Big Data' revolution (Kitchin 2014, LaDeau et al. 2017), capturing and analyzing ecological observations will become increasingly efficient; however, scale mismatches can undermine these advances. Furthermore, efforts to understand multi-scale processes can be hindered by artificial hierarchies that result from sampling schemes or analysis frameworks. For example, it is common to process irregularly-spaced observations to conform to a uniform grid of latitude and longitude. These "false hierarchies" may mask true ecological dynamics that occur or interact at multiple scales (Levin 2000), and even introduce statistical artifacts because the different "levels" are actually determined by choices made when designing the monitoring program or analysis pipeline.

Scale mismatches can have substantial consequences for understanding the ecological mechanisms that produce our observations. Consequently, scale mismatch may limit our ability to identify early warning signs of community or ecosystem collapse (Holling 1992, Scheffer 2009). Ecological 'regime shifts' can have a number of underlying mechanisms and may result in drastic and unwanted changes to ecosystem goods and services. Recovery from these disturbances is difficult without knowledge of the true scale of the problem and the underlying processes. With predicted increases in the intensity and frequency of disturbances as a result of global climate change, it is critically important to know both the potential impacts of and alternatives for scale mismatches in ecological research and management. We propose to investigate the scope of scale mismatch among ecological processes and observations (i.e., data) and to develop solutions for integrating and utilizing multiple sources, qualities, and types of data to identify ecological patterns and processes across multiple spatial and temporal scales. For example, is it possible to construct criteria for creating proxy variables that allow upscaling or down scaling in time, space or taxon?

Impacts of Scale Mismatches

Our first objective is to identify the extent to which the spatial, temporal, and taxonomic scale of datasets affect the ability to detect or predict patterns of ecological change. Although long-term monitoring programs are highly valuable for identifying trends and distributions, they may not have been designed with modern research questions in mind. Moreover, because many monitoring programs were the first to begin sampling their system of interest, they may not have collected data at the appropriate scale for investing the ecological processes that interest researchers today.

Data Integration Practices

Although the collection and analysis of fine-grained data in climatology and hydrology is increasingly efficient, large-scale ecosystem monitoring efforts are stunted by both the expenses related to collecting these data and the misalignment of science and bureaucracy (Field et al. 2007). Data integration is a practical solution to this problem - it unifies data from separate sources to address a research question(Sutter et al. 2015). In this way, out-of-sample prediction and out-of-scale inference can be supported using existing datasets. Because data needs are often unique to different models and do not always overlap, we will develop a set of guidelines for both datasets and models to lower the barrier of entry. This will help ensure that datasets can be more widely used, and that researchers/modelers spend less time wrangling data into consistent formats.

1.1 Research questions

We will examine the effects of and solutions for scale mismatch in ecological monitoring protocols and consequential information (data). Many monitoring programs protocols are designed such that the information collected maximizes monetary resources, statistical power, and are sustainable over the lifetime of the program. Monitoring program protocols, however, often implicitly assume stationarity of ecological processes, and often fail to adapt to changing environmental and sociological conditions. This occurs when the spatial and/or temporal scales at which ecological processes operate are not captured within the maximum scale of the data.

A spatial (temporal) mismatch can be defined as an incongruence between the physical (temporal) location of a process(es) and the location at which information are collected. Mismatches in ecological data can be defined broadly when one of two conditions, or a combination of each, are met with respect to spatial extent and resolution, and temporal extent and resolution. Under these conditions, either the area (or time period) sampled does not overlap with the ecological process(es) of interest, or the area (or time period) sampled does not encompass sufficient information to capture the process of interest (Figures 1 and 2).

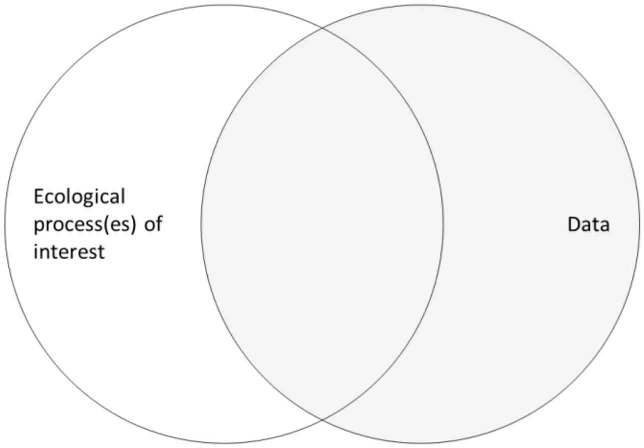

Figure 1. Scale mismatch between data and the ecological process(es) of interest. This scale mismatch occurs when the ecological process occurs outside the spatial or temporal scale or resolution at which the data is collected. Any inference gained from the data may not reveal the ecological process driving the observations.

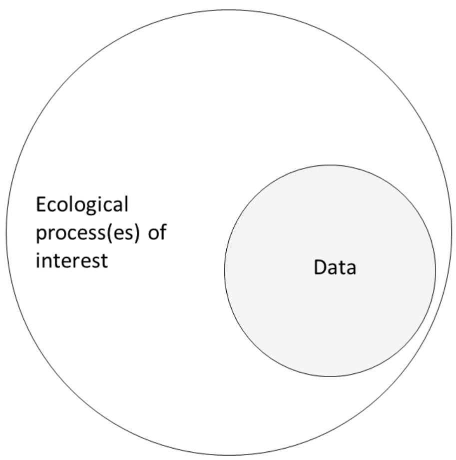

Figure 2. Scale mismatch between data and ecological process(es) of interest. This mismatch occurs when the data are captured at a spatial or temporal resolution or extent that is smaller than required.

