Abrupt changes in migratory behaviour of Pacific hake in Canadian waters

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Overview

- Pacific hake – why you should care
- Why has hake changed its migration?
  - Potential mechanisms
  - Extrinsic and Intrinsic
  - King et al. 2011. ICESJ MS.
- Ecosystem Reorganization
  - Impact on Competitors
- Stock delineation of Pacific hake
Pacific hake (*Merluccius productus*)

- maximum age: 16
- age of maturity: 3+
- age of recruitment: 2-5
- bathypelagic (up to 500 m)
- highly migratory throughout the California Current System
  - straddling stock between Canada and the US
  - 25-40% enter Canadian waters for summer feeding

California Current System
Pacific hake biomass

- Most abundant groundfish population in the California Current system
- 1.5 million tonnes
  - Humboldt squid
  - 1999 yearclass

Accoustic survey estimates age 2+

Stewart et al. 2011
Pacific hake fishery

- Important fishery; more hake caught than all other groundfish species combined

![Total Hake Catch Graph](image-url)

- Year: 1966 to 2010
- Catch (thousand tonnes)
- US
- Canada
Spawning (February)

Summer feeding

Juveniles

Adults

Large adults

CANADA

USA

Spawning (February)

25-30% into Canadian waters

“Typical” (1966-1989)

Expanded range

Additional spawning

40% into Canadian waters

El Niños (1990-1999)
Pacific hake migration mechanism

In warm (El Niño) years (1990s), Pacific hake migration is more northward:

**Extrinsic**
- poleward flow of California Undercurrent is stronger
  - equatorward flow of surface California Current is weaker
- upwelling intensity is reduced in southern waters and increased in northern waters

**Intrinsic**
- less productivity and prey availability in south;
- adult hake forage more northerly
- Prey availability improved northward

Hollowed 1992; Horne and Smith 1997; Agostini et al. 2006; King et al. 2011. ICESJMS.
Canadian fishery

- propagated on the migratory summer feeders
  - July - September

West Coast

Vancouver Island

Queen Charlotte Sound

West Coast

Vancouver Island

Queen Charlotte Sound
Canadian summer fishery

- dramatic changes in hake fishing grounds in 2006

- WCVI only
- northward expansion
- El Niño years
- back to more ‘typical’ distribution
- intense in the north
- decline off WCVI
What happened in 2010?

- **2009**: intense in the north
- **2010**: focused back on WCVI
- **2011**: preliminary return to the north
Canadian fishery

2006 changes were dramatic and unprecedented

Canadian hake landings

Most hake in QCS

No hake anywhere

2006 changes were dramatic and unprecedented
Canadian summer fishery

- distinct monthly changes in distribution after 2006

**Monthly Catch**

<table>
<thead>
<tr>
<th>Month</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>2005</td>
<td>2006</td>
<td>2005</td>
<td>2006</td>
</tr>
<tr>
<td>Catch (thousand tonnes)</td>
<td>2.5</td>
<td>0.8</td>
<td>4.2</td>
<td>2.8</td>
</tr>
</tbody>
</table>

**Late July**
Unlike the 1990s, when hake expanded northwards, there has not been strong, prolonged El Niño events from 2006-2011.
California Undercurrent mechanism

- difficult to measure
  - ROMS model results (DiLorenzo pers. comm.)
- 2006 not exceptionally different from 2000-2005
2000-2005 was actually weaker in intensity

- no difference in spring transition

- 2010 was remarkably weak - but not a year of high northward extension
Prey availability mechanism

- Pacific hake diet:
  - euphausiids; small fish (Pacific herring); shrimp

![Pie chart showing prey availability]

- Euphausiids: 85%
- Herring: 4%
- Other fish: 4%
- Invertebrates: 8%

n=12,711 stomachs
who else eats lots of euphausiids?
Mechanism of hake redistribution

- **Intrinsic mechanism due to:**
  - Bottom-up prey availability (previous conceptual mechanisms during ElNino years)
  - Top-down prey availability i.e. Impact of competition with ‘new’ competitor of sardines in WCVI

- different Extrinsic Mechanisms for each direction which requires flexibility in our search
Ecosystem reorganization

- large biomass of Pacific hake redistributed (by 2010)
  - no longer dominate the highly productive LaPerouse Bank of the WCVI
  - major component Queen Charlotte Sound

**Impacts on other competitors in Queen Charlotte Sound?**
Impacts on other Competitors—other Pacific hake?

- resident population in the Strait of Georgia
- winter fishery on spawning aggregates
  - separate quota
- distinct from the offshore migratory stock
  - concave otoliths
  - absence of parasite *Kudoa paniformis*
  - smaller size at age
Resident Pacific hake stocks

- the events of 2006 were so drastic and unprecedented that fishers raised concern over potential impacts on resident fish that might be feeding in QCS
- deep inlets adjacent to QCS
  - Rivers Inlet
  - Milbanke Sound
  - Queen Charlotte Strait
  - Johnstone Strait
Stock delineation of migratory and resident Pacific hake in Canadian waters

King et al. 2011. *Fisheries Research*  
Hake stock delineation surveys

- size distribution; population genetics; parasite presence applied to determine the demographic connectivity of Pacific hake found in Queen Charlotte Sound in summer to:
  1. the coastal migratory population of the California Current System
  2. the known resident population of the Strait of Georgia
  3. potential resident populations in adjacent deepwater inlets
**CPUE and size distributions**

**Size distribution**
- **QCS**: big and small
- **WCI**: similar big
- **inlets**: similar small
Population genetics

- n=1,430 tissue samples; mtDNA
- pairwise $F_{ST}$ estimates to determine stock

QCS hake in summer not distinct from:
- WCVI hake
- Milbanke Sound hake
- Rivers Inlet

WCVI hake are distinct from:
- Strait of Georgia + inlets
- Rivers Inlet
- Milbanke Sound
- Queen Charlotte Strait + Johnstone Strait

- the summer feeding aggregate in QCS is mixed with resident populations – except for SofG hake
- there are several distinct resident stocks in Canada
previous stock delineation augmented by:

- *Kudoa thyrsites* present in both migratory and resident stock (old parasite)

- *Kudoa paniformis* present only in migratory (new parasite)

new detection of *K. paniformis* in all resident populations; albeit at very low infection levels
- could have been previously rare and undetected
- Strait of Georgia hake do not appear to mix with other stocks so not likely due to new patterns in summer mixing
- intermediate invertebrate host (oligochaete or polychaete) is unidentified
  - environmental changes with intermediate host’s distribution or abundance changes in Strait of Georgia and other inlets
Pacific hake migration changes

- dramatic changes in 2006
  - previous extrinsic mechanisms do not match
  - direction of intrinsic mechanism may require separate extrinsic mechanisms
- the signals of 2010 did not have a lasting impact in 2011 on Pacific hake migratory patterns
- given the biomass and diet of euphausiids, this migration change has a large ecosystem impact
- implications of competition in summer with resident stocks
  - fishery impacts on unassessed resident fish