Methods for ecosystem comparisons:

Gulf of Alaska and Eastern Bering Sea case studies with preliminary California Current comparisons

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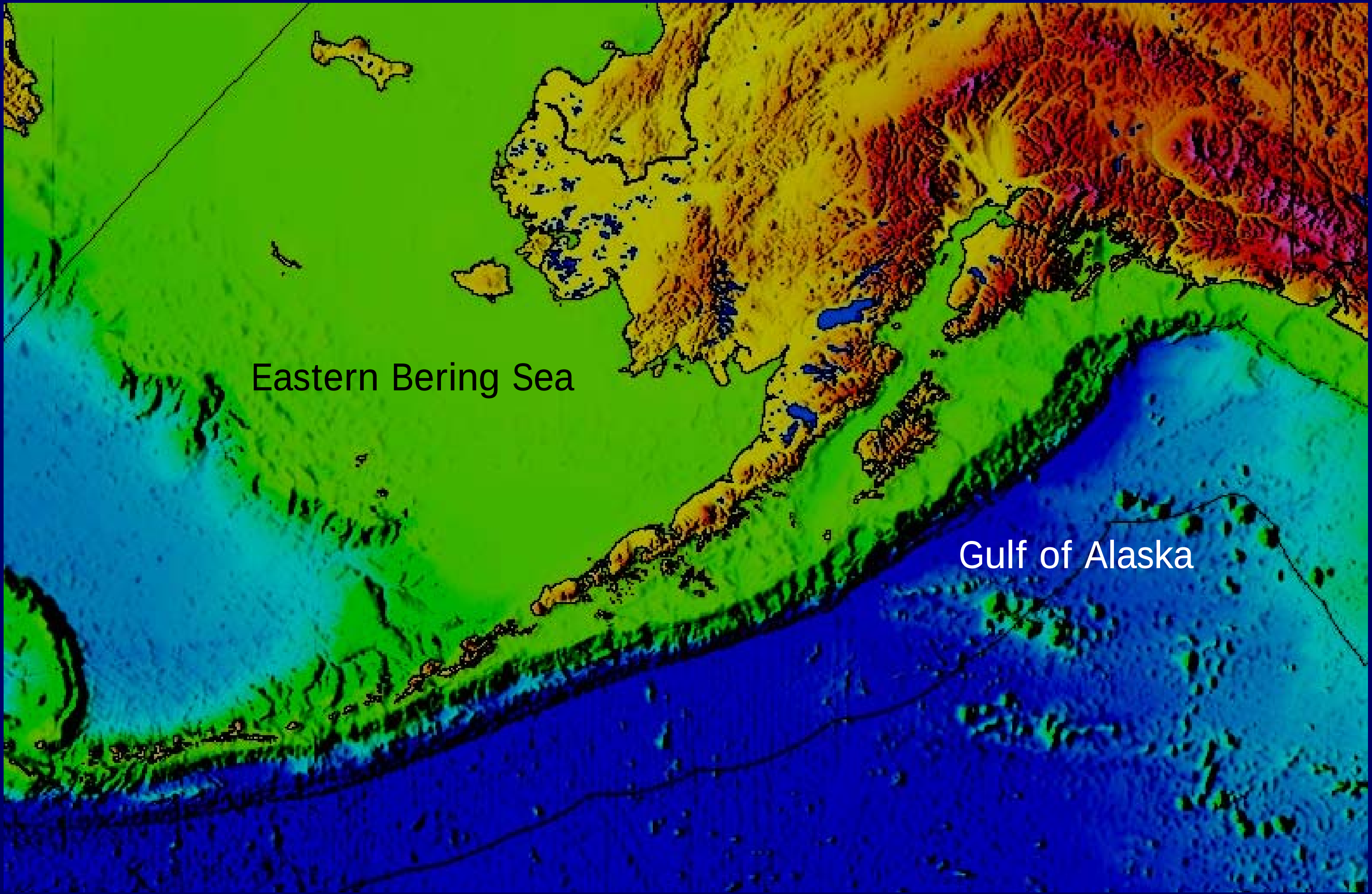
Overview

- Demonstrate two methods for ecosystem comparisons
  1. Food web models of Eastern Bering Sea and Gulf of Alaska classify different structural types
  2. Network analysis of Gulf of Alaska and California Current fish diets classify structural types, key species