Spatial and temporal mismatches, alone, are often relatively simple to resolve. Increasing the spatial or temporal extent or resolution at which the data are collected may alleviate these mismatches. It is often not the case, however, that simply increasing the spatial or temporal extent or resolution will solve problems associated with scale mismatch. Increasing the spatial extent of a monitoring program, for example, may muddle inference from the processes captured in the data if the temporal extent of the program is not subsequently increased. This working group will explore questions surrounding the issues of (i) spatial, (ii) temporal, (iii) and spatiotemporal scale mismatches in ecological monitoring data, inference, and management. We ask the following questions with respect to the aforementioned scale mismatches:

1. How can we identify scale mismatches in ecological monitoring programs?
2. What issues are inherent in spatial, temporal, and spatiotemporal scale mismatches?

3. What are solutions for handling these scale mismatches?
4. What are solutions for preventing scale mismatches?

2 Proposed Activities

Data

We have identified a diverse group of datasets which differ in variety (types of data), velocity (sampling frequency and/or the rate at which the data is available for analysis; e.g., retrieving mass quantities of data at one time vs. real-time data from sensors), veracity (uncertainty in the observation; e.g., remotely-sensed data)(see LaDeau et al. 2017).

Analytical Approach

We propose to investigate the potential impacts of these scale mismatches on research into long-term change and regime shifts in the following way. First, we will examine publicly-funded and/or publicly-available data (see Table 1) and assemble standardized metadata to enable cross-dataset comparison. Next, we will impose artificial hierarchies (e.g., through down-sampling, aggregation, and extent restrictions) on these data to understanding how scale mismatches affect analyses. Finally, we will test different methods of analysis to see how the spatial, temporal, or taxonomic scale of the data impact ability to detect patterns of change or regime shifts.

We will identify the effects of scale mismatches on the quantitative and qualitative results of from multiple regime shift detection methods including changes in point estimates (e.g., first through fourth moments, variance), multivariate time series analysis, and clustering techniques. Analytical details will be hashed out in the first meeting, and will be contingent upon the final research questions and associated data. Many of our team members have considerable experience in a variety of quantitative methodologies for detecting ecological regime shifts and nonlinear dynamics (e.g., Sugihara and May 1990, 1998, Gill et al. 2009, Batt et al. 2013).

3 Participants

We have identified a diverse team of researchers (Table 2) whose expertise, together, will advance the objectives proposed herein. All but one team member (Dr. Ryan Batt) are confirmed participants at the time of submission. Our team members represent two countries (U.S. and Australia), work in ecological and research and management and represent both academic and federal institutions.

3.1 Diversity statement

Our team comprises 5 women (1 African American) and 10 men. The age and career stages of our confirmed participants are well distributed (3 doctoral students, 3 postdoctoral researchers, 5 early- to mid-career researchers, and 4 mid- to late-career scientists). Additionally, some of our team members are especially active in local and national efforts to promote and retain diversity in the natural resource sciences. As a first-generation college student, the Powell Center fellow

(Jessica Burnett) is particularly interested in generating awareness among and creating opportunities for natural resource research and management in the first-generation community.

4 Timetable of Activities

This project will be aided most by the in-person meetings and discussions. Although some participants are familiar with each other most have yet to work together. It is therefore important we meet as a group for longer, rather than shorter, periods of time. We propose one, five-day workshop and two, four-day workshops.

January—April 2019

- Initial email correspondence
- Circulate scale mismatch and other pertinent literature
- Video conference with entire group to
  - establish rapport
  - discuss literature (see above)
  - refine agenda for January workshop
- During and after video conference we will, as a group, draft a code of ethics and expectation
- The Powell Center fellow will gather and summarize, at a minimum, the data presented in Table 1

April or May 2019

- First in-person meeting (4 days)
  - refine group objectives and methods
  - define preferred study systems/taxa
  - finalize data to be included in analyses
  - define a common metadata (this will likely be updated before or at next meeting)
  - define specific methodologies and data combinations for analytical approaches
  - define potential products and project point-persons

May—July 2019

- Powell Center fellow will gather additional data accordingly
- Fellow will work with Powell Center to identify data storage options, if necessary
- Data munging
- Data will be published such that all team members can access
- Introduce artificial hierarchies into data
- Run regime shift/change point detection analyses on data (as identified in April/May meeting)

August 2019

- Disseminate results to team prior to meeting
- Video conference with entire team

August or September 2019

- Second in-person meeting (5 days)
    - Day 1:
        - review and discuss results
        - expert interpretation for system-specific analyses
        - run additional analyses as necessary
        - define manuscript audiences
    - Day 2:
        - breakout groups
        - writing
    - Day 3:
        - regroup, updates
        - writing
        - regroup and assign tasks as necessary

October 2019—August 2020
- Email correspondence and video conferencing as necessary
- Work on manuscript drafts

June 2020
- Third in-person meeting (4 days)
    - Finalize manuscripts and submit for internal reviews
    - Discuss future directions
    - Draft management recommendations / final report

July—August 2020
- Publish data and metadata as applicable with Powell Center and ScienceBase
- Submit manuscripts

5 Anticipated Results and Benefits

Ecological monitoring programs can provide valuable information about species distributions and population trends, ideally informing relevant policy and management actions. However, some long-term and/or large-scale monitoring programs consume large amounts of resources (*i.e.*, manpower, non-renewable resources, money) and their protocols are often not adaptive (Lindenmayer *et al.*, 2009). Non-adaptive data collection may fail to capture processes operating across multiple functional scales (Holling 1992). In fact, some ecological studies and monitoring programs gather information at a single level of interest yet extrapolate results beyond the spatial and temporal resolution and extent of the data (e.g., species distribution modeling). Furthermore, some programs may fail to capture processes operating across broad temporal and spatial extents (Brown 1995) if the spatial resolution of the data is smaller than that of the processes. In many cases, this occurs because the true scale of relevant processes was unknown before designing the monitoring program, or because conditions have changed that necessitate collecting additional data streams.

