Systems Processes Theory (SPT) and Sustainability: IV. Application of Network Theory to the Upper Newport Bay's Ecological Restoration Program

Gisela Lopez
MSRS Candidate
CSA 411 – Troncale
Lyle Center for Regenerative Studies
Institute for Advanced Systems Studies
Cal Poly Pomona, Pomona, CA 91768

Introduction

Ecological restoration is one of the fastest growing fields in applied ecology. However, many restoration projects have been considered unsuccessful. Although well-intentioned, many fail due to lack of ecological understanding and lack of knowledge on the natural system processes that operate within this context. Rather than restoring the processes and network connections as the essential elements of a functional ecosystem, failed restoration projects have focused on the aesthetics of a landscape. By understanding the connections between the various components of a system, we can better address the changes to an ecosystem and help restore its function.

Systems Science and Sustainability

- Networks can be found in any place, at any level. A systems science understanding can therefore serve many applications and functions.
- Possessing an awareness for the mechanisms that operate networks--be it social networks, environmental, economic, or biological, can play a vital part in successfully intervening, controlling, strengthening, or weakening such network.
- Approaching sustainability with a systems perspective allows one to examine the linkages and interactions between the parts that comprise a whole system.
- It is through understanding connectivity between these elements that environmental problems can be successfully addressed.
- Although understanding how all the individual components of an ecosystem function together is nearly impossible, a systems approach can provide information as to how to restore its systems affected by anthropogenic causes (Liu, Slotine, et al 2011).

Systems Process Theory

- Systems Theory focuses on 100 different, but interrelated processes.
- In the CSA 411 course, we went through tenets of SPT, the strategies for integration, linkage propositions, neologisms, lifecycles, emergence & origins, and self-organization.
- The spheres on the diagram below represent systems processes, while the lines represent linkage propositions.

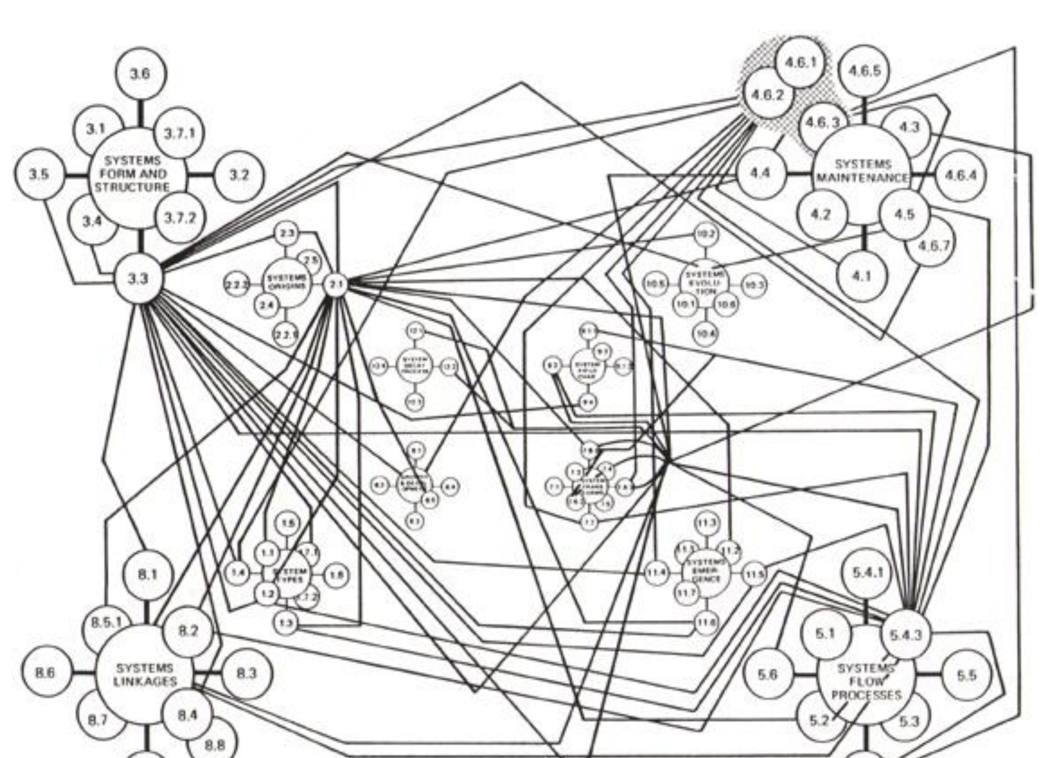
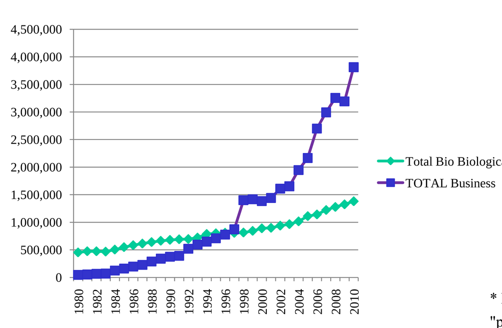
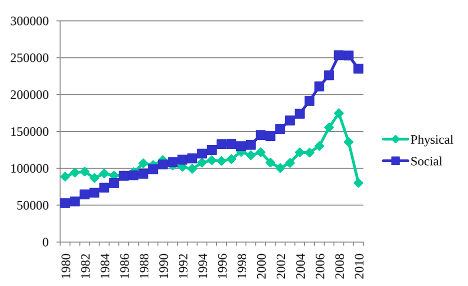


