Application of Loop Analysis to Examine the Role of Alternative Community Structures in Determining Steller Sea Lion Population Changes

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ABSTRACT

We used Qualitative Analysis or Loop Analysis to examine the role of community structure in determining Steller sea lion population changes after a disturbance affects one or more species in the community. The response of each community member to disturbance was analyzed in alternative community webs to understand the role of direct and indirect effects considering different community networks. Alternative models were generated based on stomach contents information that has been reported in the literature. Alternative community webs help to understand what presses or disturbances will cause Steller sea lions to decrease based on their response to changes in the biotic community.

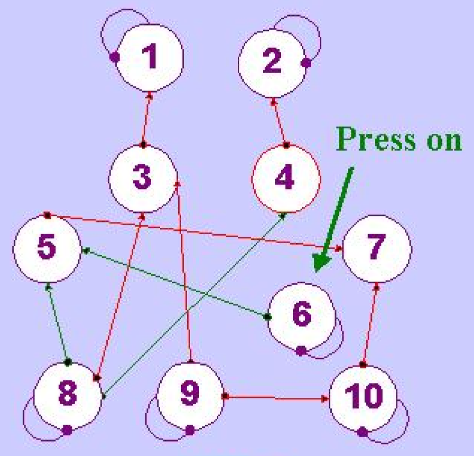
METHODS

Loop Analysis incorporates direct interactions between community species to represent system models in a community matrix (Lane and Levins 1977; Puccia and Pederson 1983; Puccia and Levins 1985). The models are represented as signed digraphs that are built from the biological knowledge of the system or by obtaining the data from field observations. The power of qualitative analysis relies on the lack of need to measure interaction strengths. Only positive (+), negative (-) or no interactions (0s) between variables are sufficient. Within and among trophic level interactions can be modeled.

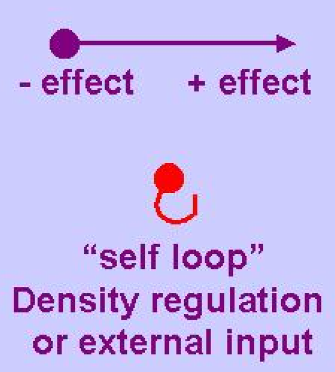
Unlike Ecosim models of biomass transfer through trophic levels, loop analysis is a model of community interactions that does not require a complete food web. Community members that are regulated by elements outside of the modeled system (e.g., plankton eaters) can be assigned a "self loop" of negative feedback. Thus, the loop analysis can focus exclusively on interactions of interest and predicted responses of the community web to perturbations.

FROM MODEL TO PREDICTIONS

Signed-Digraph



WEB 1
(Example 1)



1. Sharks
2. Transient Killer Whales
3. Seals
4. Steller Sea Lions (SSL)
5. Adult Pollock
6. Pelagics (herring, capelin)
7. Cod
8. Juvenile Pollock
9. Cephalopods (squid, octopus)
10. Mackerel

Community Matrix

Variable	Shark	Orca	Seal	SSL	Ad Poll	Pelagic	Cod	J Poll	Cepha	Mack
Shark	-1	0	1	0	0	0	0	0	0	0
Orca	0	-1	0	1	0	0	0	0	0	0
Seal	-1	0	0	0	0	0	0	1	1	0
SSL	0	-1	0	0	0	0	0	1	0	0
Ad Poll	0	0	0	0	0	1	-1	1	0	0
Pelagic	0	0	0	0	-1	-1	0	0	0	0
Cod	0	0	0	0	1	0	0	0	0	1
J Poll	0	0	-1	-1	-1	0	0	-1	0	0
Cepha	0	0	-1	0	0	0	0	0	-1	-1
Mack	0	0	0	0	0	0	-1	0	1	-1

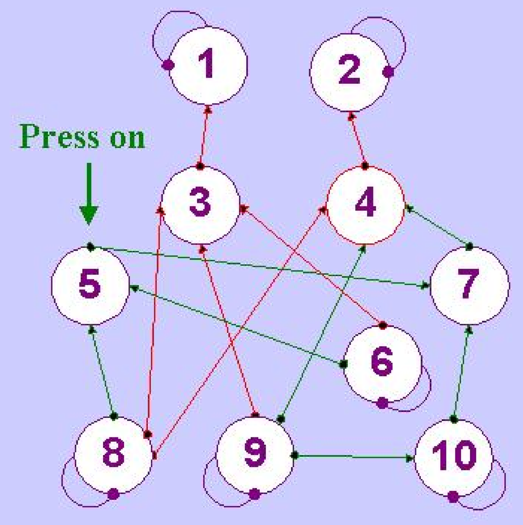
Weighted Table of Predictions

Positive Disturbance (press that *increases* biomass) on:

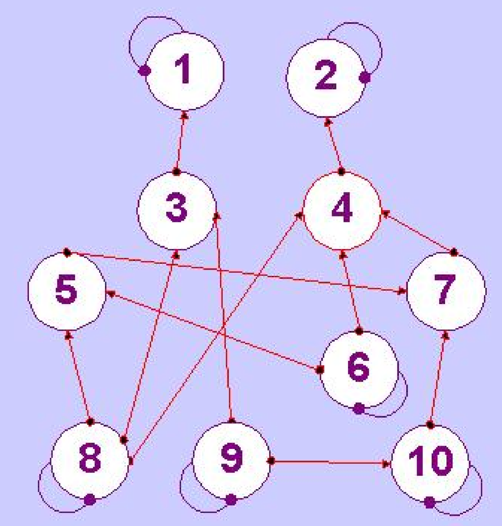
Response	Variable	+ ↓ Shark	+ ↓ Orca	+ ↓ Seal	+ ↓ SSL	+ ↓ Ad Poll	+ ↓ Pelagic	+ ↓ Cod	+ ↓ J Poll	+ ↓ Cepha	+ ↓ Mack
	Shark	1	1	1	– 1	.33	.33	1	1	1	–.33
	Orca	1	1	– 1	1	– 1	– 1	.50	1	–.33	1
	Seal	– 1	1	1	– 1	.33	.33	1	1	1	–.33
	SSL	1	– 1	– 1	1	– 1	– 1	.50	1	–.33	1
	Ad Poll	–.33	1	.33	– 1	1	1	– 1	1	– 1	– 1
	Pelagic	.33	– 1	–.33	1	– 1	1	1	– 1	1	1
	Cod	1	.50	– 1	–.50	1	1	1	.50	.60	1
	J Poll	1	1	– 1	– 1	– 1	– 1	.50	1	–.33	1
	Cepha	1	–.33	– 1	.33	1	1	.60	–.33	1	– 1
	Mack	.33	– 1	–.33	1	– 1	– 1	– 1	– 1	1	1

A positive press on pelagics will cause killer whales, SSL, juvenile pollock, and mackerel to decrease in abundance or biomass. The rest of the species will increase. Numbers indicate the probability of a given response to actually occur. Values ≥ .50 are highly predictable.

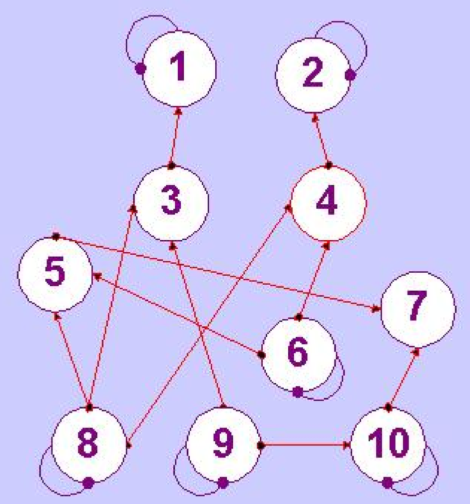
Alternative Community Webs



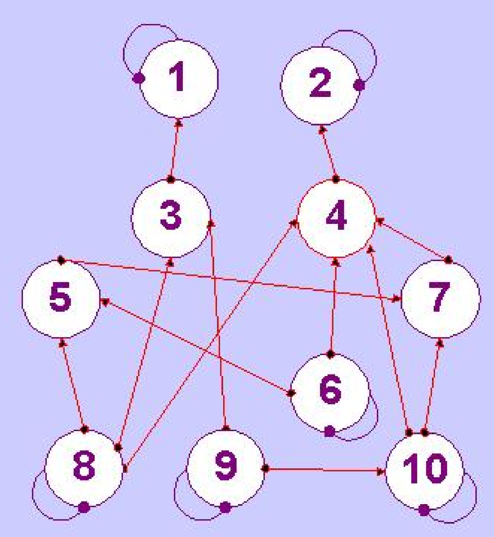
WEB 2
(Example 2)