We propose that adaptive monitoring and management protocols provide a way to effectively use and reuse scientific resources. This approach is not intended to replace current fixed monitoring programs, but rather to supplement existing efforts in a way that addresses scale mismatches. Notably, effective use of resources for adaptive monitoring requires clear definitions of both the research questions and models to guide decisions on what additional observations will be most helpful. Ultimately, these adaptive schemes can aid adaptive policy to enable flexible management under changing climate conditions and no-analogue scenarios. Again, this requires standardized protocols for defining datasets and models. Thus, our objective is to create a set of recommendations based on current research needs and data availability.

Our team strategically comprises ecologists with strong mathematical backgrounds (Batt, Deyle, Sugihara), applied ecologists with a firm management background (Allen, Gross, Twidwell), and experts in ecological statistics and data management (Bahlai, Burnett, Roberts, Ye), social-ecological systems and feedbacks (Bailey, Cumming), macroecology (Ernest, Gill), and environmental management and policy (Garmestani). As such, we expect the first meeting of this diverse group to generate novel and interesting ideas focused around the theme of scale mismatch in ecological research, management, and monitoring (data). At a minimum, we expect to produce two high-impact manuscripts (effects of scale mismatch on detecting ecological regime shifts and management recommendations for data integration best practices) and a practitioner's guide for addressing and preventing scale mismatch in an adaptive monitoring framework.

Submitted: 30 January 2018

Table 1. Examples of the publicly-available datasets to be used by this working group.

Monitoring program/data source	System(s)	Data curator/funding
North American Breeding Bird Survey (NABBS)	Avifaunal community	US Geological Survey
Amphibian and Reptile Monitoring Initiative (ARMI)	Herpetofauna (abundance estimates)	US Geological Survey
Eglin Air Force Base	Various	Department of Defense
California Current Ecosystem (CCE)	Coastal upwelling biome (planktonic communities; fish abundance; climatic and oceanic sensors)	National Science Foundation
Forest Inventory Analysis (FIA)	Private land forest conditions and harvest	US Forest Service
Paleoclimatology Data	Paleoocean; ice cores; lake; plant macros	NOAA
Neptune Sandbox	Microfossil occurrence data	Neptune Sandbox Berlin
Continuous Plankton Recorder Survey (CPR)	Northern Atlantic Ocean plankton chlorophyll index	Sir Allister Hardy Foundation for Ocean Science (SAHFOS)

Submitted: 30 January 2018

Table 2. List of participants (in alphabetical order; 1 unconfirmed).

Participant	Position	Affiliation(s)	Expertise
Craig Allen[Θ]	Unit leader, Professor	U.S. Geological Survey, Nebraska Cooperative Fish and Wildlife Research Unit, University of Nebraska-Lincoln	Adaptive management, resilience, invasion ecology
Christie Bahlai	Assistant Professor	Kent State University	Break-point analysis, data science
Karen Bailey	Ph.D. Candidate (graduating May 2018)	University of Florida	Social-ecological feedbacks, livelihood decision making
Ryan Batt[*]	Postdoctoral Fellow	U.S. Environmental Protection Agency, National Academy of Sciences	Limnology, time series analysis, critical transitions
Jessica Burnett[Θ § ¥]	Ph.D. Candidate	University of Nebraska-Lincoln	Quantitative ecology, regime shifts, applied ecology
Graeme Cumming	Research Professor	James Cook University	Scale mismatch, social-ecological systems
Ethan Deyle	Postdoctoral Research Associate	University of California San Diego	Ecological mathematics, complex systems
Morgan Ernest	Associate Professor	University of Florida	Community ecology, macroecology, LTER, NEON

[*] Unconfirmed participant
[§] Technical liaison to Powell Center computing staff & party responsible for adherence to Powell Center Data and Information Policy
[¥] Powell Fellow

Submitted: 30 January 2018

Table 2 continued. List of participants (in alphabetical order).

Participant	Professional title(s)	Affiliation(s)	Expertise
Ahjond Garmestani	Research Scientist	U.S. Environmental Protection Agency	Environmental law and policy, environmental governance, social-ecological systems, ecology
Jacquelyn Gill	Assistant Professor	University of Maine	Paleoecology, biodiversity
John E. Gross	Ecologist	National Park Service	Climate science, land use change, ecosystems
Caleb Roberts	Ph.D. Student	University of Nebraska-Lincoln	Applied ecology, landscape ecology
George Sugihara[Θ]	McQuown Chair, Professor	Scripps Institution of Oceanography, University of California San Diego	Time series modeling, theoretical ecology
Dirac Twidwell	Assistant Professor	University of Nebraska-Lincoln	Rangeland ecology, fire ecology, resilience
Hao Ye [Θ]	Postdoctoral Research Associate	University of Florida	Complex systems, nonlinear forecasting

[Θ] Principal Investigator
[*] Unconfirmed participant
[§] Liaison to Powell Center computing staff and party responsible for adherence to Powell Center Data and Information Policy
[¥] Powell Fellow

6 References

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LaDeau, S. L., B. A. Han, E. J. Rosi-Marshall, and K. C. Weathers. 2017. The Next Decade of

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Sugihara, G., and R. M. May. 1990. Nonlinear forecasting as a way of distinguishing chaos from. Nature 344:6268.

