

# FCM Consensual Map / WOE Initial Summary

March 17, 2009

## Definitions and Terminology:

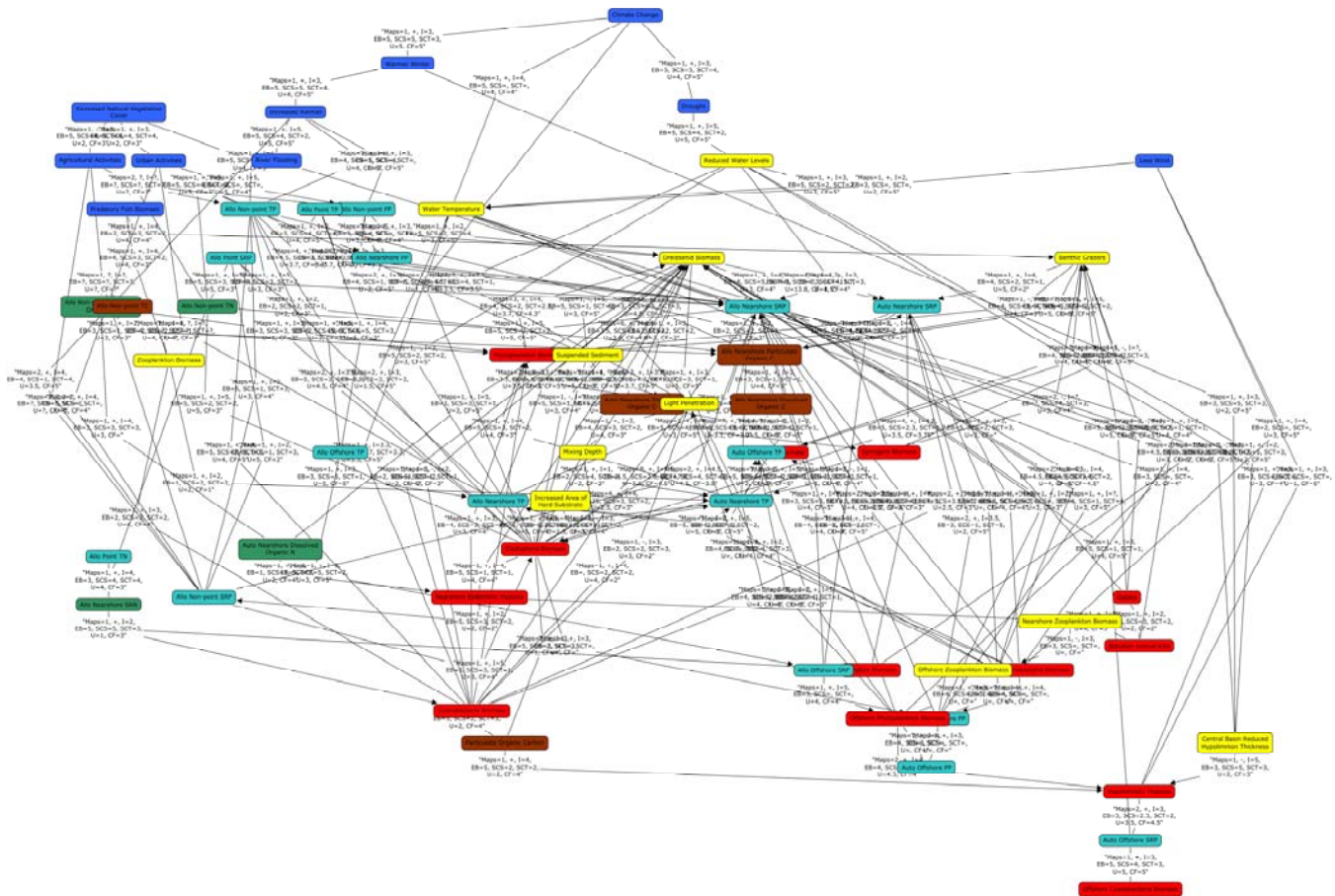
- **Fuzzy Cognitive/Conceptual Map (FCM):** A tool for schematically representing causal relationships within a system. A qualitative model of how a given system operates.
- **Concept (node, vertex):** A “box” in a FCM. Represents a factor or process.
- **Arc:** An “arrow” in a FCM. Depicts a causal relationship between two factors or processes.
- **Proposition (link):** Two concepts connected by an arc, depicting the effect one concept has on another concept.
- **Arc Attributes:** Descriptors assigned to an arc, describing the relationship (e.g., directionality, strength). For this exercise, we used seven attributes: Sign; Importance/Strength; Evidence\_base; Scale\_space; Scale\_time; Universality; and Change\_feasibility.
- **Consensual Map:** the union of individual maps.
- **Weight of Evidence:** \_\_\_\_\_
- **WOE Consensual Map:** the union of individual maps, with arcs appropriately weighted (e.g., arcs which have high prevalence in the sample have a higher WOE score).