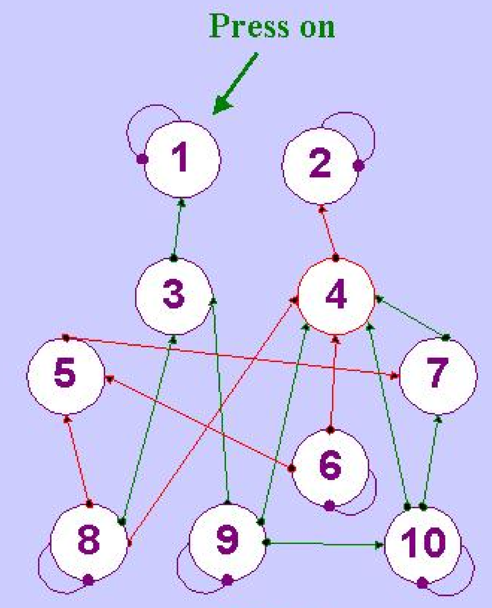
WEB 4



WEB 3



WEB 5



WEB 6
(Example 3)

Six alternative community structures were tested considering Steller sea lion's diet differences, going from a less diverse diet (only pollock = **WEB 1**) to a more diverse diet (5 species = **WEB 6**).

RESULTS (Table 1)

◆ All web structures predicted that Steller sea lions abundances will decrease (↓) when the system is pressed on killer whales and seals.
◆ Differences among webs were found when adult pollock, pelagics, and juvenile pollock are affected.
◆ 4 models predicted that and increase in pelagics will cause Stellers to increase; however, when Stellers relay on juvenile pollock as the only prey (**WEB 1**), Stellers will decrease.

Positive Disturbance (press that *increases* biomass) on:

Response of SSL		Shark	Orca	Seal	SSL	Ad Poll	Pelagic	Cod	J Poll	Cepha	Mack
	WEB 1	↑	↓	↓	↑	↓	↓	↑	↑	UP	↑
	WEB 2	↑	↓	↓	↑	↑	UP	↑	↑	UP	↑
	WEB 3	↑	↓	↓	↑	↓	↑	↑	UP	UP	↑
	WEB 4	↑	↓	↓	↑	0	↑	↑	UP	UP	↑
	WEB 5	↑	↓	↓	↑	↓	↑	↑	UP	↑	↑
	WEB 6	↑	↓	↓	↑	0	↑	↑	0	↑	↑

Table 1. Changes in Steller sea lion's abundances after a positive press perturbation affects the system in each variable. Rows indicate the prediction for different web structures. UP = "Unreliable" prediction (< 0.5).

Indirect Effects

Example 1. Why do SSL decrease in WEB 1 when Pelagics increase?
An increase in pelagics (6) will cause adult pollock (5) to increase and juvenile pollock (8) to decrease due to cannibalism. Since SSL rely on juvenile pollock as the only prey in WEB 1, they will decrease.

Example 2. Why do SSL increase in WEB 2 when Adult Pollock increase?
An increase in adult pollock (5) will cause pelagics (6) and juvenile pollock (8) to decrease; however, cod (7) and cephalopods (9) will increase. Since SSL prey on cod and cephalopods in addition to juvenile pollock in WEB 2, they will increase.

Example 3. Why do SSL increase in all WEBS when Sharks increase?
An increase in sharks (1) will cause seals (3) to decrease, allowing juvenile pollock (8) and cephalopods (9) to increase. An increase in cephalopods will cause alternative SSL prey (mackerel and cod) to increase; therefore, SSL increase.

CONCLUSIONS

◆ Preliminary results suggest that the response of SSL to perturbations are generally similar in these community models, regardless of differences in the diversity of sea lion diet. The exception to this is a switch in the response of SSL to changes in pelagic fish biomass, from a negative response when juvenile pollock is the only prey (**WEB 1**) to a positive response when the SSL diet includes multiple prey items. Loop Analysis reveals that indirect effects can cause a totally different response in the system when different web structures are analyzed.
◆ More web structures need to be compared to further explore these relationships. These models will include non predatory relationships between variables (competition, commensalism, amensalism), as well as alternative prey scenarios.