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Jessica L. Burnett

Macroecology | Complex Systems

Education

University of Nebraska-Lincoln in Lincoln, NE
Ph.D. (*expected* 2019) Natural Resource Sciences and Applied Ecology
University of Florida in Gainesville, FL
M.Sc. (2015) Wildlife Ecology and Conservation
B.Sc. (2013) Wildlife Ecology and Conservation

Peer-reviewed Publications

1. Donovan, V.M., **J.L. Burnett**, C.H. Bielski, H. E. Birge, R. Bevans, D. Twidwell, and C.R. Allen. (*submitted*) Patterns of woody encroachment from native tree plantings in a temperate grassland. *Journal of Applied Ecology*
2. Roberts, C.P., **J.L. Burnett**, V.M. Donovan, C. Wonkka, C.H. Bielski, C.R. Allen, A. Garmestani, D.G. Angeler, T. Eason, S. Sundstrom, D. Twidwell (*revisions submitted*) Early warnings for state transitions. *Rangeland Ecology and Management*
3. La Sorte, F.A., C.A. Lepczyk, **J.L. Burnett**, A. Hurlbert, M. Tingley, and B. Zuckerberg. (*revisions submitted*) Opportunites and challenges for Big Data ornithology. *The Condor*
4. Chuang, W.C., T. A. Garmestani, T. Eason, T.L. Spanbauer, H.B. Fried-Peterson, C. Roberts, S. Sundstrom, **J.L. Burnett**, D. G. Angeler, B. Chaffin, L. Gunderson, D. Twidwell, C. R. Allen (*accepted*) Quantitative approaches for assessing ecological and community resilience. *Journal of Environmental Management.*
5. **Burnett, J.L.**, K. L. Pope, A. Wong, C. R. Allen, D. M. Haak, B. J. Stephen, and D. R. Uden. (*accepted*) Thermal tolerance limits of the invasive Chinese mysterysnail *Bellamya chinensis* and implications for management". *American Malacological Bulletin*
6. **Burnett, J.L.**, C. R. Allen, C. P. Roberts, M. Bomberger Brown, and M. P. Moulton. 2017. Eurasian Tree Sparrow (*Passer montanus*) range expansion in North America. *Biological Invasions* 19(1): 5-9 doi:10.1007/s10530-016-1273-4
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9. **Burnett, J.L.** and M. P. Moulton. 2015. Recent trends in House Sparrow (*Passer domesticus*) distribution and abundance in Gainesville, Alachua County, Florida. *Florida Field Naturalist* 43(4):167-172

Select Honors & Awards

2017-18	Fling Fellowship, University of Nebraska-Lincoln **$20,000**
2017	Big Ten Academic Alliance Traveling Scholar
2016-18	University of Nebraska Center for Great Plains Studies Graduate Fellow
2016-	AAAS/Science Program for Excellence in Science Award
2016	2nd place, School of Natural Resources Elevator Speech Competition **$300**

2016-18 Resilience Alliance Young Scholar, The Resilience Alliance
2015-18 Othmer Fellowship, University of Nebraska-Lincoln **$24,000**

Grants

for research

2013 IFAS Extension Internship for Undergraduate Research, University of Florida **$2,200**
2013 Ordway-Swisher Biological Station Undergraduate Research, University of Florida **$550**

for travel

2017 Nelson Memorial Fellowship, Univeristy of Nebraska-Lincoln **$695**
2017 Kellogg Biological Station, Michigan State University and Big Ten Academic Alliance **$500**
2016 Nelson Memorial Fellowship, Univeristy of Nebraska-Lincoln **$900**
2016 Center for Great Plains Studies, Univeristy of Nebraska-Lincoln **$750**
2016 American Ornithologists' Union **$250**
2015 NSF Diversity Award, Southeastern Ecology and Evolution Conference **$650**
2015 Department of Wildlife Ecology and Conservation, University of Florida **$250**
2015 Graduate Student Council, University of Florida **$350**
2015 Office of Research University of Florida **$500**
2014 Department of Wildlife Ecology and Conservation, University of Florida **$250**
2013 Office of the Dean, Institute of Food and Agricultural Sciences, University of Florida **$750**

for community outreach

2015 Outdoor Education Program, Reichert House, Gainesville Police Department, FL **$1,200**

for membership

2013 American Ornithologists' Union Undergraduate Student Membership Award

Recent Service

at the University of Nebraska-Lincoln

2018 Natural Resources Diversity Initiative committee, University of Nebraska-Lincoln
2017 Key player in achieving institutional membership to the Association for Women in Science
2016- Student Representative, Faculty Advisory Committee, School of Natural Resources
2016- Student Representative, Digital Team, School of Natural Resources
2016 Organizer, Association for Women in Science Mentor Workshop
2016 Seminar Coordinator, School of Natural Resources
2015-16 Founder & President, Natural Resources Diversity Initiative student group
2015-16 Department Representative Representative, Graduate Student Association
2015 Founder, Affiliate Chapter of the Association for Women in Science

to the profession

2016 Contributor to founding documents, Committee for Inclusive Ecology Section, ESA
2016- Reviewer, Wilson Journal of Ornithology
2015-16 Liaison, Urban Ecosystem Ecology Section, ESA