# Characteristics of “The Hairball”

Total number of approved FCMs contributing to the consensual map: **10**

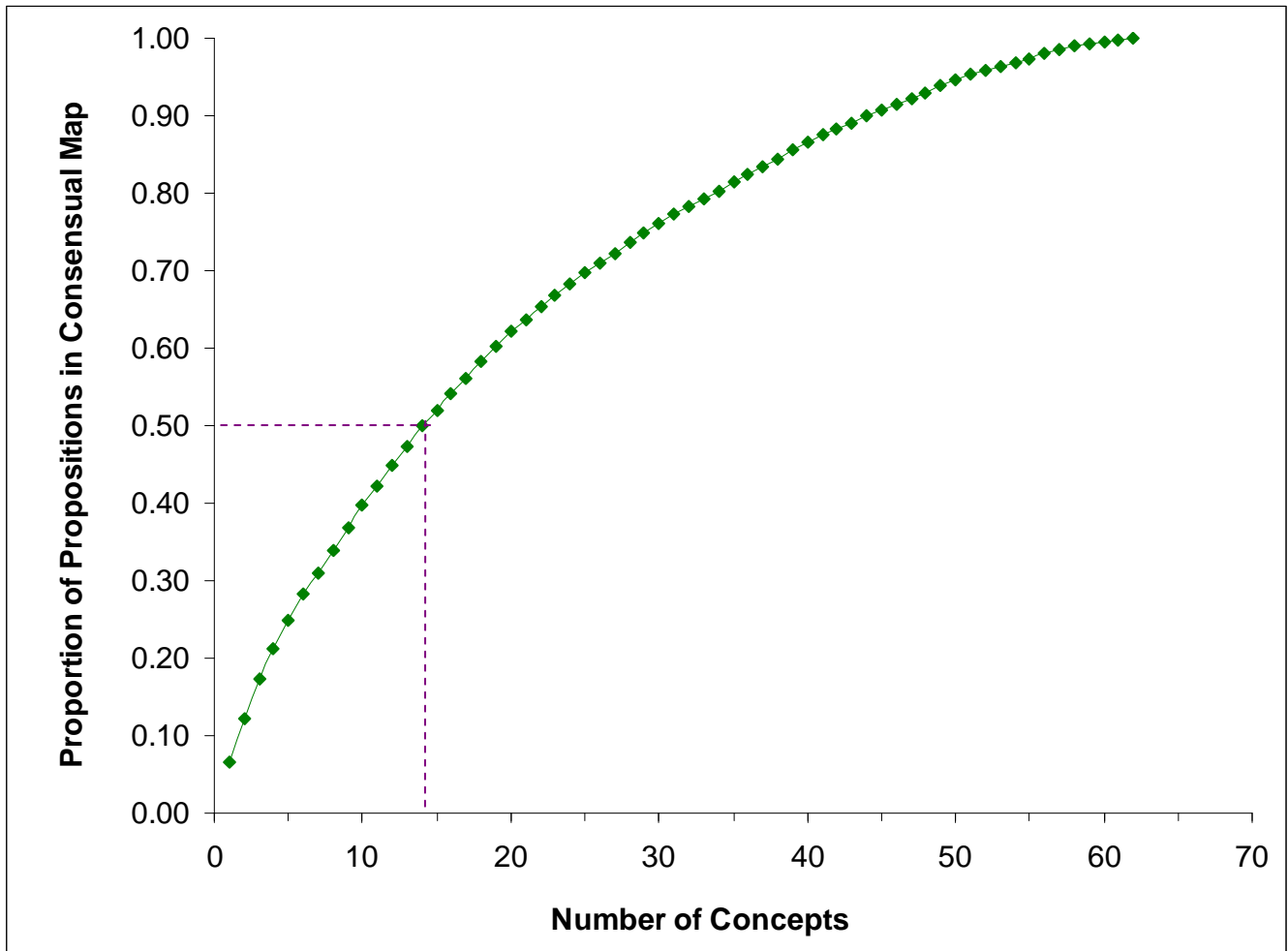
After combining all unique positions from each submitted FCM to form the consensual map, we have a final map (i.e. “the hairball”; Fig.1) comprised of:

62 concepts  
forming  
193 propositions



**Figure 1.** The consensual map (i.e., “The Hairball”). Arc attributes represent the averages in situations when more than one map had that particular relationship. “Maps” = Number of maps that relationship was present on. Blue=“Emitter”; Aqua=Phosphorus-related; Greenish=Nitrogen-related; Brown=Carbon-related; Red=“endpoint”; Yellow=1 directly upstream from Endpoint and not already corresponding to another colour. See also CXL file.

**Question 1.** How much information in the consensual map (in terms of number of propositions) is added by increasing the number of unique concepts?



**Figure 2.** Accumulation curve for the consensual map, showing number of concepts vs. proportion of propositions in the consensual map.

***Question 2. Which concepts are most prevalent/interconnected within the consensual map?  
i.e. Which factors are connected to many other factors and processes in terms of the problem  
of re-eutrophication?***

**Table 1.** Number of propositions each concept appears in, within the consensual map. Concepts are ordered from most propositions to least; darker shading indicates more propositions.

<b>Concept</b>	<b>Total Number of Links</b>
Dreissenid Biomass	25
Cladophora Biomass	22
Allo Nearshore SRP	20
Auto Nearshore TP	15
Cyanobacteria Biomass	14
Allo Non-point TP	13
Allo Non-point SRP	11
Phytoplankton Biomass	11
Auto Nearshore SRP	11
Benthic Grazers	11
Allo Nearshore TP	10
Nearshore Phytoplankton Biomass	10
Light Penetration	10
Water Temperature	10
Allo Nearshore Particulate Organic C	8
Offshore Phytoplankton Biomass	8
Auto Nearshore PP	8
Agricultural Activities	8
Reduced Water Levels	8
Nearshore Cyanobacteria Biomass	7
Hypolimnetic Hypoxia	6
Bacterial Biomass	6
Allo Non-point PP	6
Allo Non-point TN	6
Allo Offshore SRP	5
Nearshore Epibenthic Hypoxia	5
Suspended Sediment	5
Increased Rainfall	5
River Flooding	5
Allo Point SRP	5
Spirogyra Biomass	4
Allo Nearshore PP	4
Central Basin Reduced Hypolimnion Thickness	4
Allo Nearshore Dissolved Organic N	4
Allo Offshore TP	4
Auto Offshore TP	4
Gobies	4
Zooplankton Biomass	4
Allo Non-point Dissolved Organic N	4
Urban Activities	4
Climate Change	4
Botulism Animal Kills	3
Lyngbya Biomass	3
Auto Nearshore Dissolved Organic N	3
Auto Offshore SRP	3

Particulate Organic Carbon	3
Mixing Depth	3
Warmer Winter	3
Allo Point TP	3
Increased Natural Vegetation Cover	3
Less Wind	3
Auto Offshore PP	2
Allo Nearshore Dissolved Organic C	2
Allo Non-point TC	2
Auto Nearshore Dissolved Organic C	2
Drought	2
Increased Area of Hard Substrate	2
Predatory Fish Biomass	2
Offshore Cyanobacteria Biomass	1
Allo Point TN	1
Nearshore Zooplankton Biomass	1
Offshore Zooplankton Biomass	1

***Question 3. Which concepts have the greatest number of links out?  
(i.e., directly influence the greatest number of other concepts)***

**Table 2.** Number of links out for each concept within the consensual map (i.e., number of propositions that each concept appears in as a FROM concept). Darker shading indicates more propositions. Concepts are ordered from most propositions to least; darker shading indicates more propositions.

