The influence of the Leeuwin Current on economically important fish and invertebrates off temperate Western Australia

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Outline

• Recap of major conclusions from earlier reviews.
• Report on some of the recent advances in our understanding of the influence of the LC on economically important fish and invertebrates.
• Discuss how this knowledge can contribute to better management of our fisheries.
Leeuwin Current
(Warm low-nutrient waters flowing south)
Earlier Reviews

- LC contributed to warmer/low nutrient water column environment off WA.
- As a consequence, fisheries production dependent on benthic-based food web.
- Species investigated for LC effects included WRL, SB prawns, SB scallops, A salmon, A herring & pilchard.
- Relationships invoked from statistical correlations.
- Mechanisms underlying observed relationships poorly understood.
Earlier Reviews

Caputi et al 1996.

- Improved understanding of annual, seasonal, & regional behaviour of LC.
- Further exploration of mechanisms underlying observed effects of LC on
  - larval stages - recruitment.
  - later life history stages – growth and catchability.
- Updated investigations on WRL, SB prawns, SB scallops, A salmon, A herring pilchards.
- added whitebait.
Recent Advances

- Leeuwin Current “system” i.e. Leeuwin Current, Leeuwin undercurrent, on-shelf Capes Current & Ningaloo Current.
- Range of interannual & seasonal variability in LC strength & behaviour, and it’s effect on temperature, salinity, and productivity is related to ENSO cycle.
- Global atmospheric changes also contributing to observed physical oceanographic changes i.e. gradual warming of oceanic waters off lower west coast.
Rate of warming (°C/year) 1951 – 2004 (Pearce & Feng, in press.)
Recent Advances

- Of the 7 species hitherto considered, investigations have continued with WRL, SB prawns, SB scallops, A. herring.
- Additional species studied include mudcrabs, WA dhufish, & tailor.

- A. salmon in WA - Changing nature of the fishery has prevented ongoing work.
- Albany pilchards - Stock abundance and distribution changes relative to LC has changed this relationship.
- Whitebait - Restructure of the fishery means whitebait relationship needs to be reviewed.

Fish for the future
Western Rock Lobster
(*Panulirus cygnus*)
Rock Lobster Life Cycle

**OCEANIC PHASE**
- Hatching (Nov to Feb)
- Incubate eggs for 19 to 68 days
- Berried females (Sept to Jan)
- Phyllosoma

**NURSERY AREAS INSHORE**
- Carried by currents and wind offshore
- Carried by currents back towards the coast (mainly Aug to Jan)
- Final stage phyllosoma
- Puerulus
- Juveniles
- Whites migrate to deeper water (Nov to Jan)
- Some remain on the shallow reefs
- Swims across continental shelf to settle inshore
- Feed and grow on shallow reefs for 4 to 6 years

**COMMERCIAL AND RECREATIONAL CATCH**
- Nov. to June

Fish for the future
Updated from Pearce & Phillips 1988
Strong Leeuwin Current effect on Puerulus abundance & distribution

- Warmer temperature (lower salinity)
  - effect on larval survival & growth?
- Stronger eddy structure
  - retaining larvae close to the coast?
- Higher productivity with stronger eddies
  - Increased larval survival & growth?
- Strong southerly flow of water
  - Spatial distribution of puerulus
Puerulus abundance & temperature

Puerulus Jurien - Temperature (Feb - Apr)
(Rain South Oct - Nov)

Temperature (Feb - Apr)

--- >80 mm Rainfall
--- <80 mm Rainfall

Fish for the future
Chl A v Puerulus Jurien & Alkimos

**Jurien**

- Scatter plot showing the relationship between Puerulus index and Annual Chlorophyll A.
- Correlation coefficient: $r = 0.8818$

**Alkimos**

- Scatter plot showing the relationship between Puerulus index and Annual Chlorophyll A.
- Correlation coefficient: $r = 0.5868$

*Fish for the future*
11-Year Mean Eddy Kinetic Energy
(Ming Feng)
Fremantle sea level v. Eddy Energy (M. Feng)
Spatial Distribution of Puerulus Settlement versus Leeuwin Current

Latitude

Puerulus settlement

1993/94 (FSL=65)

1990/91 (FSL=70)

1985/86 (FSL=74)

2000/01 (FSL=87)

Pt. Greg.  Abrohlos  Dongara  Jurien  Lancelin  Warnbro  M. River

Fish for the future
Leeuwin Current – RL puerulus abundance

• Puerulus abundance, LC strength (Freo sea level), temperature, chlorophyl A, eddy kinetic energy all positively correlated.