Hao Ye

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Research Interests

Time Series Analysis, Ecological Forecasting, Dynamic Systems

Education

Ph.D., M.S., Oceanography, University of California, San Diego

M.A., Psychology, University of California, San Diego

B.S., Computer Science, California Institute of Technology

Selected Publications

2018, Ushio, M., Hsieh, C.H., Masuda, R., Deyle, E., **Ye, H.**, Chang, C.W., Sugihara, G., and M. Kondoh. Fluctuating interaction network and time-varying stability of a natural fish community. *Nature* [in press].

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2017, McGowan, J.A.*, Deyle, E.R.*, **Ye, H.***, Carter, M.L., Perretti, C.T., Seger, K.D., de Verneil, A., and G. Sugihara*. Prediction of coastal algal blooms in Southern California. *Ecology* **98**: 1419-1433. (* = co-first authors)

2017, Storch, L.S., Glaser, S.M., **Ye, H.**, and A.A. Rosenberg. Stock assessment and end-to-end ecosystem models alter dynamics of fisheries data. *PLOS ONE* **12**: e0171644.

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2015, **Ye, H.**, Deyle, E.R., Gilarranz, L.J., and G. Sugihara. Distinguishing time-delayed causal interactions using convergent cross mapping. *Scientific Reports* **5**: 14750.

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2012, Sugihara, G., May, R., **Ye, H.**, Hsieh, C.H., Deyle, E., Fogarty, M., and S. Munch. Detecting causality in complex ecosystems. *Science* **338**: 496-500.

2011, Glaser, S.M., **Ye, H.**, Maunder, M.N., MacCall, A.D., Fogarty, M.J., and G. Sugihara. Detecting and forecasting complex nonlinear dynamics in spatially-structured catch-per-unit-effort time series for North Pacific albacore. *Canadian Journal of Fisheries and Aquatic Sciences* **68**: 400-412.

Honors and Awards

2015, SIO - E.A. Frieman Director's Prize

2014, SIO - E.W. Fager Memorial Award

Grants

2017, co-authored proposal for NSF DEB 1655203 - $407,000 (PI: George Sugihara)

2017, co-authored proposal for NSF ABI 1660584 - $658,634 (PI: George Sugihara)

2014, co-authored proposal for Lenfest Ocean Program 00028335 - $337,100 (PI: George Sugihara)

2014, co-authored proposal for US DOD SERDP 15 RC-2509 - $817,046 (PI: George Sugihara)

2010, NSF - Graduate Research Fellowship

Invited Talks

2017, Data-driven modeling of biological systems. *University of Florida Biocomplexity Engineering Group Seminar*, December 5, Gainesville, FL.

2016, Addressing nonlinearity in biological systems. *UCSC/NOAA Ecology Seminar*, June 14, Santa Cruz, CA.

2015, Information leverage in complex systems. *International workshop on development and application of empirical dynamic modeling for forecasting nonlinear systems*, September 16-18, Taipei, Taiwan.

Symposia and Workshops

2018, Ecological Knowledge and Predictions: Integrating Across Networks and National Observatories. (Early Career Invitee) *NSF OISE*, February 19-21, Tucson, AZ.

2017, sPred 2 - Synthesizing Predictability Research of Ecological Dynamics. (Working Group Participant) *German Centre for Integrative Biodiversity Research*, October 23-27, Leipzig, Germany.

2017, Empirical Dynamic Modeling for Fisheries Prediction and Management. (Symposium Chair) *AFS Annual Meeting*, August 20-24, Tampa, FL.

2017, Open Science and Reproducible Research. (Panel Participant) *Research Bazaar Arizona*, March 31-April 1, Tucson, AZ.

2015, A Hands-on Tutorial in Empirical Dynamic Modeling and Convergent Cross Mapping. (Session Organizer) *ESA Annual Meeting*, August 9-14, Baltimore, MD.

Service and Outreach

The American Naturalist, Ecology, Ecosphere, Marine Ecology Progress Series, Marine Mammal Science, Methods in Ecology and Evolution, Nature Communications, Oikos, Proceedings of the National Academy of Sciences, Science, Scientific Reports
Reviewer

Mozilla Science
Open Leadership Training / Open Project Lead Spring 2017

Craig Reece Allen
Nebraska Cooperative Fish & Wildlife Research Unit
School of Natural Resources
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University of Nebraska
Lincoln, Nebraska 68583-0984
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Professional Preparation

Institution	***Area of study***	***degree***	***year***
University of Wisconsin-Green Bay	Biology	B.S.	1989
Texas Tech University	Wildlife Management	M.S.	1993
University of Florida	Wildlife Ecology	Ph.D.	1997
University of Florida	Zoology	Post-doc	1998

Appointments

Leader - Nebraska Cooperative Fish and Wildlife Research Unit, July 2004 – present, **Professor**, School of Natural Resources, University of Nebraska, **August Larson Visiting Professor**, Swedish University of Agricultural Sciences, Uppsala, Sweden, 2012 – 2017. My appointment is 100% research, although I am responsible for the administration and supervision of the Nebraska Cooperative Fish and Wildlife Research Unit. I contribute to the academic and graduate education mission of the University of Nebraska by conducting grant-supported research, mentoring graduate students, and teaching graduate-level courses. My research focuses on the role of biological diversity in maintaining resilience in complex systems, and the impact of landscape change on native animal populations and diversity.