Concept	Number of Links OUT
Dreissenid Biomass	16
Cladophora Biomass	6
Allo Nearshore SRP	9
Auto Nearshore TP	6
Cyanobacteria Biomass	2
Allo Non-point TP	9
Allo Non-point SRP	4
Phytoplankton Biomass	4
Auto Nearshore SRP	6
Benthic Grazers	7
Allo Nearshore TP	4
Nearshore Phytoplankton Biomass	4
Light Penetration	5
Water Temperature	7
Allo Nearshore Particulate Organic C	3
Offshore Phytoplankton Biomass	3
Auto Nearshore PP	4
Agricultural Activities	7
Reduced Water Levels	7
Nearshore Cyanobacteria Biomass	2
Hypolimnetic Hypoxia	1
Bacterial Biomass	2
Allo Non-point PP	3
Allo Non-point TN	3
Allo Offshore SRP	2
Nearshore Epibenthic Hypoxia	2
Suspended Sediment	3
Increased Rainfall	4
River Flooding	4
Allo Point SRP	5
Spirogyra Biomass	0
Allo Nearshore PP	1
Central Basin Reduced Hypolimnion Thickness	1
Allo Nearshore Dissolved Organic N	2
Allo Offshore TP	2
Auto Offshore TP	2
Gobies	2
Zooplankton Biomass	3
Allo Non-point Dissolved Organic N	3
Urban Activities	3
Climate Change	4
Botulism Animal Kills	0
Lyngbya Biomass	0
Auto Nearshore Dissolved Organic N	1
Auto Offshore SRP	1

Particulate Organic Carbon	1
Mixing Depth	2
Warmer Winter	2
Allo Point TP	3
Increased Natural Vegetation Cover	3
Less Wind	3
Auto Offshore PP	0
Allo Nearshore Dissolved Organic C	1
Allo Non-point TC	1
Auto Nearshore Dissolved Organic C	1
Drought	1
Increased Area of Hard Substrate	1
Predatory Fish Biomass	2
Offshore Cyanobacteria Biomass	0
Allo Point TN	1
Nearshore Zooplankton Biomass	1
Offshore Zooplankton Biomass	1

***Question 4. Which concepts have the greatest number of links in?  
(i.e., are directly influenced by the greatest number of other concepts)***

**Table 3.** Number of links in for each concept within the consensual map (i.e., number of propositions that each concept appears in as a TO concept). Darker shading indicates more propositions. Concepts are ordered from most propositions to least; darker shading indicates more propositions.

Concept	Number of Links IN
Dreissenid Biomass	9
Cladophora Biomass	16
Allo Nearshore SRP	11
Auto Nearshore TP	9
Cyanobacteria Biomass	12
Allo Non-point TP	4
Allo Non-point SRP	7
Phytoplankton Biomass	7
Auto Nearshore SRP	5
Benthic Grazers	4
Allo Nearshore TP	6
Nearshore Phytoplankton Biomass	6
Light Penetration	5
Water Temperature	3
Allo Nearshore Particulate Organic C	5
Offshore Phytoplankton Biomass	5
Auto Nearshore PP	4
Agricultural Activities	1
Reduced Water Levels	1
Nearshore Cyanobacteria Biomass	5
Hypolimnetic Hypoxia	5
Bacterial Biomass	4
Allo Non-point PP	3
Allo Non-point TN	3
Allo Offshore SRP	3
Nearshore Epibenthic Hypoxia	3
Suspended Sediment	2
Increased Rainfall	1
River Flooding	1
Allo Point SRP	0
Spirogyra Biomass	4
Allo Nearshore PP	3
Central Basin Reduced Hypolimnion Thickness	3
Allo Nearshore Dissolved Organic N	2
Allo Offshore TP	2
Auto Offshore TP	2
Gobies	2
Zooplankton Biomass	1
Allo Non-point Dissolved Organic N	1
Urban Activities	1
Climate Change	0
Botulism Animal Kills	3
Lyngbya Biomass	3
Auto Nearshore Dissolved Organic N	2
Auto Offshore SRP	2



Particulate Organic Carbon	2
Mixing Depth	1
Warmer Winter	1
Allo Point TP	0
Increased Natural Vegetation Cover	0
Less Wind	0
Auto Offshore PP	2
Allo Nearshore Dissolved Organic C	1
Allo Non-point TC	1
Auto Nearshore Dissolved Organic C	1
Drought	1
Increased Area of Hard Substrate	1
Predatory Fish Biomass	0
Offshore Cyanobacteria Biomass	1
Allo Point TN	0
Nearshore Zooplankton Biomass	0
Offshore Zooplankton Biomass	0

Could also calculate Outdegree and Indegree to help answer Questions 3 and 4.

