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Aggregation of incomplete food web data may help to suggest sampling strategies

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ABSTRACT

Aggregation of data and incomplete sampling are two notoriuos problems of food web research. We suggest to look at them in parallel since their effects are interdependent. Different aggregation methods are not equally sensitive to missing data and they lead to different biases in describing food web structure. In this paper, we construct a low-quality food web of Lake Balaton (based only on high-quality literature), aggregate it in several ways, compare the different versions of the food web by network analysis and discuss how the results can help future sampling, field work and data management. We identify groups where resolution or aggregation should be increased.

1. Introduction

In the era of bioinformatics, big data and high-throughput experiments, ecology is also moving towards a direction where managing large databases and applying analytical techniques become increasingly important. Large food web databases are available in ecology and a range of network analytical techniques support research. But some key issues, mostly of biological nature, are still unresolved. One of the most critical problems of food web research is still aggregation. While transforming raw data into a network model, some kind of aggregation is always unavoidable. Aggregation can be of spatial nature (pooling data sampled in different location, Warren, 1989) and it can be of temporal nature (pooling data sampled in different time, Baird and Ulanowicz, 1989). Moreover, it can be based also on the taxonomy of the sampled organisms (e.g. belonging to the same family) and it can be derived mathematically, based on the structure of the database (e.g. trophospecies, Yodzis and Winemiller, 1999). The first two approaches (space and time) are more about the amount of data but it may also influence food web structure (selectively for different network properties: Jordán and Osváth, 2009). The two latter approaches (taxonomy and topology) are about how to define the nodes of the network and these approaches surely and massively change food web structure.

Understanding the effects of aggregation on food web structure is an old problem. Key questions are which network properties scale with the level of aggregation (Sugihara et al., 1989), what are the differences between various kinds of aggregation (Gauzens et al., 2013) and what are the effects of inconsistent, heterogeneous aggregation (Thompson and Townsend, 2000). Biological expertise and mathematical algorithms are both used as aggregation principles but our knowledge is still very limited – yet, each food web ever described has been built by some level of aggregation of primary field data.

Earlier results suggest that food webs containing trophic species and taxonomic species are differently sensitive to sampling efforts (Martinez et al., 1999). Thus, here we link the aggregation problem to the incompleteness of data. Sampling efforts and database completeness have been shown to seriously influence food web structure (Goldwasser and Roughgarden, 1997), especially in case of non-weighted, binary networks (Banašek-Richter et al., 2004). Stronger aggregation is frequently motivated by the unavailability of detailed and better-resolved data (e.g. bacteria). We suggest that research on aggregation and sampling should go hand in hand, in a potentially synergestic way. Clarifying the logic of the aggregation process can suggest where to improve the database and better data may call for stronger or weaker resolution. The incompleteness of food web data is a poorly studied field but some findings are quite important to consider (see the sensitivity of network measures to missing data: Fedor and Vasas, 2009). Large (and possibly public)

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Table 1
List of organisms. The list of organisms (codes and names of trophic groups) in each version of the food web: the master network (m), the taxonomically aggregated versions (t1, t2, t3, t4, t5) and the topologically aggregated version (s). Presence is marked by "X". Codes can be numbers (for trophic groups of the master network), letters (for taxonomically aggregated groups) and both (for topological aggregates).

code	trophic group	m	t1	t2	t3	t4	t5	s
1	Abramis brama	X	X					
2	Abramis brama LARGE	X						
3	Abramis brama SMALL	X						X
4	Acanthocyclops vernalis	X	X	X	X			
5	Alburnus alburnus	X	X					X
6	Algae	X	X	X	X	X		X
7	Amphipoda	X	X	X	X			X
8	Anas platyrhynchos	X	X	X				X
9	Anas querquedula	X	X	X				X
10	Anguilla anguilla	X	X					
11	Anser albifrons albifrons	X	X	X				
12	Anser fabilis	X	X	X				
13	Aquatic insects	X	X	X	X			X
14	Asellus	X	X	X	X			X
15	Aspius aspius	X	X					X
16	Aythya ferinaferina	X	X	X				X
17	Aythya fuligula	X	X	X				X
18	Aythya nyrocanyroca	X	X	X				X
20	Bacteria	X	X	X	X	X	X	X
21	Blicca bjoerkna	X	X					
22	Bucephala clangula clangula	X	X	X				X
23	Carassius auratus gibelio	X	X					
24	Carassius gibelio	X	X					X
25	Ceratopogonidae larvae	X	X	X	X			
26	Chironomidae larvae	X						X
27	Chironomidae pupae	X						
28	Chironomidae imago	X						X
29	Chlorophyta	X	X	X	X	X		
30	Chrysophyta	X	X	X	X	X		
31	Cladocera	X	X	X	X			X
32	Copepoda	X	X	X	X			X
33	Corophium	X	X	X	X			X
34	Culicidae larvae	X	X	X	X			X
35	Cyanophyta	X	X	X	X	X		
36	Cyclops	X	X	X	X			
37	Cyclops vicinus	X	X	X	X			X
38	Cyprinus carpio	X	X					
39	Daphnia cucullata	X	X	X	X			
40	Daphnia galeata	X	X	X	X			
41	Daphnia hyalina	X	X	X	X			
42	Detritus	X	X	X	X	X	X	X
43	Diaphanosoma birgei lacustris	X	X	X	X			
44	Diaphanosoma mongolianum	X	X	X	X			X
45	Diatoms	X	X	X	X	X		X
46	Dikerogammarus	X	X	X	X			X
47	Dreissena polymorpha	X	X	X	X			X
48	Ephemeroptera larvae	X	X	X	X			
49	Eudiaptomus gracilis	X	X	X	X			
50	Fish eggs	X						X
51	Fulica atra	X	X	X				X
52	Fuligula ferina	X	X	X				X
53	Fungi	X	X	X	X	X	X	
54	Gammaridea	X	X	X	X			
55	Gastropoda	X	X	X	X	X	X	
56	Gymnocephalus cernuus	X	X					
57	Hirudinoidea	X	X	X	X			
58	HNF	X	X	X	X	X	X	X
59	Hypophthalmichthys	X	X					X
60	Jaera sarsi	X	X	X	X			
61	Land insects	X	X	X	X			X
62	Lepomis gibbosus LARGE	X						X
63	Lepomis gibbosus SMALL	X						X
64	Leptodora kindtii	X	X	X	X			
65	Limnomysis benedeni	X	X	X	X			
66	Lithoglyphus naticoides	X	X	X	X			X
67	Macrophyta	X	X	X	X	X		X
68	Mesocyclops leuckarti	X	X	X	X			
69	Micronecta	X	X	X	X			
70	Neogobius fluviatilis	X	X					X
71	Odonata larvae	X	X	X	X			X
72	Oligochaeta	X	X	X	X			
73	Ostracoda	X	X	X	X			X
74	Pelecus cultratus	X	X					X