Diagram Above: Actual Connected net graph derived from 64 specific linkage propositions between 33 systems processes that contribute to 5 key systems functions.

Trends in Literature

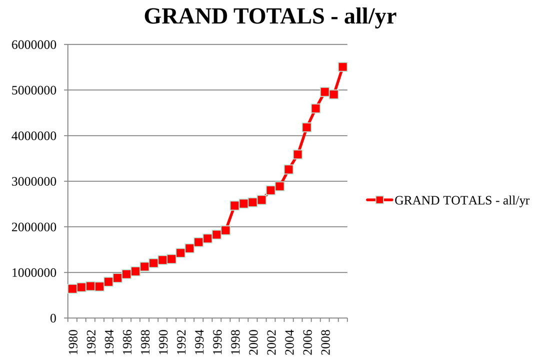


* Restricted to two largest domains i.e. "living systems" and "business/industry" to better allow discrimination of trends in smaller domains (note high numbers on X axis)
* Note gradual and steady increase in lit of bio domain; any jumps in target lit searches indicates distinction from baseline
* Exponential increase in "business domain" after about 2002

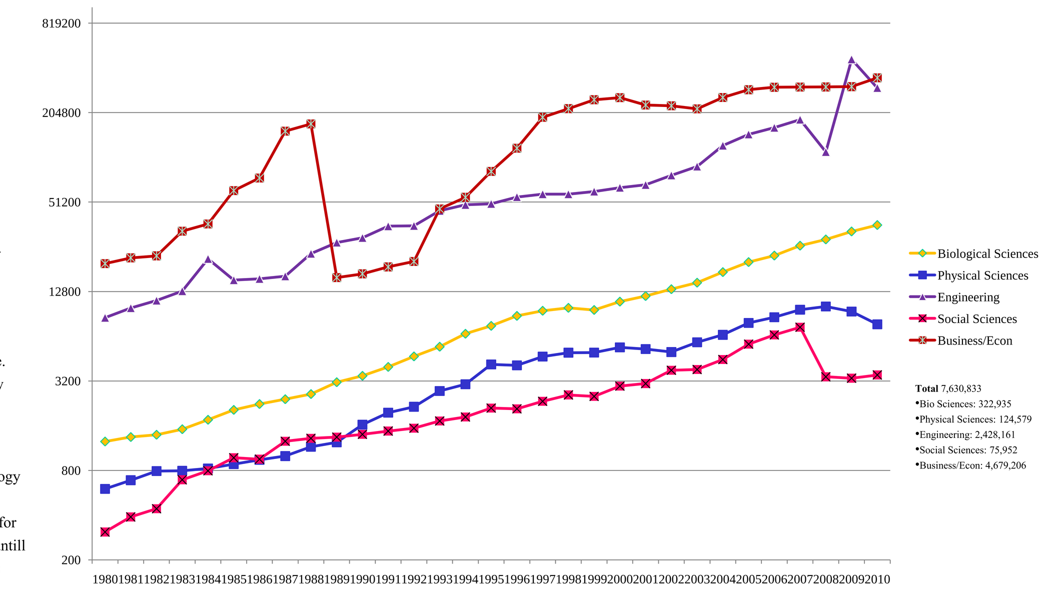


* Restricted to two smallest article activity domains i.e. "physical systems" and "social systems" to better allow discrimination of trends in smaller domains
* Ignore drop off shown for most recent two years; anomaly of databases
* Note that physical sciences only represented by geology pending obtaining data on total articles in chemistry, astronomy, and physics databases which may account for virtual flatline growth of total lit in physical sciences untill mid-current-decade; so any jumps in target lit searches show significant increases in interest in key systems process(es)
* Note gradual and steady increase in lit of social science domain especially pronounced since 2000; any jumps in target lit searches indicates distinction from baseline showing greater interest in systems processes that was subject of search

GRAND TOTALS - all/yr



- a Grand Total of 68 million articles were searched across eleven key databases
- * Average per year searches ranged from about 1 to 6 million per year
- Trends across the totals show arithmetic increases up to roughly 2002 and then an exponential increase pattern