- Discuss refinement and applications of methods in other ecosystems

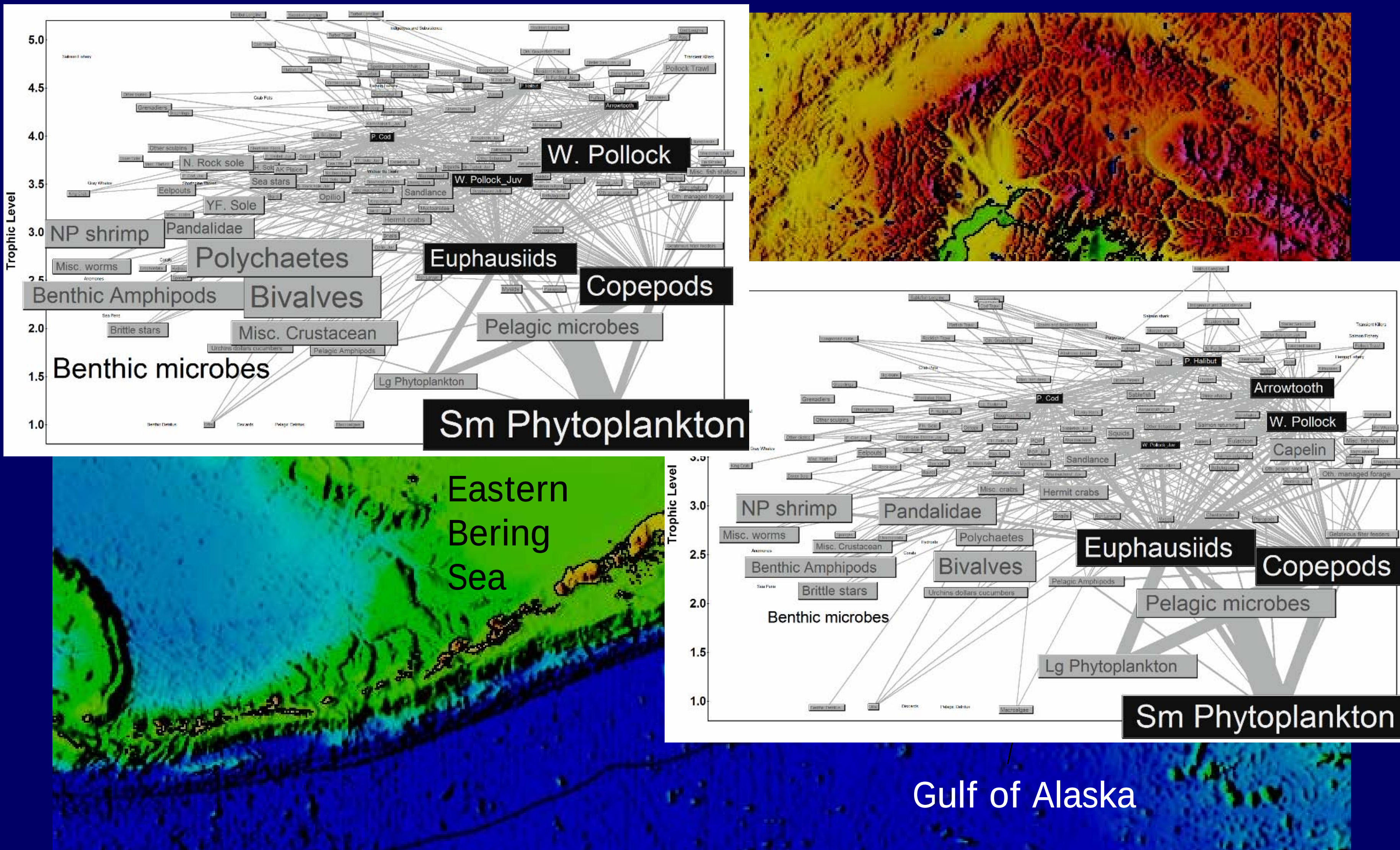
Two Alaskan Ecosystems...



