Life History Strategies: Applications to Fisheries Management

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Pacific Finfish Currently “Unassessed”

- Overwhelming list of species with large bycatch or new fisheries
  - Over 400 species caught in Canadian Pacific fisheries each year
  - Less than 35 have formal assessments
    - Pacific Salmon
    - Pacific Herring
    - Hake
    - Some flatfish
    - Halibut
    - Some rockfish
Life History Traits & Environmental Forcing

- Life history traits are the underlying determinants for population response to environmental forcing
  - On top of this natural variation will be a modification of the response due to fishing removals
Here’s the idea!

- If we have a number of “new” species of interest
  - No biomass estimate
  - No relative abundance measure (surveys, CPUE)
  - No reliable measure of catch

- And we assume that underlying population response to environmental forcing and fishing pressure is determined by life history traits...
Then can we....?

Use fish groupings based on life history traits

- life history strategies
to typify strategists population dynamics and outline fishery management strategies that are fundamentally based on a fish’s biology
Why?

size
age
growth
fecundity

Strategist A
Management Strategy A

Strategist B
Management Strategy B

Strategist C
Management Strategy C

Strategist D
Management Strategy D
Life History Strategies

- Winemiller & Rose (1992)
- McCann & Shuter (1997)
  1. Opportunistic strategists
  2. Periodic strategists
  3. Equilibrium strategists
  4. Salmonic strategists
## Life History Strategies

- **Winemiller & Rose (1992)**
- **McCann & Shuter (1997)**
  1. Opportunistic strategists
     - fast-growing; short-lived; intermediate fecundity
  2. Periodic strategists
     - slow-growing, long-lived, high fecundity
  3. Equilibrium strategists
     - fast-growing, long-lived, low fecundity
  4. Salmonic strategists
     - opportunistic strategists but with freshwater and marine phase
<table>
<thead>
<tr>
<th>Life History Strategies</th>
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<tbody>
<tr>
<td>■ Winemiller &amp; Rose (1992)</td>
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<td>■ McCann &amp; Shuter (1997)</td>
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<tr>
<td>➔ Freshwater and some tropical species</td>
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<tr>
<td>➔ Limited range of life history parameters</td>
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<tr>
<td>■ King and McFarlane (2003)</td>
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<tr>
<td>➔ Focus on marine sub-arctic species</td>
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<td>➔ Inclusion of elasmobranchs</td>
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Methods

1. Assemble life history traits of commercially important Pacific marine species
2. PCA on life history traits
3. Identify marine life history strategists
4. Assign management scenarios
Assemble Life History Traits

- Selected 42 marine species across ecological guilds
  - Plankivores → top predators
  - Pelagics → demersal
  - All of commercial importance or interest

- Life history traits (literature or research data)
  - Size at 50% maturity
  - Maximum size
  - Growth coefficient ($k$)
  - Fecundity
  - Egg size
  - Maximum age
### PCA on life history traits

- **First 2 components are significant**

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<thead>
<tr>
<th></th>
<th>PC1</th>
<th>PC2</th>
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<tbody>
<tr>
<td><strong>Eigenvalue</strong></td>
<td>2.64</td>
<td>2.06</td>
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<tr>
<td><strong>Percent Variation</strong></td>
<td>44.05</td>
<td>34.31</td>
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<tr>
<td><strong>Eigenvector</strong></td>
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<td></td>
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<tr>
<td>Size at maturity</td>
<td>0.94</td>
<td>-0.15</td>
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<tr>
<td>Maximum size</td>
<td>0.95</td>
<td>-0.13</td>
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<tr>
<td>Growth (k)</td>
<td>-0.34</td>
<td>-0.79</td>
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<tr>
<td>Fecundity</td>
<td>0.06</td>
<td>-0.76</td>
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<tr>
<td>Egg size</td>
<td>0.79</td>
<td>-0.41</td>
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<tr>
<td>Maximum age</td>
<td>0.34</td>
<td>0.84</td>
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PCA on life history traits

Opportunistic strategists

Periodic strategists

Equilibrium strategists

Salmonic strategists
Marine Life History Strategies

Periodic strategists (Demersal fish)
- slow-growing
- long-lived
- high fecundity

Opportunistic strategists (Forage fish)
- fast-growing
- short-lived
- intermediate fecundity

Salmonic strategists
- fast-growing
- long-lived
- low fecundity

Equilibrium strategists (Elasmobranchs)
Typical Population Dynamics: opportunistic strategists