Outdegree is the row sum of absolute values of a variable in the adjacency matrix. It shows the cumulative strengths of connections ( $a_{ij}$ ) exiting the variable, where  $N$  is the total number of variables:

$$od(v_i) = \sum_{k=1}^N \bar{a}_{ik}$$

Indegree is the column sum of absolute values of a variable. It shows the cumulative strength of variables entering the variable.

$$id(v_i) = \sum_{k=1}^N \bar{a}_{ki}$$

From: Ozesmi U. & Ozesmi L. *Ecological models based on people's knowledge: a multi-step fuzzy cognitive mapping approach. Ecological Modelling: 176, 43-64.*

**Question 4. Which concepts are primarily emitters?**

**Table 4.** Concepts that are primarily “emitters” (i.e. those concepts that have few or no links in). There are 58 concepts that appear in the FROM column, in total. Ten of them appear only in the FROM column (i.e. not in the TO column).

Concepts that only have links OUT	Number of Links OUT
Allo Point SRP	5
Climate Change	4
Allo Point TP	3
Increased Natural Vegetation Cover	3
Less Wind	3
Predatory Fish Biomass	2
Allo Point TN	1
Nearshore Zooplankton Biomass	1
Offshore Zooplankton Biomass	1
<b>Concepts that have only one link IN</b>	
	<b>Number of Links OUT</b>
Agricultural Activities	7
Reduced Water Levels	7
Increased Rainfall	4
River Flooding	4
Allo Non-point Dissolved Organic N	3
Urban Activities	3
Zooplankton Biomass	3
Mixing Depth	2
Warmer Winter	2
Allo Nearshore Dissolved Organic C	1
Allo Non-point TC	1
Auto Nearshore Dissolved Organic C	1
Drought	1
Increased Area of Hard Substrate	1

**Question 5. Which concepts are primarily endpoints?**

**Table 5.** Concepts that are primarily “endpoints” (i.e. those concepts that have few or no links out). There are 53 concepts that appear in the TO column, in total. Four of them appear only in the TO column (i.e. not in the FROM column).

Concepts that only have links IN	Number of Links IN
Spirogyra Biomass	4
Botulism Animal Kills	3
Lyngbya Biomass	3
Auto Offshore PP	2
Offshore Cyanobacteria Biomass	1

Concepts that have only one link OUT	Number of Links IN
Hypolimnetic Hypoxia	5
Central Basin Reduced Hypolimnion Thickness	3
Allo Nearshore PP	3
Auto Nearshore Dissolved Organic N	2
Auto Offshore SRP	2
Particulate Organic Carbon	2
Allo Non-point TC	1
Auto Nearshore Dissolved Organic C	1
Drought	1
Increased Area of Hard Substrate	1
Allo Nearshore Dissolved Organic C	1

## Weight of Evidence:

### Examining Variability Among the Individual FCMs that Contributed to the Consensual Map

Twenty-seven concepts are unique to a single map, 35 are common to at least two maps, and six are present on more than half (i.e., 6-10) of the maps (Table 6).

158 propositions are unique to a single map.

35 propositions occur on more than one map.

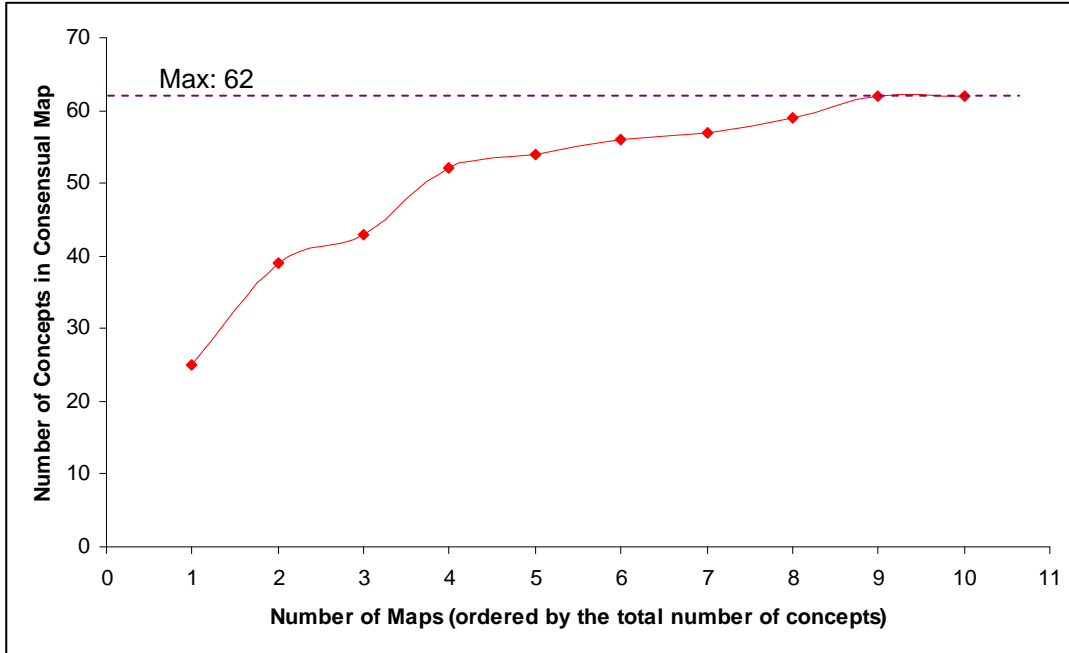
**Table 6.** Number of individual maps each concept appears. Concepts that are present in many maps suggest strong Weight of Evidence. Darker shading indicates more maps.