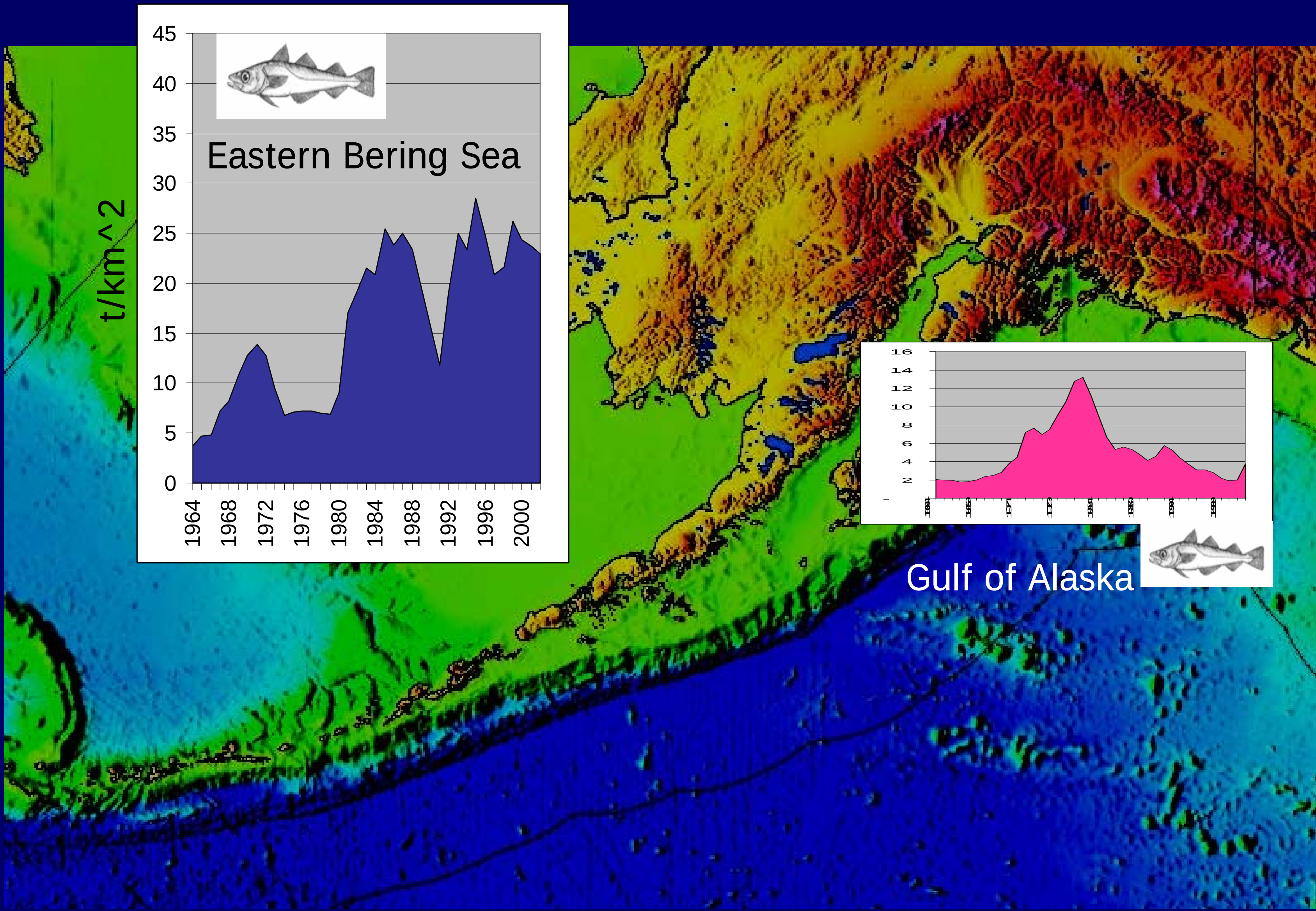
Two Alaskan Ecosystems

- The Eastern Bering Sea (EBS)
  - Wide, uniform, featureless shelf with sluggish circulation
  - Sea ice influence strong, oceanic exchange weak
  - High volume, lower value corporate fisheries (pollock, soles)
  - Commercial inverts (king crab) still there but less important
- The Gulf of Alaska (GOA)
  - Variable shelf incised by canyons and gullies, strong circulation
  - No sea ice influence, significant oceanic exchange
  - Fewer corporate interests, more boutique IFQ fisheries
  - High dollar fish (halibut, sablefish, salmon) rule, king gone
- Management structure and models are equivalent

Two Alaskan Ecosystems: Relationships



Walleye Pollock in two Alaskan ecosystems



Describing Food Web Structural Types

- Bottom up forcing:
  - Physical environment mediates change in primary productivity
  - Altered primary production changes consumer production

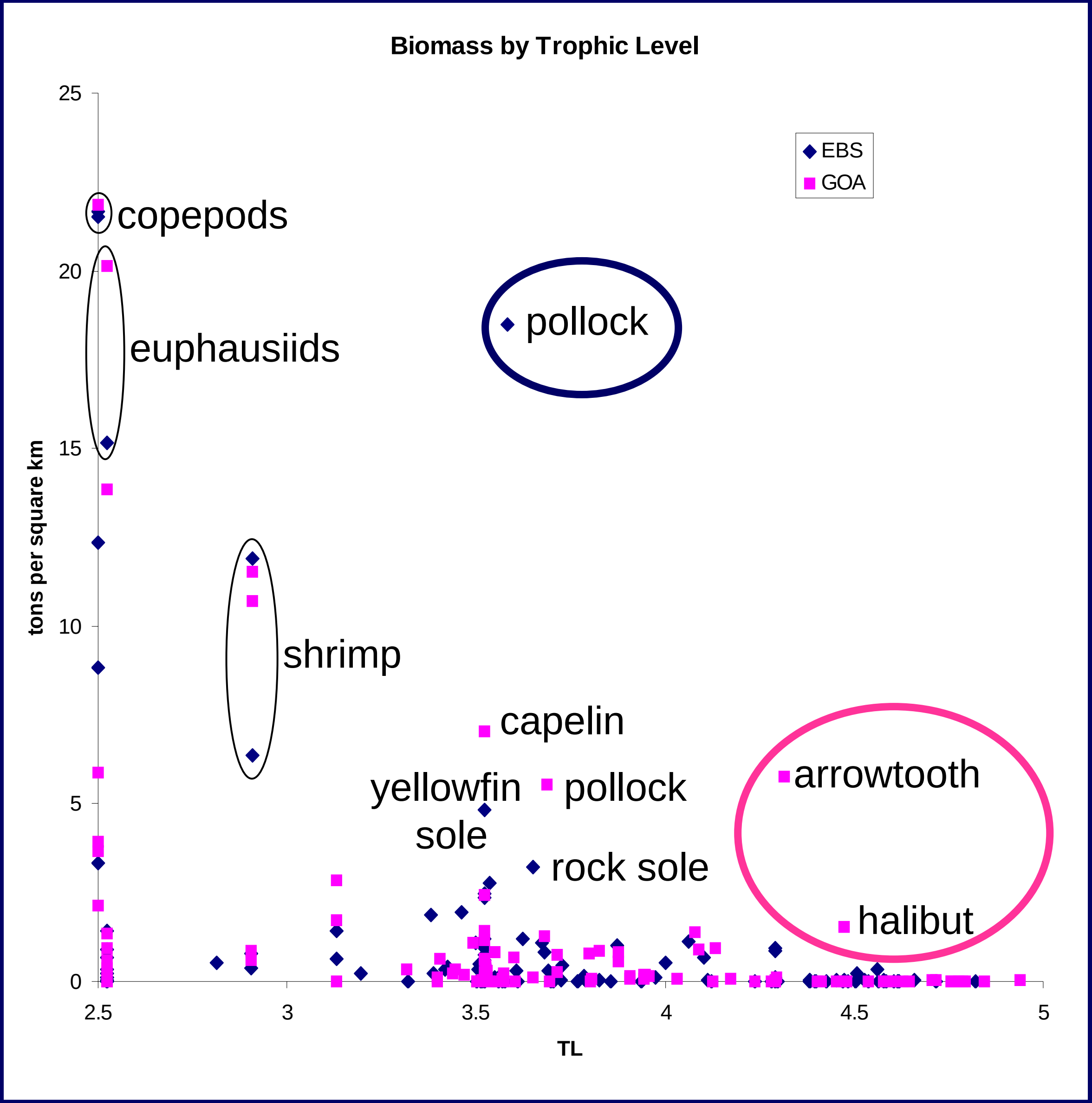
- Top down forcing:
  - Consumers (including fisheries) limit biomass of prey
  - Physical environment change not necessarily invoked

"It is misguided to try to decide which is the mode by which marine ecosystems are driven." –Rice 2001

- Middle out forcing—"wasp waist" ecosystem structure:
  - A numerically dominant group at middle levels exerts top down control on its prey, and bottom up control on its predators (Cury et al 2000)
  - The physical environment may interact with this group

Describing Food Web Structural Types

- Similar biomass groups up to TL 3
- EBS pollock dominate at TL 3.5, highest biomass of any fish
- GOA has highest biomass above TL 4 (halibut, arrowtooth)