Publications most closely related to the project (of >150)

Allen, C.R., H. Birge, D.G. Angeler, C.A. Arnold, B.C. Chaffin, D. DeCaro, A.S. Garmestani, and L.H. Gunderson. 2017. Quantifying uncertainty and tradeoffs in resilience assessments. Ecology and Society: *in press*.

Cumming, G., D. Cumming, K. Maciejewski, M. Nenadovic, K. Kotschy, G. Epstein, H. Biggs, C. Moore, N. Ban, A. de Vos, M. Etienne, R. Mathevet, C. Allen, D. Biggs, and M. Schoon. 2015. Understanding protected area resilience: a multi-scale, social-ecological framework. Ecological Applications 25: 299-319.

Peterson, G., C.R. Allen, C.S. Holling. 1998. Ecological resilience, biodiversity, and scale. Ecossytems 1(1): 6-18.

Allen, C.R. and C.S. Holling. 2002. Cross-scale structure and scale breaks in ecosystems and other complex systems. Ecosystems 5(4): 315-318.

Gunderson, L.H, C.R. Allen, and C.S. Holling. 2010. Foundations of Ecological Resilience. Island Press, New York, NY. 466pp.

Nash, K.L., C.R. Allen, D.G. Angeler, C. Barichievy, T. Eason, A.S. Garmestani, N.A.J. Graham, D. Granholm, M. Knutson, R.J. Nelson, M. Nystrom, C.A. Stow and S.M. Sundstrom. 2014. Discontinuities, cross-scale patterns, and the organization of ecosystems. Ecology 95(3): 654-667.

Five other significant publications:

Angler, D.G. and C.R. Allen. Quantifying resilience. 2016. Journal of Applied Ecology 53: 617-624.

Allen, C.R., D.G. Angeler, C. Folke, D. Twidwell, D. Uden and G. Cumming. 2016. Quantifying spatial resilience. Journal of Applied Ecology 53: 625-635.

Birgé, H.E., C.R. Allen, D.G. Angeler, S.G. Baer, R.A. Bevans and D.H. Wall. 2016. Adaptive management for soil ecosystem services. Journal of Environmental Management 183: 371-378.

Garmestani, A. and C.R. Allen. 2014. Social – Ecological Resilience and Law. University of Columbia Press, New York, New York. 404pp.

Synergistic Activities

1. Executive Board, The Resilience Alliance (http://www.resalliance.org/), 2002 – present. The Resilience Alliance is a global consortium of institutions that seeks novel ways to integrate science and policy in order to discover foundations for sustainability.

2. Board of Science, The Resilience Alliance, 2014 – present.

3. Science Advisory Panel, James S. McDonnell Foundation, Studying Complex Systems (https://www.jsmf.org/programs/cs/), 2014 – present.

4. Board of Editors, Ecology and Society (http://www.consecol.org/Journal/), 2001 – present. Ecology and Society is an electronic, peer-reviewed, scientific journal devoted to the rapid dissemination of current research related to resilience and sustainability.

5. Principal Investigator, NSF-IGERT, Resilience and Adaptive Governance of Stressed Watersheds.

George Sugihara
Scripps Institution of Oceanography
University of California San Diego
La Jolla, CA 92093-0202

Professional Preparation

The University of Michigan	Natural Resources	B.S. 1973
Princeton University	Biology	M.S. 1980
Princeton University	Mathematical Biology	Ph.D. 1983

Academic Appointments

1995 - present	McQuown Chair, Distinguished Professor of Natural Science, SIO/UCSD
2002	Visiting Research Fellow, Merton College, University of Oxford
1990 - 1996	John Dove Isaac's Chair of Natural Philosophy, SIO/UCSD
1989 - 1995	Associate Professor, SIO/UCSD
1986 - 1989	Assistant Professor SIO/UCSD
1986	Visiting Professor, Department of Biophysics, Kyoto University, Japan
1985 - 1986	Senior Research Fellow, Japan Society for Promotion of Science
1985	Associate Professor of Mathematics, University of Tennessee
1984	Assistant Professor of Mathematics, University of Tennessee
1983 - 1985	Eugene P. Wigner Prize Fellow, Oak Ridge National Laboratory

Non-Academic Appointments (academic leave 1996-2001)

1998 - 2000	Managing Director, Deutsche Bank
1996 - 2000	Director, Deutsche Bank Global Markets, Head of Global Quantitative Proprietary Trading

Awards

2000	20th Century Distinguished Service Award
1999	Distinguished Statistical Ecologist Award (Trieste, Italy)
1983	Eugene P. Wigner Prize, Oak Ridge National Lab
1982	Ogden Porter Jacobus Prize, Princeton Univ. Graduate School highest academic honor

Expertise as Related to the Proposed Research

Theoretical approaches based on extracting information from observational data applied to algal physiology, atmospheric science, paleoecology and fisheries; research on generic early warning signs of critical transitions that apply across different classes of systems.

Selected Publications

Perretti, Charles T, Stephan B Munch, and George Sugihara. 2013. "Model-free Forecasting Outperforms the Correct Mechanistic Model for Simulated and Experimental Data." Proceedings of the National Academy of Sciences 110: 5253–5257.