Concept	#of Maps Present on In Total	# Maps Present on in FROM	# Maps Present on in TO
Cladophora Biomass	10	5	10
Light Penetration	8	8	8
Allo Nearshore SRP	7	7	6
Dreissenid Biomass	7	9	7
Allo Non-point TP	6	6	2
Cyanobacteria Biomass	6	2	6
Agricultural Activities	4	4	1
Allo Non-point SRP	4	3	4
Auto Nearshore SRP	4	4	4
Benthic Grazers	4	3	3
Hypolimnetic Hypoxia	4	2	4
Phytoplankton Biomass	4	4	4
Allo Nearshore TP	3	2	3
Allo point SRP	3	3	0
Allo point TP	3	3	0
Climate Change	3	3	0
Increased Area of Hard Substrate	3	4	3
Nearshore Cyanobacteria Biomass	3	1	3
Nearshore Phytoplankton Biomass	3	3	3
Offshore Phytoplankton Biomass	3	3	3
Allo Nearshore Particulate Organic C	2	2	2
Allo Nearshore PP	2	2	2
Allo Non-point PP	2	2	2
Allo Non-point TN	2	2	2
Allo Offshore SRP	2	2	2
Auto Nearshore PP	2	2	2
Auto Nearshore TP	2	2	2
Auto Offshore SRP	2	1	2
Bacterial Biomass	2	2	2
Botulism Animal Kills	2	0	2
Gobies	2	2	2
L yngbya Biomass	2	0	2
Nearshore Epibenthic Hypoxia	2	2	2
Suspended Sediment	2	2	2
Water Temperature	2	5	2

Allo Nearshore Dissolved Organic C	1	1	1
Allo Nearshore SRN	1	1	1
Allo Non-point Dissolved Organic N	1	1	1
Allo Non-point TC	1	1	1
Allo Offshore TP	1	1	1
Allo point TN	1	1	0
Auto Nearshore Dissolved Organic C	1	1	1
Auto Nearshore Dissolved Organic N	1	1	1
Auto Offshore PP	1	0	1
Auto Offshore TP	1	1	1
Central Basin Reduced Hypolimnion Thickness	1	0	2
Drought	1	1	1
Increased Natural Vegetation Cover	1	1	0
Increased Rainfall	1	3	1
Less Wind	1	1	0
Mixing Depth	1	1	1
Nearshore Zooplankton Biomass	1	1	0
Offshore Cyanobacteria Biomass	1	0	1
Offshore Zooplankton Biomass	1	1	0
Particulate Organic Carbon	1	1	1
Predatory Fish Biomass	1	1	0
Reduced Water Levels	1	3	1
River Flooding	1	1	1
Spirogyra Biomass	1	0	1
Urban Activities	1	2	1
Warmer Winter	1	1	1
Zooplankton Biomass	1	1	1

**Question 6. How does the sample size (i.e., number of individual FCMs) influence the information within the final map?**

**Figure 3.** Accumulation curve of total number of concepts vs. number of maps. Maps are ordered on the x axis according to their total number of concepts.



**Figure 4.** Accumulation curve of total number of concepts vs. number of maps. Maps are ordered on the x axis according to their total number of concepts.