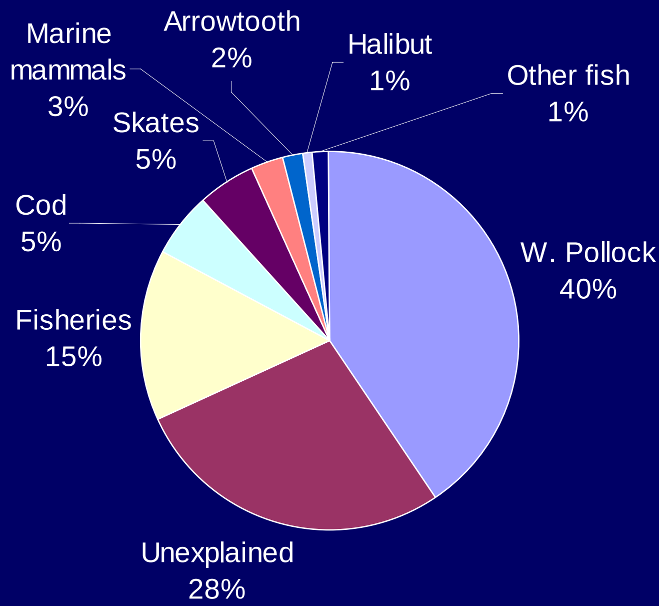
Describing Food Web Structural Types: Does this difference in structure matter?

- Perturbation analysis (considering uncertainty)
  - Increase production of a single group
  - Allow entire ecosystem to adjust to perturbation (50 years)
  - Examine new equilibrium relative to original

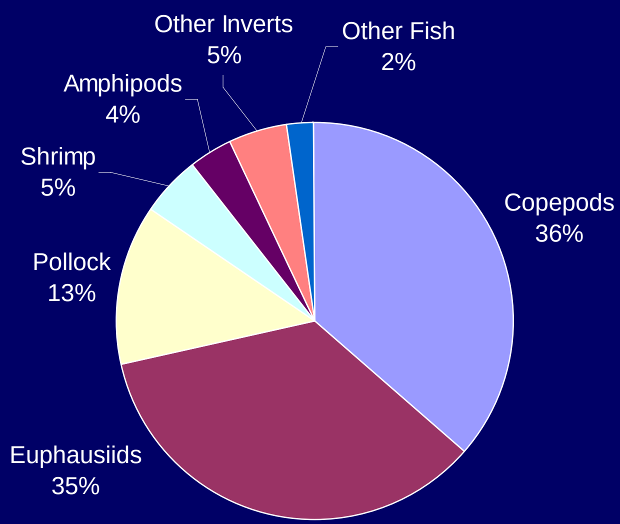
- Focus on pollock:
  - Potential top down control? (effect of increasing predators)
  - Potential bottom up control? (effect of increasing prey)
  - What would a wasp waist centered on pollock look like?

    Who do pollock control? (effect of increasing pollock)

EBS pollock mortality sources



EBS pollock diet composition



Describing Food Web Structural Types: Simulation Results

- EBS pollock are a dominant group at mid trophic level
  - Some bottom up effect on some of their predators
  - Little to no top down control of their prey
  - No evidence of top down control on EBS pollock
  - Self regulating: pollock most important to pollock
- GOA pollock are not dominant, share TL with capelin, etc
  - Uncertainty is high!
  - Some bottom up effects of pollock on halibut suggested
  - Large top down effect on GOA pollock from their predators, and from increasing their prey (...?)
  - Even the effects of pollock on themselves are uncertain!

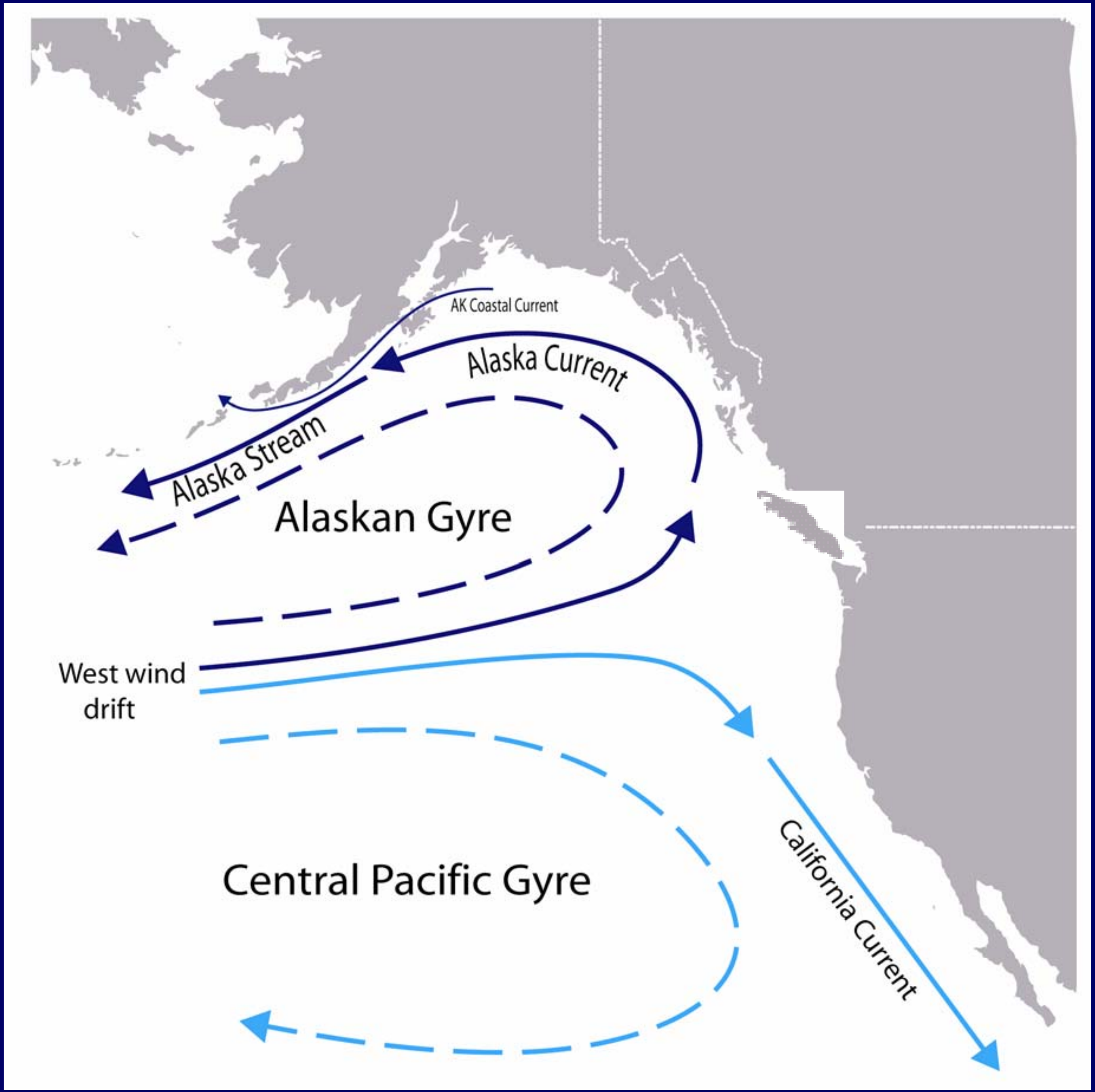
Describing Food Web Structural Types: Wasp Waist or Beer Belly?