Sugihara, G., R.M. May, H. Ye, E. Deyle, M. Fogarty and S. Munch. 2012. Detecting causality in complex ecosystems. Science 338:496-500.

Dakos, V., S.M. Glaser, C.H. Hsieh, G. Sugihara. 2017. Elevated nonlinearity as an indicator of shifts in the dynamics of populations under stress. Journal of the Royal Society Interface 14: 20160845.

Scheffer M., J. Bascompte, W.A. Brock, V. Brovkin, S.R. Carpenter, V. Dakos, H. Held, E.H. van Ness, M. Rietkerk and G. Sugihara. Early-warning signals for critical transitions. Nature 461:53-59.

Hsieh C.H., S.M. Glaser, A.J. Lucas and G. Sugihara. 2005. Distinguishing random environmental fluctuations from ecological catastrophes for the North Pacific Ocean. Nature 435:336-340.

Dixon, P.A., M. Milicich and G. Sugihara, 1999. Episodic fluctuations in larval supply. Science 283: 1528-1530.

Sugihara, G. and R.M. May. 1990. Nonlinear forecasting as a way of distinguishing chaos from measurement error in time series. Nature 344:734-741

Deyle, E. R., M. J. Fogarty, C. H. Hsieh, L. Kaufman, A. D. MacCall, S. B. Munch, C. T. Perretti, H. Ye, and G. Sugihara. 2013. Predicting climate effects on Pacific sardine. Proceedings of the National Academy of Sciences, 110(16), 6430–6435.

Synergistic Activities

Finance: Managing Director for Deutsche Bank for 5 years, heading a highly successful global proprietary trading group which applied nonlinear methods (Sugihara Trading System, STS) to forecast and exploit pricing inefficiencies in financial markets. These models were in use by DB proprietary trading for over a decade. Currently on the Editorial Board of Quantitative Finance.

Atmospheric Science: The Sugihara-May simplex projection method and the residual delay map have been used by the Bureau of Meteorological Research Centre as part of the Australian national standard for weather prediction tool set.

Neuroscience: Associate member of The Neurosciences Research Institute.

Cardiology: Introduced nonlinear methods as a noninvasive way to assess risk of heart disease in human infants. Advisory Board of LifeScore.

Conservation-Education and Fisheries Management: Past member of Scripps-Center for Marine Biodiversity and Conservation IGERT project to train graduate students in marine conservation, policy and resource economics. Developed a market-based incentive plan to manage Chinook salmon bycatch in the Bering Sea walleye pollock fishery (largest U.S. fishery) – modified and adopted as the "Inshore Chinook Salmon Savings Incentive Plan Agreement" (2008-2009). Collaborating with Head of Canada's Dept. of Fisheries and Oceans (Laura Richards) and her staff to implement nonlinear forecasting in setting targets for Fraser River sockeye salmon.

Genomics: Collaborating with the Salk Institute to apply EDM and CCM to problems in gene expression in cancer. We are finding that gene expression is a nonlinear *dynamic* process (occurs as interdependent processes in time) so that EDM and CCM can be highly informative.

Research Leadership: Two-term Member of the National Academies Board on Mathematical Sciences and it Applications; Member of NAS Committee to Evaluate US Fisheries Rebuilding; Member of NRC Committee to Evaluate the Effects of Sudden Climate Change

SUGIHARA BIOSKETCH NARRATIVE: Sugihara was a Managing Director at Deutsche Bank (1996-2001, AAA-rated with $1.2tr in assets) and was Head of Global Quantitative Proprietary Trading where he successfully used his proprietary forecasting methods to manage bank investments. He is on the Advisory Boards of several companies and helped found Prediction Company (sold to UBS) and Quantitative Advisors LLC (an advisory company created by Deutsche Bank which leased Sugihara's trading system until 2006). Sugihara has advised the Bank of England, the Federal Reserve Bank of New York, and to The United States Federal Reserve System on questions of systemic risk, and has appeared on panels regarding this topic with Henry Kissinger, Paul Volker, Joseph Steiglitz, and Pres. Musharaf (Pakistan). In 2009 he was interviewed and subsequently solicited for the position of Chief Scientist of NOAA at the level of Assistant Secretary Department of Commerce. His long-standing academic interest in true out- of-sample forecasting and in nonlinear (unstable, non-equilibrium) systems is having impact in various practical realms, where the implications of such behavior (eg. for management of risk or resources) are profound.

Powell Center Data Management Plan

Please submit along with the proposal for Prospective Working Groups.

Data Inputs (see Table 1 in proposal)				
Title	**Format (csv, ascii)**	**Data Volume Estimate (MB, GB, TB)**	**Source/URL**	**Use Restrictions**
North American Breeding Bird Survey (USGS)	.csv	0.75 GB	ftp://ftpext.usgs.gov/pub/er/md/laurel/BBS/DataFiles/	None
Amphibian and Reptile Monitoring Initiative (ARMI)	.csv	2.0 GB	https://armi.usgs.gov/amphibian_monitoring.php	None
California Current Ecosystem (NSF LTER)	.csv	1 GB	http://oceaninformatics.ucsd.edu/datazoo/catalogs/ccelter/datasets	None
Forest Inventory Analysis (USGS)	.csv	1 GB	https://www.fia.fs.fed.us/tools-data/index.php	Some data requires pull request
Paeoclimatology (NOAA)	.txt	0.50 GB	https://www.ncdc.noaa.gov/data-access/paleoclimatology-data/datasets	None
Microfossil occurrence records (Neptune Sandbox)	.csv	0.5 GB	http://www.nsb-mfn-berlin.de/	Pull request required for all data; invite curator(s) to collaborate; data destroyed at end of study period
Continuous Planktonic Recorder (SAHFOS)	.csv	1.0 GB	https://www.sahfos.ac.uk/data/our-data/	Pull requests required