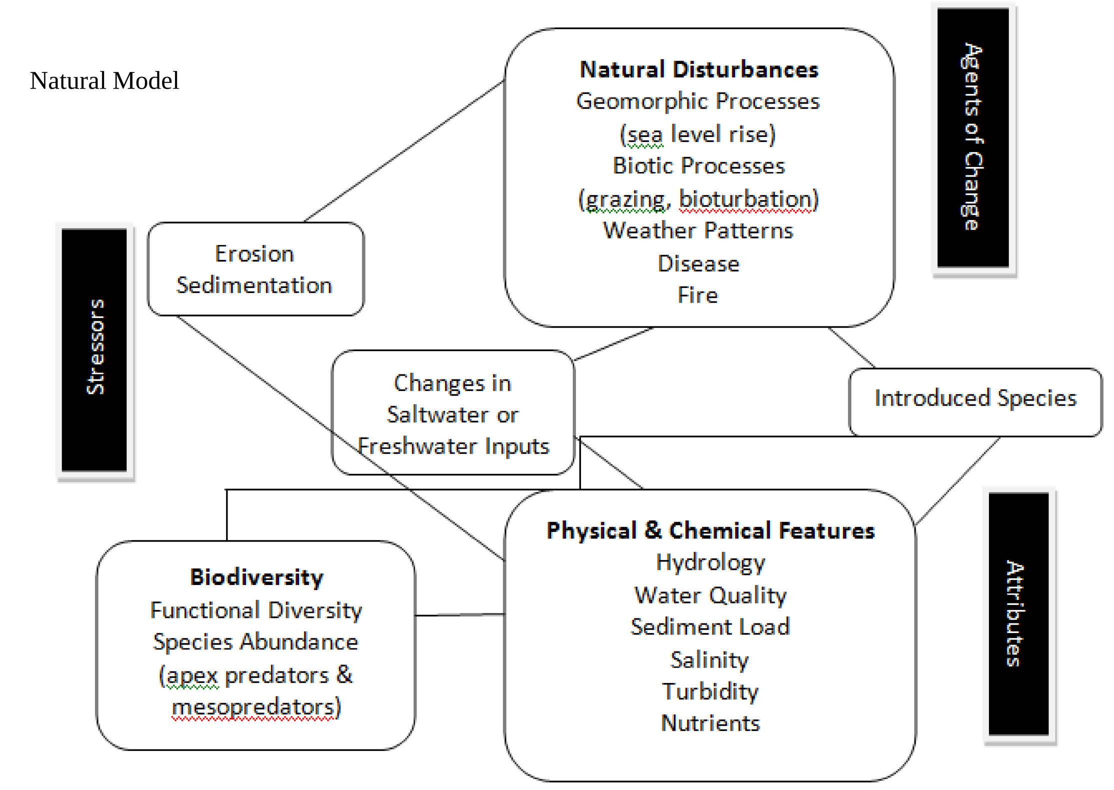


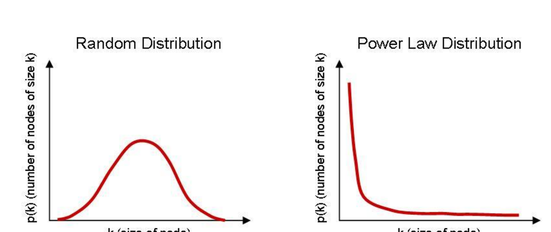
Caveats: In searching for literature on "network dynamics", all databases were limited to the following search parameters:
- 1980-2010
- Network*
- Not limited to Peer-Reviewed or Scholarly articles
- In addition, redundancies were not deleted.

Totals: The sum for the domains searched equaled 7,630,833
- Biological Sciences: 322,935
- Physical Sciences: 124,579
- Engineering: 2,428,161
- Social Sciences: 75,952
- Business/Econ: 4,679,206
- There is a steady increase for all database domains.
- Note sharp decrease for Business/Econ (1988-1989) and for Social Sciences (2007-2008)
- Sharp increase for Engineering (2008-2009)
- The trends follow very closely to the total hits searched in the baseline graphs below