- EBS: Influential group at mid trophic levels
  - Wasp waist transmits signal to other groups (neither AK system)
  - Self regulating dominant group (beer belly) absorbs signals
  - Beer belly systems are more predictable,
    stable as long as the beer belly maintains itself?

- GOA: Influential groups at high trophic levels
  - A less predictable system?
  - Subject to more radical change?

What to call the GOA—top heavy? High center of gravity?

GOA and California Current (CC)



Ecosystem structural analyses II

- "Complex systems" models used to describe physical, biological, social phenomena
- Themes:
  - Self-organization, robust to error, random disturbance
  - System reorganization at critical thresholds
  - Emergent properties unpredictable from components
- Network model of the food web (static)

Network properties I: “Small world”

- Milgram (1967), Watts and Strogatz (1998)
- Widely scattered groups are connected by a few key relationships

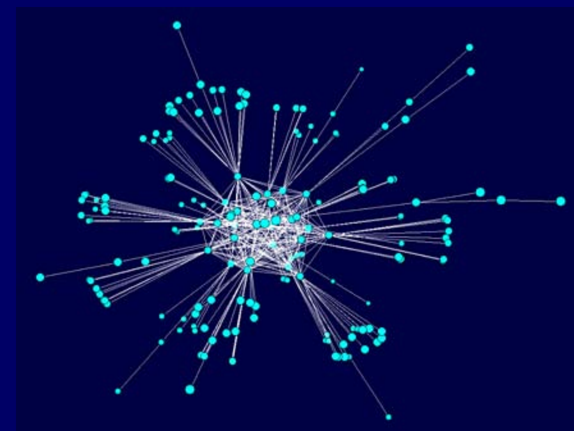
- Distant points are more related than you think

“Six degrees of separation”

- Dynamic property implied: Rapid flow of information (or disease, or other impacts) across a huge network

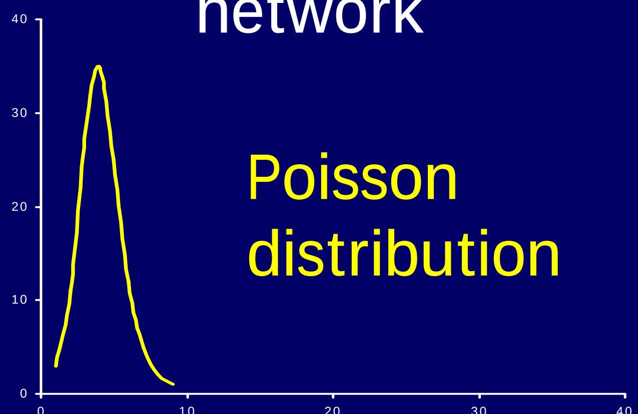
Networks II: visuals, link distributions