- Small, rapidly maturing, short-lived
- Small eggs, intermediate fecundity

E.g. Pacific sardines (Sardinops sagax)

[Graph showing catch in the Gulf of California and California west coast from 1915 to 2000]
Assign Management Scenarios: 

**opportunistic strategists**

- Pelagic, planktivores
  - Highly variable habitat
  - Large sources of energy

→ Tightly linked to climate-ocean conditions
  - Interannual and decadal
  - Very high degree of variability
  - Susceptible to rapid depletion augmented by fishing pressure

**Critical Minimum Spawning Biomass**

- Historical low abundance
- Periods when population can not be exploited
- Higher maintenance stocks need careful monitoring
Typical population dynamics: periodic strategists

- Intermediate-large size, slow growing, long-lived
- Lots of eggs

e.g. Sablefish (Anoplopoma fimbria)
## Assign Management Scenarios: *periodic strategists*

- Demersal, piscivores
  - Low variable habitat
  - Limited sources of energy
- Longevity ensures long reproductive cycle
  - Ability to outlast poor environmental conditions
  - Period between strong year classes can be long

⇒ **Association with decadal-scale climate-ocean conditions**

**Robust Age Structure** e.g. Rockfish Conservation Areas

- Annual recruitment only a fraction of spawning stock biomass
- Paramount to *always* maintain appropriate age structure, ensuring older fishes are in the spawning biomass
Identify typical population dynamics: *salmonic strategists*

- Large, short-lived
- Low fecundity
- Freshwater – ocean stages

**e.g. Sockeye salmon** (*Oncorhynchus nerka*)

![Graph showing Sockeye salmon population returns](image-url)
Assign Management Scenarios: *salmonic strategists*

- Opportunistic strategist with freshwater and marine survival components
- Marine survival (first ocean summer & winter) is important
  - Strong linkage to climate-ocean conditions

**Freshwater density dependent relationship**
(egg to smolt production)

**Marine Survival Rate**
(smolt to adult production)
- Low marine survival, low returns
- Reduced hatchery programs
Typical population dynamics: equilibrium strategists

e.g. Spiny dogfish (*Squalus acantbias*)

- Late maturation: 35 years
- Long lived: 100+ years
- Extreme low fecundity: 9 pups

→ very low rate of intrinsic population increase
### Assign Management Scenarios: equilibrium strategists

- Top predators
- Low intrinsic rate of increase
- Young are very well developed

⇒ Little linkage to climate-ocean conditions

### Low Harvest Rates

- No targeted fisheries (or very low F)
- Bycatch fisheries managed to maintain low capture rates
“We want to fish hagfish”

Pacific hagfish
(*Eptatretus stouti*)

Opportunistic Strategists

Periodic Strategists

Intermediate Strategists

Equilibrium Strategists

Salmonic Strategists

- Critical Spawning Biomass
- Robust Age Structure
- Critical Spawning Biomass
- Very Low Harvest Rates
- Marine Survival Component

Very Low Harvest Rates
“We want to fish hagfish”

Pacific hagfish (Eptatretus stouti)

Small experimental fishery:
- Size = 63 cm
- Fecundity = 15
- Maximum age = 17
- Egg size = 5 mm
- Size at 50% maturity = 35 cm
- $k = 0.07$

Opportunistic Strategists
- Critical Spawning Biomass

Periodic Strategists
- Robust Age Structure

Intermediate Strategists
- Critical Spawning Biomass

Equilibrium Strategists
- Very Low Harvest Rates

Salmonic Strategists
- Marine Survival Component
"We want to fish hagfish"

Pacific hagfish
(*Eptatretus stouti*)

Opportunistic Strategists

Critical Spawning Biomass

Periodic Strategists

Robust Age Structure

Intermediate Strategists

Critical Spawning Biomass

Equilibrium Strategists

Low Harvest Rate \( \approx 4\% \) (Incidental catch)

Salmonic Strategists

Marine Survival Component
Filling in the Assessment and Management Gaps

- Fishermen are increasingly diversifying their operations
  - must account for all species caught
  - large-scale ecosystem changes and major abundance/distribution changes
- Greater demand for advice on “new and developing” fisheries and unassessed species
- Using a species’ biology (life history strategies)
  - to advise on likely population dynamics under fishing pressure and climate variability
  - select suitable management scenarios