

sDiv Workshop Summary

"Functional Information: its potential for quantifying biodiversity and its relation to ecosystem functioning"

sFIND

1. **sFind** (Functional Information: its potential for quantifying biodiversity and its relation to ecosystem functioning) met on 7th-11th September 2015.

Project Summary: This highly interdisciplinary workshop unites knowledge and understanding from information theory, community ecology, and molecular and computational biology. It will be preceded by remotely managed collaboration; hence, its purpose is to consolidate developing ideas. We will explore the use of information theory to address the iDiv theme question of how biodiversity gives rise to ecological function. This will address the complexity of biological systems as dynamic networks, seeking to quantify systemic complexity and explore the potential for complexity metrics to improve understanding of how biodiversity contributes to ecological function. We will focus on "How to scale-up existing information-based measures from the molecular scale to all scales, including that of ecological networks". The workshop shall examine information-theoretical methods to quantify biodiversity as complexity, in terms of information content, using network models of biological systems at multiple scales of organisation. We will explore ways to measure the contribution of biological complexity to ecosystem function by mapping the state-space of biological-network models in a range of 'function' metrics using a case study system to encourage its take-up by empirical scientists. Following the workshop we will apply our developments to estimate the functional information of the case study system and relate this to empirical measures of ecological function to test the value of this concept for practical prioritising of ecosystem attributes in conservation plans.

2. Contact person/s

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3. participant list (name & institution, no email address)

Surname	Forename	Institution
Albantakis	Larissa	University of Wisconsin
Annala	Arto	University of Helsinki

Surname	Forename	Institution
Ardell	David	University of California
Baverstock	Keith	University of Eastern Finland
Cobbold	Christina	University of Glasgow
Farnsworth	Keith	Queen's University Belfast
Gamfeldt	Lars	University of Gothenburg
Gross	Ivo	Martin-Luther-University Halle-Wittenberg
Kim	Hyunju	Arizona State University
Lyashevskaja	Olga	NIOZ Royal Netherlands Institute for Sea Research (NL)
Rossberg	Axel	Queen Mary College, London University
Schneider	Thomas	National Cancer Institute Maryland, USA

4. workshop agenda

Mini Seminars. Diversity, Redundancy and Function: the observations that motivate our workshop. Round table discussion: What is biodiversity and what is biological function? Seminar Repeated Patterns in Nature and how to quantify them. Seminar Living systems as Networks: repeated patterns and how to quantify them. Round table discussion: repeated patterns: is there a mathematical basis for biological complexity at every level? Mini Seminars Information metrics for complexity: from molecules to ecosystems. Seminar: Generalised Entropy - use and quantification. Seminar: Entropy - thermodynamics and ecological function. Round table discussion: Is Entropy a unifying quantitative concept for understanding functional biodiversity? Mini Seminars Biodiversity and Function in Real Ecosystems. Round table discussion: How do we apply the theory to quantifying functional diversity in real systems? Round table discussion: Forming a conceptual framework for understanding functional diversity through information metrics. Discussion: A practical and concrete plan for publication: who does what.



5. Feedback of applicants

The discussion focussed on metrics for biodiversity, definitions and the relationships between complexity -derived and information theory -derived concepts of diversity, using examples from real ecosystems and genetic systems. We also closely considered the meaning and implications of biological function and its relationship with complexity, via causal network theory. We considered how to use these concepts in creating fundamental axes and units of measure for biodiversity-function relationships. It turned out that information theoretic (Shannon) concepts for biodiversity cannot be directly related to complexity (Kolmogorov) concepts, but the two can be used in complementary approaches, which it would be fair to say, we are still working out. Discussions clarified that functional diversity needed a dynamic description for quantification and we agreed on network metrics with generalised entropy measure equivalents for this. We also considered the physical (thermodynamic) basis for function (which is physical action) using a fundamental description of the thermodynamics of ecosystems in general, recognising how the evolution of complexity follows from this

general description. We are writing a paper which establishes a generalised biodiversity function relationship. By generalised, we mean a) applying to more than one ontological level of organisation (e.g. cell signal network and ecosystem) b) biodiversity is defined in a general way (e.g. effective number of 'units' (may be taxonomic units or molecules)) c) function is defined in a general, but quantifiable way, via network dynamics and ontological classification. The main open question remaining was how to relate complexity measures to information theoretic measures of biodiversity quantities and this will be further examined in the writing of the jointly authored paper that is now in preparation.

- focal areas of discussion + main results/conclusions + open questions
- content of presentations

Presentations were provided on biodiversity-function relationships; dynamic foodwebs; generalised entropy measures; biodiversity metric profiles; Shannon's information theory applied to molecular and ecological examples; the thermodynamic basis of life and the universe (with application to ecology) network complexity and measures of causation; cellular information storage and processes and genetic ontologies.

- which outputs were discussed and which steps were undertaken: We agreed to write a jointly authored paper for a review journal such as Trends in Ecology and Evolution, to write a paper on dynamics biodiversity metrics for a special issue of the journal Conservation Biology and to develop a proposal for a follow-up workshop in 2016.

- balance between work on outputs, general brainstorming/ The first three days of the workshop were taken up with seminars and discussions as the diverse range of scientific disciplines represented had to find a common understanding. On day 4, we moved towards this common understanding and identified key interfaces and open questions; Day 5 was devoted to outputs.

- information exchange and participants presentations in %: close to 50% / 50% and not entirely separable because much discussion followed and often penetrated the presentations.

- inspiration for own work and/or further cooperation (?) The workshop brought up important and yet unresolved issues concerning the notion of causality, the construction of causal models, and potential practical and theoretical measures for quantifying causation across various disciplines. One particularly interesting issue is the interrelation between

identifying relevant (macro) variables of a causal model and quantifying their causal interaction. While solving these open problems about causation lies outside the scope of the workshop, it certainly helped to show the universality and urgency of solving these issues across scientific disciplines.

"Over recent weeks I've been thinking very hard about how my ideas fit with those held by others at the meeting. I am a little disappointed that no one has criticised the presentation I made".

- general working atmosphere and feedback on sDiv support (?)

"The location and atmosphere were very pleasant, thanks to the fellow participants and the sDiv support. I especially appreciated the help with dinner reservations, which is not so common and guaranteed more discussion and social interaction during dinner time".

"Support by sDiv, in particular Agnes Reuter, was superb."

" I feel I made some new friends".

- next steps (?)

We are presently working together by email and using the sDIV cloud and other resources for sharing papers and files over the internet. We are writing one or more joint papers together and presently circulating drafts, discussions and suggestions. We plan to propose a followup meeting as soon as we are able (next year). We are also very active in finding data to illustrate our ideas with and have already made progress with that.

[Please note that we want you writing about the workshop itself and the general agenda and outcomes, not about internal unpublished ideas.]

In case of questions, please contact Marten Winter marten.winter@idiv.de or tel. +49 (0)341 97 33129.