Random network



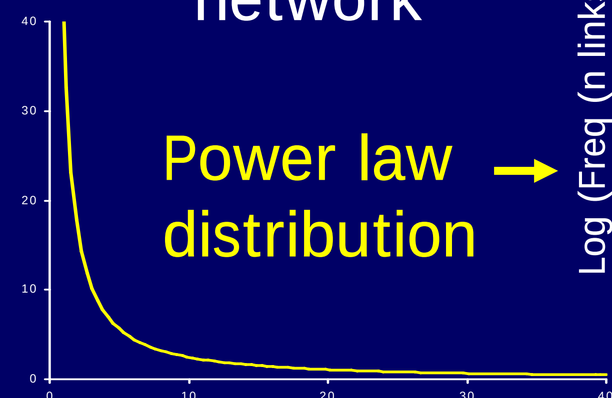
Scale free network

Number of nodes with n links

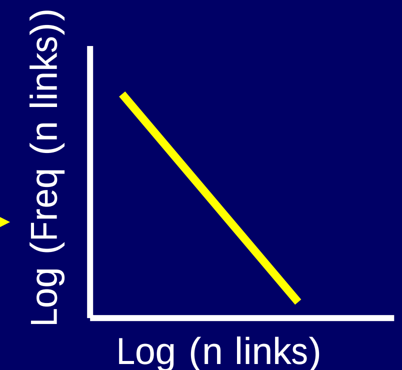


Poisson distribution

Number of links

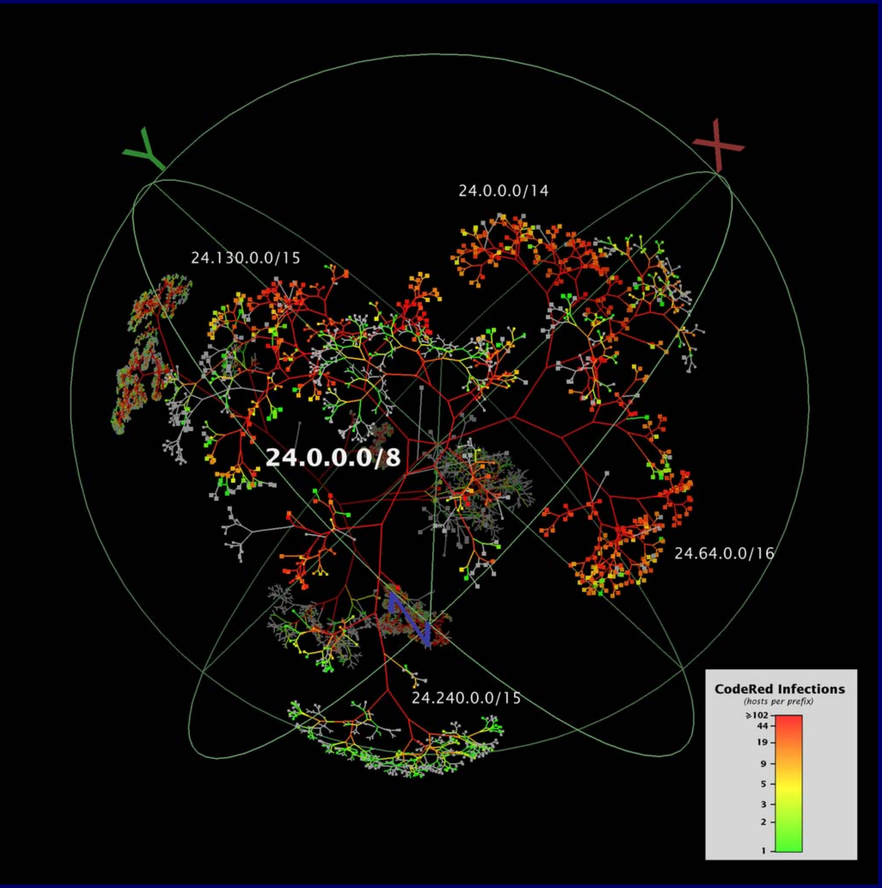


Power law distribution

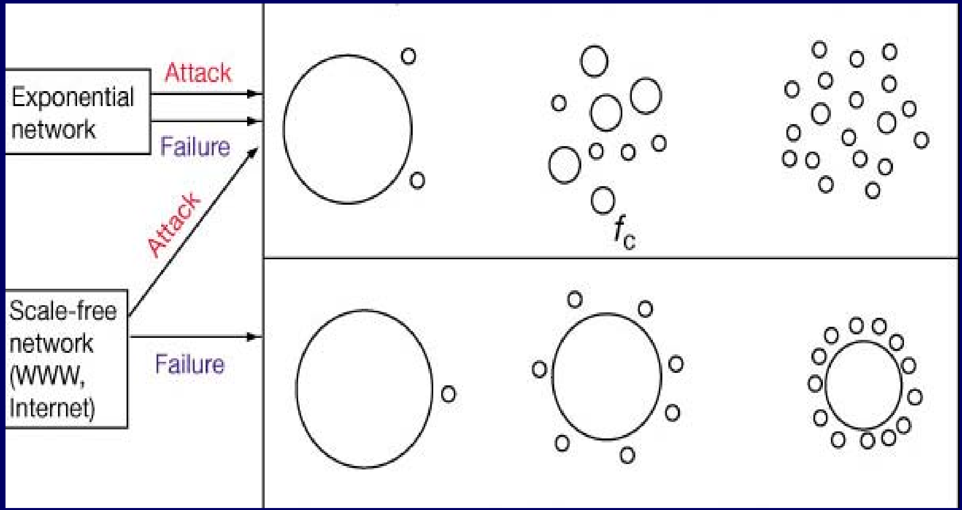