Data Processing (will occur during the course of Working Group activities)	
Access and Sharing	Data will be accessed via direct download or through pull requests (when necessary) from the original data source. We intend to use only data that is publicly available to limit barriers for reproducibility.
Data Storage	The Powell Center Fellow will work with the Powell Center to make all data available through USGS ScienceBase (unless otherwise restricted by the data curator/collector).
Transformation and processing workflow	We will conduct all statistical analysis in Program R. All manuscripts and products will be accompanied by a Program R script (.R) or a RMarkdown file (.RMD + .PDF), and all steps and files necessary to reproduce our analyses and results. Steps will be clearly outlined started at the data import process through the production of Figures and Tables.
Technology needs	We will conduct all data management and statistical analyses in Program R. Although our team would benefit from an FTP or Cloud Storage server through the Powell Center it is not necessary.

POWELL CENTER BUDGET SHEET

Working Group Name:	**Scale mismatch**					
A. Travel	**Year 1**			**Year 2**		**TOTAL TRANSPORTATION**
Names of Working Group members	Name of Departure City	Roundtrip Economy Airfare	Other transportation expenses	Roundtrip Economy Airfare plus 10%	Other transportation expenses	
Jessica Burnett	Omaha, NE	$ 260.00	$ 235.00	$ 546.00	$ 470.00	$ 1,511.00
Craig Allen	Omaha, NE	$ 260.00	$ 235.00	$ 546.00	$ 470.00	$ 1,511.00
Hao Ye	Gainesville, FL	$ 418.00	$ 235.00	$ 877.80	$ 470.00	$ 2,000.80
George Sugihara	San Diego, CA	$ 360.00	$ 235.00	$ 756.00	$ 470.00	$ 1,821.00
Ethan Deyle	San Diego, CA	$ 360.00	$ 235.00	$ 756.00	$ 470.00	$ 1,821.00
Dirac Twidwell	Omaha, NE	$ 260.00	$ 235.00	$ 546.00	$ 470.00	$ 1,511.00
Caleb Roberts	Omaha, NE	$ 260.00	$ 235.00	$ 546.00	$ 470.00	$ 1,511.00
Ahjond Garmestani	Cincinnati, OH	$ 426.00	$ 235.00	$ 894.60	$ 470.00	$ 2,025.60
Morgan Ernst	Gainesville, FL	$ 418.00	$ 235.00	$ 877.80	$ 470.00	$ 2,000.80
Christie Bahlai	Akron, OH	$ 320.00	$ 235.00	$ 672.00	$ 470.00	$ 1,697.00
Karen Bailey	Gainesville, FL	$ 418.00	$ 235.00	$ 877.80	$ 470.00	$ 2,000.80
Ryan Batt	Cincinnati, OH	$ 426.00	$ 235.00	$ 894.60	$ 470.00	$ 2,025.60
Jacquelyn Gill	Bangor, ME	$ 554.00	$ 235.00	$ 1,163.40	$ 470.00	$ 2,422.40
John E. Gross	LaPorte, CO	$ -	$ 150.00	$ -	$ 300.00	$ 450.00
Graeme Cumming	Cairns, AUS	$ 1,650.00	$ 235.00	$ 3,465.00	$ 470.00	$ 5,820.00
	Total Year 1 Transportation expenses=		$ 9,830.00	**Total Y2 transportation=**	$ 20,299.00	**$ 30,129.00**
B. Per Diem	**Year 1 Per Diem**			**Y2 Per Diem (with est. cost increase)**		**TOTAL PER DIEM**
Number of participants * number of days (4 day minimum) * $180/day	**(# of people) x (# days) x (180) =**		$16,200.00	**(# of people) x (# days) x (200) =**	**$ 24,000.00**	**$ 40,200.00**
C. Fellow Support*	**Year 1 Fellow Support***			**Year 2 Fellow Support***		**TOTAL FELLOW SUPPORT**
Fellow salary and benefits cost:	Fellow Salary&Benefits:		$ 51,025.00	Fellow Salary&Benefits:	$34,075.00	$ 85,100.00
Indirect/Overhead Costs (@17.5%)	Indirect/Overhead Costs (@17.5%)		$ 8,929.38	Indirect/Overhead Costs (@17.5%)	$5,963.13	$14,892.50
Total, not to exceed $100,000	**YEAR 1 FELLOW SUPPORT**		**$ 59,954.38**	**YEAR 2 FELLOW SUPPORT**	**$40,038.13**	**$ 99,992.50**
D. Page Charges						**$ 1,800.00**
E. Salary support for Water Science Center Particpants during Working Group meetings ONLY	**Year 1 WSC salary**			**Year 2 WSC salary**		**TOTAL WSC SALARY SUPPORT**
WSC participant name						
WSC participant name						$
	YEAR 1 WSC SALARY		$	**YEAR 2 WSC SALARY**	**$**	
F. WORKING GROUP TOTAL EXPENSES	**Year 1 Total:**		**$ 85,984.38**	**Year 2 Total:**	**$ 84,337.13**	**WORKING GROUP TOTAL**
Notes						**$ 172,121.50**