Systems Models: Upper Newport Back Bay Model vs. Natural Estuary Model

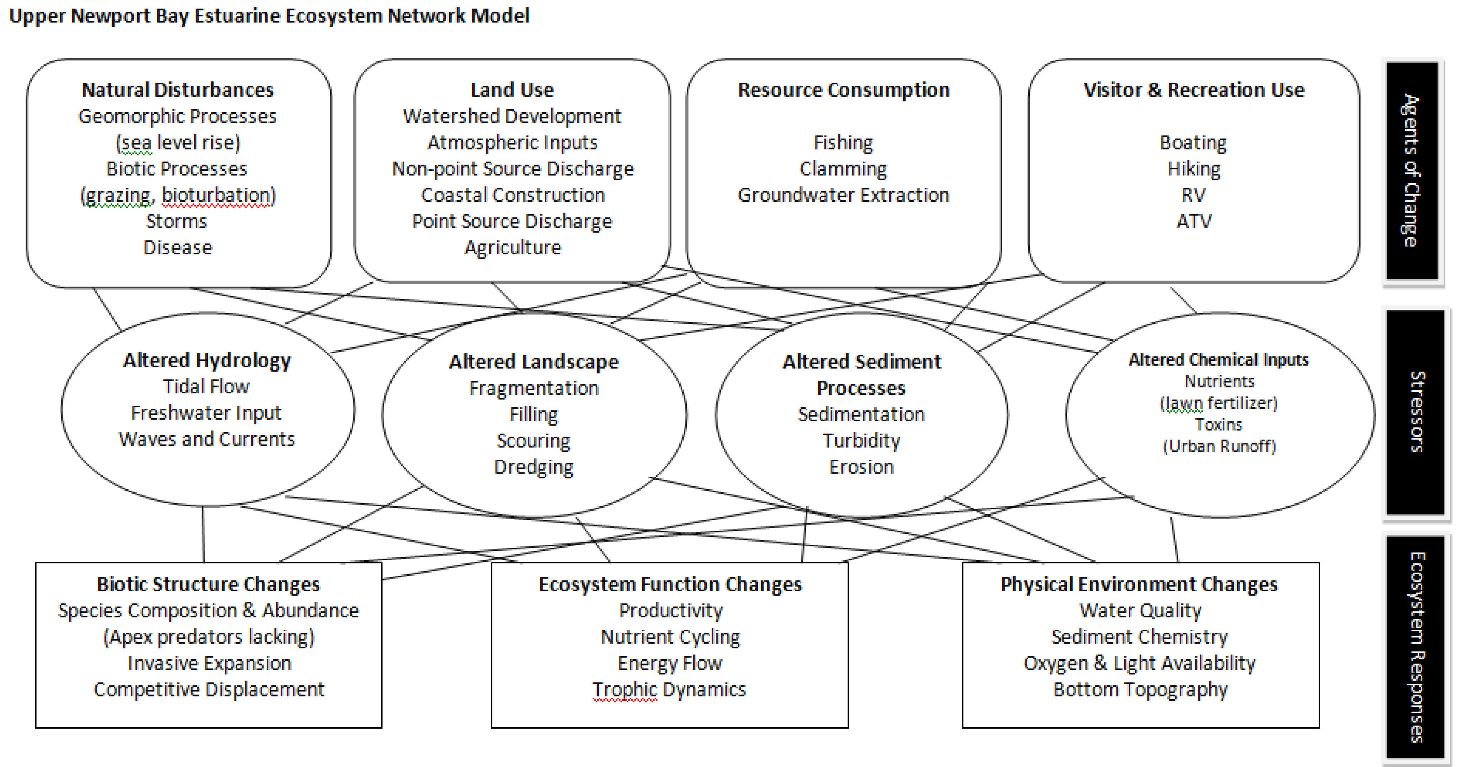
Natural Model





(Barabasi & Bonabeau 2003)

Upper Newport Bay Estuarine Ecosystem Network Model



- In the Natural Model, all nodes interact with one another.
- In the Upper Newport Bay Model, more recently introduced stressors are present. The network has not evolved to respond to these disruptions.
- Newport Bay's recreational activities impact the presence of apex predators (lack mountain lions, trout, or steelhead)
- Dredging introduced and invasives have integrated themselves into landscape

Application

- In regards to ecological restoration, understanding how all the individual components of an ecosystem function together is impossible, particularly with the added stressors and disturbances of anthropogenic causes.
- However, it is clear that the health of an ecosystem depends on the balance of resource and processes that function within the system. The complex network of interactions that compose an ecosystem affect the entire health and function of that system.
- Changes to one node (species/process) will in turn affect other nodes it is connected to. Whenever a species is removed or physical process damaged from a network, the effects of that removal or damage affects other nodes.
- Although researchers have found data on ecosystem network classification inconclusive, they seem to possesses characteristics of small-world and scale-free networks (Barabasi & Bonabeau 2003).
- As a small-world network, removing nodes from an ecosystem can quickly result in disengagement in contrast to scale-free networks where removing a few nodes does not affect the network due to presence of highly connected hubs (Watts 2004, Barabasi & Bonabeau 2003) .
- However, an ecosystem can also be seen as possessing characteristics of scale-free networks where a keystone species can be considered a highly connected hub. Its removal from the network can have a dramatic impact (Barabasi 2002).

Incose-ISSS Collaboration

