Salmon & jellyfish: bumping elbows in the Northern California Current

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Goals:

- Explore effects of variable trophic network structure on production of juvenile salmon in Northern California Current (NCC)
- Develop an end-to-end trophic model to quantify net direct and indirect effects of large jellyfish on juvenile salmon
- Examine relation between local juvenile salmon feeding and jellyfish biomass
- Examine relationship between observed Columbia River salmon production and jellyfish abundance
The sea nettle, *Chrysaora fuscescens*
NCC Coastal Upwelling Ecosystem: model domain

Full domain: 42.0 - 48.34°N; 1-183m; 26,000 km²

Coverage years: 1999-2011…

Seasons: June – September

Platform: ECOTRAN (Steele & Ruzicka, 2011)

Currency: wet weight (jellyfish normalized to forage fish water content)
“ECOTRAN”

- maps flow of production UP food web
- account for bioenergetic budgets of each group
- propagation of variability & uncertainty (incl. migration)

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consumption = production + metabolism + non-assimilated

5/23
Upwelling driver
“unit” driver

Sensitivity scenarios
Trophic network efficiency metrics
NPZD driver

Dynamic time-series scenarios
Foraging relation scenarios

NH_4^+
Pelagic survey

Day sampling (Night off CR)
1998 - 2011
May, June, September

264 Rope Trawl fished at the surface
Fishing width = 30 m

Nordic trawl
30 x 20m
How important are jellyfish? (in terms of energy flow)
Reach: contribution to upper trophic levels

Footprint: demand on lower trophic levels
Three juvenile salmon types
(abundance time-series & diets)
Yearling: 1 winter in freshwater more abundant in June
Sub-Yearling:
No winter in freshwater (smaller) more abundant in September
Sea Nettles

Coho Yrlng - June
Coho Yrlng - Sept
Chinook SubYrlng - June
Chinook Yrlng - Sept
Chinook Yrlng - June

DIET

Suchman et al., 2008
Daly et al., 2009
Sensitivity Scenario:

- Which functional groups have the strongest effects on juvenile salmon production?
  - Estimate juvenile salmon response to a sequential, fixed change across each trophic linkage in the model
- Estimates effect of high jellyfish biomass across functional groups
  - Scenario at 1 STD increase over mean biomass (6.2 + 5.8 t/km²)
PRODUCERS ➔

CONSUMERS

- large phyto
- small phyto
- micro-Zoop
- small copepod
- invert larva
- pteropod
- pelagic shrimp
- macro-Zoop
- small jelly-herbivore
- herring
- anchovy
- juv. rockfish
- juv. other fish

- micro-Zoop
- large copepod
- small copepod
- invert larva
- pteropod
- amphipod
- pelagic shrimp
- macro-zoop
- small jelly-herbivore
- small jelly-carnivore
- large jellyfish
- E. pacifica
- squid
- coho yearling
- planktiv. rockfish
- hake
- small benthic fish
- juv. rockfish
- juv. other fish
Sensitive to direct increase in prey availability
Sensitive to increase in energy available to prey
Negative effect of adding a trophic level
Two Most Influential Competitors

Direct: Pacific hake
Indirect: jellyfish (Chrysaora fuscens)
juveni
le sal
juveni
le fish
≈18%

Relative Change in Production

-0.5
-0.4
-0.3
-0.2
-0.1
0

juvenile fish
juvenine salmon

small copepods
macro-zooplankton
juven. rockfish
juven. fish (other)
sardine
coho yearling
Chinook subyearling
Jack mackerel
hake
pacific rockfish
common mure
large pinnipeds
large odontocetes
Is there a relation between local feeding success and jellyfish biomass?
Index of Feeding Intensity

Sea Nettle Biomass (quantile)

June

- Coho yearling
  - 386
  - 50
  - 169

- Chinook subyearling
  - 27
  - 17
  - 94

- Chinook yearling
  - 133
  - 38
  - 133

September

- Coho yearling
  - 114
  - 37
  - 34

- Chinook subyearling
  - 128
  - 68
  - 102

- Chinook yearling
  - 26
  - 15
  - 22

Sea Nettle Biomass (quantile)
Is there a relationship between observed Columbia River salmon production and jellyfish abundance?
SALMON RETURNS

Spring&Summer-run Chinook
Fall-run Chinook
coho

Bonneville dam

19/23
SALMON RETURNS

Bonneville dam

Returns by smolt-entry year & life-history

coho yearling
SALMON RETURNS

Bonneville dam

Returns by smolt-entry year & life-history

Sprng&Smmr yearling
Coho yearling

June

September

Adult returns

1 ocean year

\( \ln(\text{Sea Nettle biomass}) \)

\( R^2 = 0.09 \)

\( R^2 = 0.43^* \)
Fall Chinook subyearling

June

September

Spring/Summer Chinook yearling

June

September

Adult returns

3 ocean years

$\ln(\text{Sea Nettle biomass})$

$\ln(\text{Sea Nettle biomass})$

$R^2 = 0.56^{**}$

$R^2 = 0.51^*$

$R^2 = 0.76^{**}$

$R^2 = 0.7^{**}$

21/23
Annual age structure not yet available extrapolated from 99-10 mean (excluded from correlation)

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**Fall Chinook subyearling**

Summer Chinook

June

- 3 ocean years
- Adult returns

\[ R^2 = 0.56^{**} \]

\[ R^2 = 0.51^{*} \]

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**Spring/Summer Chinook yearling**

June

- 3 ocean years
- Adult returns

\[ R^2 = 0.76^{**} \]

\[ R^2 = 0.7^{**} \]

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**In(Sea Nettle biomass)**
Conclusions:

- Juvenile salmon are sensitive to indirect competition from *Chrysaora fuscescens*
  - Otherwise insensitive to indirect trophic pathways

- Interannual correlation between adult salmon returns and *C. fuscescens* biomass during year when smolts enter the ocean
  - True for all three life-history stages examined
  - Relation to June jellyfish biomass is not robust

- Inverse relation between local jellyfish abundance and feeding incidence of juvenile salmon in September
  - (using <100 m isobath restriction)

- 1 STD *C. fuscescens* scenario estimates 18% reduction in salmon production
Thanks

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