Number of links

Network type implies system behavior



Albert, Jeong & Barabasi, 2000. Nature 406: 378-382

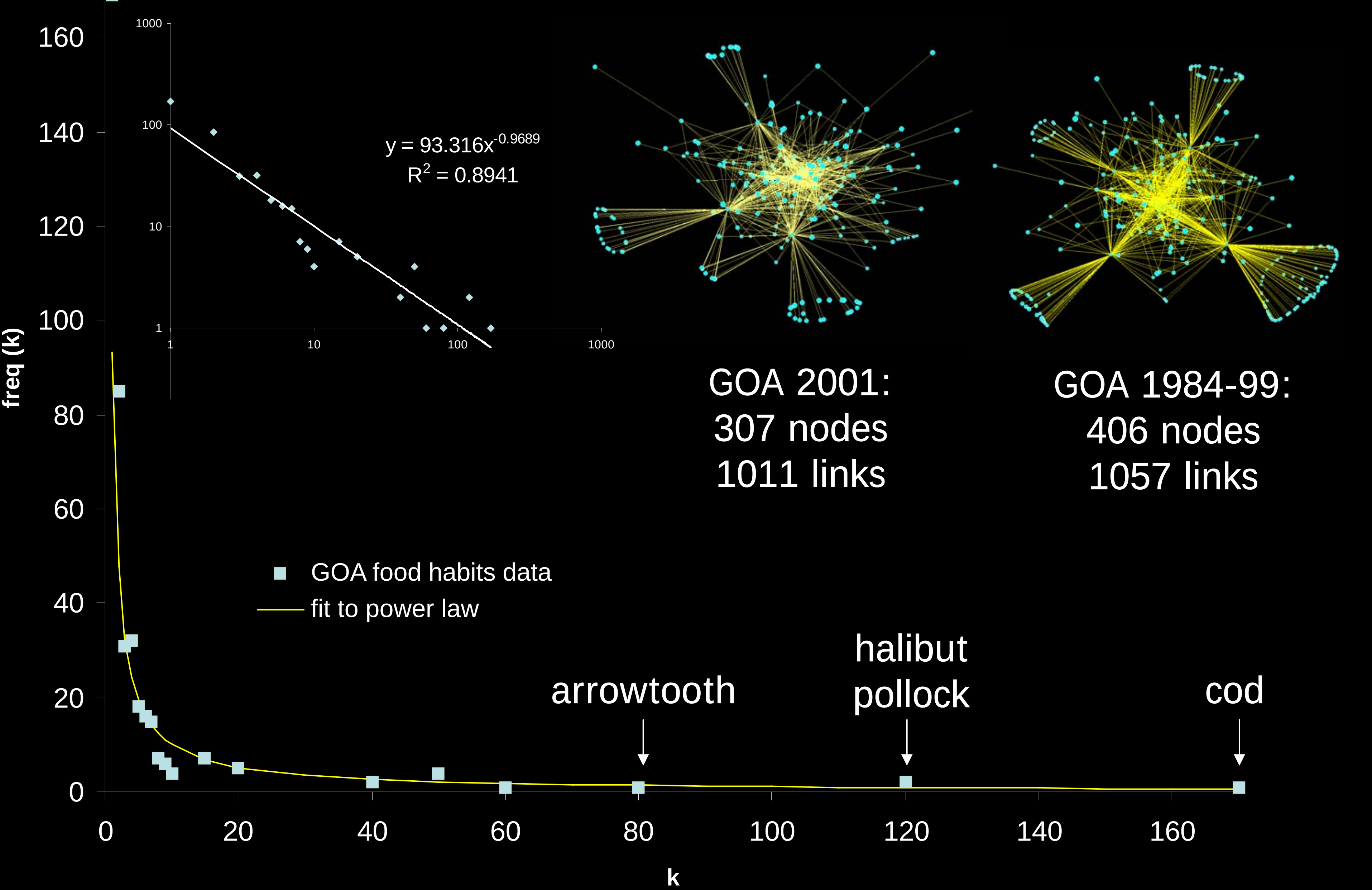


Percent of nodes removed | 5% | 18% | 45%

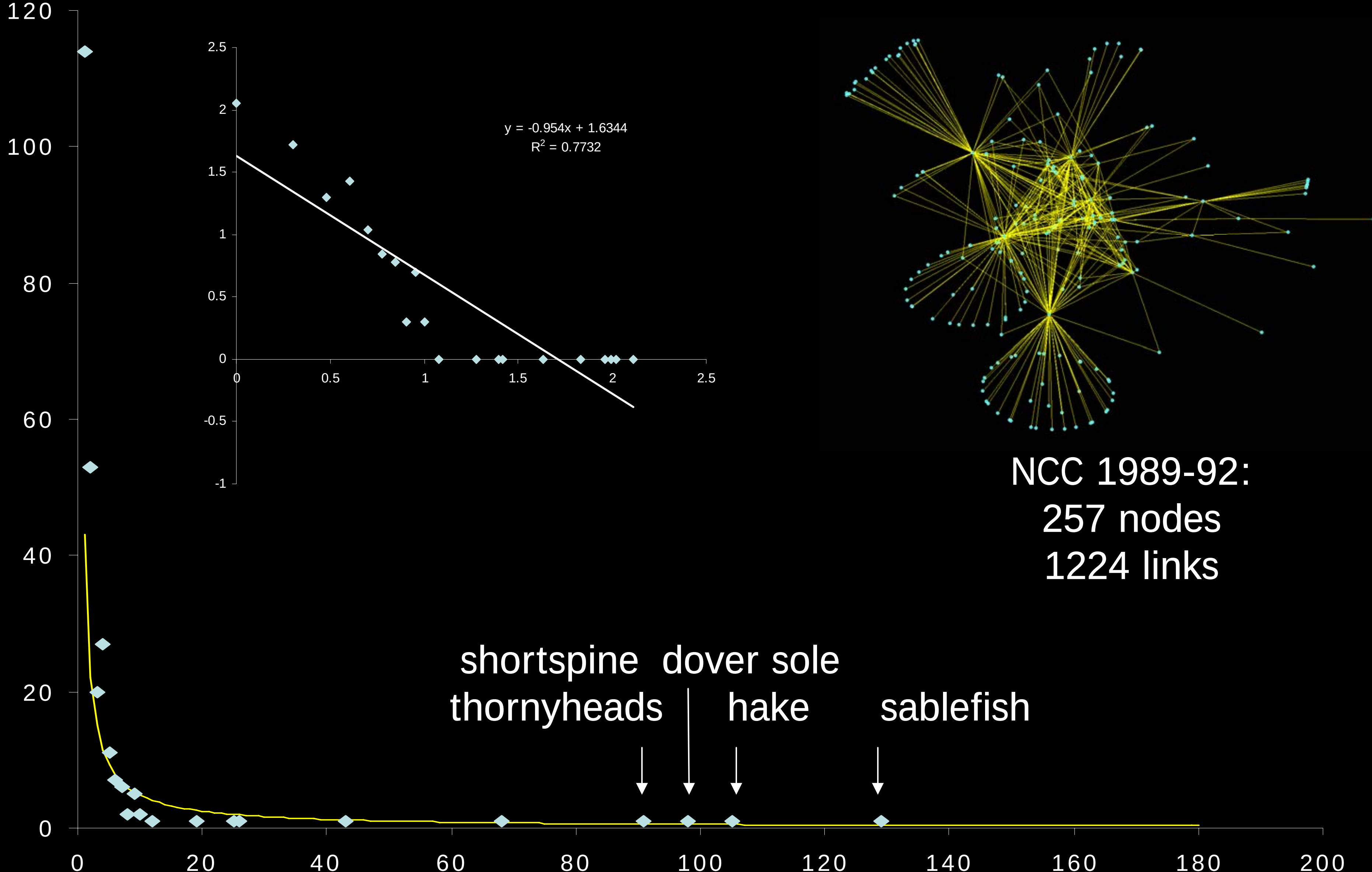
Attack = target and remove highly connected nodes