- The International Council on Systems Engineering and the International Society for the Systems Science have formally agreed to cooperate in exploring and developing systems science as a knowledge base for both fields. Representatives from both organizations have met in Canada, Arizona, and England to plan these joint efforts.
- The Systems Science Working Group (SSWG) has identified four or five official projects. Two of these focus on SPT and Systems Pathology, which are also SIGs of the ISSS.
- This poster is an example of one of these strategies of the joint SPT projects to enable several graduate students in systems science, systems engineering, or related new fields to share their extensive literature survey on the large number of systems processes.
- By cooperating on search and analysis of the diverse literature and especially by integrating, preserving, and making available their individual products, all thesis writers benefit as does the practicing fields of systems engineering, etc.

Conclusions

- The conceptual model presented in this poster attempts to illustrate the complex interactions of the Upper Newport Back Bay Estuary network in comparison to a model of a natural system.
- In an effort to provide a useful model and comparison, the conceptual network models on this poster do not try to name or describe every element of an ecosystem, instead, they are kept general.
- Although the generality of the models may oversimplify an estuarine ecosystem, they aim to exemplify the complexity of the network and the anthropogenic effects to the system in order to understand how different species and mechanisms affect the structure and function of the ecosystem network.
- Highlighting the anthropogenic agents and the ecosystem responses they induce can provide valuable information as to where to intervene and address those stressors with the goal of restoring the health of those natural processes.

References

Barabási, Albert-László, *Linked: How Everything Is Connected to Everything Else and What it Means for Business, Science, and Everyday Life*, 2002.
Liu, Y.-Y., J.-J. Slotine, et al. (2011). "Controllability of complex networks." Nature 473(7346): 167-173.
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Watts, Duncan (2003). *Six Degrees: The Science of a Connected Age*. W. W. Norton & Company.