Failure = remove nodes at random

Results: GOA food web networks

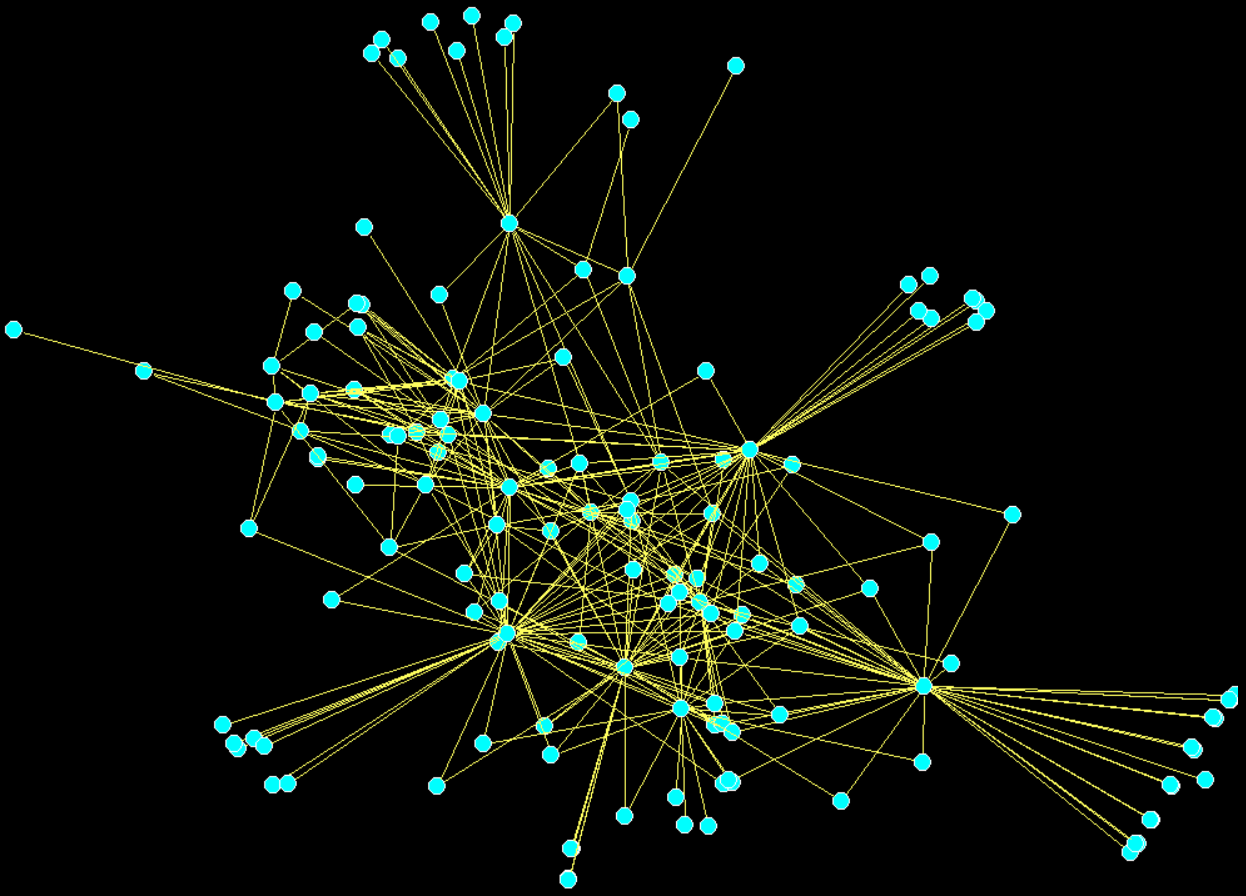


Results: CC food web networks



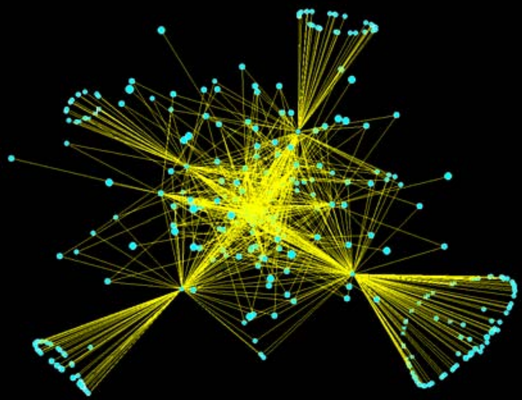
NCC 1989-92:
257 nodes
1224 links

Results: CC network, alternate method



NCC even samples:
150 nodes
345 links

Reorganization in the complex food web?



- "Scale free" food web network is robust to random species losses, but
- Small world property means impacts to one species can transmit rapidly, and
- "Attack" on highly connected species (cod, sablefish, arrowtooth, hake) may fragment the network

➢ *What is "attack"? Overfishing? More? Less?*

➢ *Management can focus on protecting the few highly connected species to avoid rapid reorganization*

Conclusions....

- Food web comparisons
  - Identify key structural types, species
  - Suggests system dynamics...see discussion

- Food web structure as ecosystem indicator
  - Sensitive to climate driven changes in zooplankton
  - Connection between zooplankton, fish and fisheries
  - Associate food web structural types with the 3 "intermediate mechanisms" identified?