• More southerly distribution of higher puerulus abundance positively correlated with LC strength.
Frequency of ENSO events

• 8 events in 16 years (1991-2006)
  – 1 in 2 years

• 5 events in 20 years (1971-1990)
  – 1 in 4 years
Updated from Pearce & Phillips 1986
The immediate future?

- More years of weaker currents?
- More years of poor recruitment centered around the northern regions of the fishery?
Shark Bay Western King Prawns
(Kangas, unpublished)

King prawn landings (tonnes)

Fremantle sea level (May-Aug)

1980’s
R² = 0.697

Post 1990
R² = 0.374
Shark Bay Scallops

- Earlier published reviews report a strong negative correlation between juvenile abundance and the strength of the Leeuwin current.
- The addition of more recent data has weakening the relationship considerably ($R^2=0.1221$).
Southerly Shift in Species Distribution
Mud Crabs  (Gopurenko, et al 2003)
Fremantle Sea Level

Year:

FSL (cm):
60 70 80 90

Graph showing the Fremantle Sea Level from 1990 to 2000.
Exmouth ($N = 24$)
Broome ($N = 8$)

All south west sites ($N = 32$)

Haplotypes
- 2-J
- 2-K
- 2-L
- 1-A
Life cycle of Australian herring

ADULTS
Spawn around coastal reefs (May-June)

Around the onset of maturity (about 2 yrs) migrate to WA to spawn

Distribution of larvae to south coast inshore nursery areas

Fish for the future
A herring – Larval Distribution throughout south coast nursery areas. (Dimmlich et al 2000)

• Biophysical transport model
  – inputs: Leeuwin Current velocities at various distances from spawning area, wind patterns (9 BoM stations), fish swimming velocities (literature).
  – outputs: predicted degree of recruitment success to various regions of the southern coastline.

• Recruitment indices across the south coast range of nursery areas between 1996 – 1998
Updated from Pearce & Phillips 1986
Figure 4.5 Results of model run for the years 1996-1998.
<table>
<thead>
<tr>
<th>Species</th>
<th>Adults</th>
<th>Spawning Period</th>
<th>Larvae</th>
<th>Juveniles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dhufish</td>
<td>Temperate West Coast Mid to Outer Shelf</td>
<td>Summer</td>
<td>Water column</td>
<td>Inner to Mid Shelf</td>
</tr>
<tr>
<td>Tailor</td>
<td>Temperate West Coast Inner Shelf</td>
<td>Spring through Autumn</td>
<td>Neustonic</td>
<td>Nearshore/Estuarine</td>
</tr>
</tbody>
</table>
Work in progress – Dhufish
(St John unpubl.)

![Surface salinity and No. of recruits over years](chart.png)

- **Surface salinity**
- **No. of recruits**

**Year**: 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 00, 01

**No. of recruits**: 4000, 36.5, 3000, 2000, 1000, 0

**Surface salinity**: 36.5, 36.0, 35.5, 35.0

**Work in progress – Dhufish**

(St John unpubl.)

**Fish for the future**
Work in Progress – Tailor
(Ayvazian et al Unpubl.)

Point Walter juvenile catch rate (no./person/hour)

WC salinity (lagged 1 year)

Fish for the future
Management

• Knowledge of LC effects
  – better understanding of spatial & temporal distribution of recruits (recruitment variability)
  – more rigorous recruitment sampling methodology, and
  – more robust recruitment index for use as a predictive tool (RL & A. herring).
  – helps interpret changes in catchability (RL, SB prawns, A salmon)

• Also assists with modeling the “on-shelf marine community” level response to environmental change and fishing (EBFM).
Conclusions

<table>
<thead>
<tr>
<th>Species</th>
<th>Leeuwin Current Relationships</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0+ recruits abundance</td>
</tr>
<tr>
<td>Rock lobster</td>
<td>+ve robust</td>
</tr>
<tr>
<td>SB Scallops</td>
<td>-ve weak</td>
</tr>
<tr>
<td>SB prawns</td>
<td>?</td>
</tr>
<tr>
<td>A herring</td>
<td>-ve(WA)</td>
</tr>
<tr>
<td>Dhufish</td>
<td>&quot;-ve&quot;</td>
</tr>
<tr>
<td>Tailor</td>
<td>&quot;-ve&quot;</td>
</tr>
</tbody>
</table>

While important, many factors other than Leeuwin Current contribute to recruitment variability.
Conclusions (cont.)

- **Future research:**
- Elucidate finer-scale detail of Leeuwin current “on-shelf” behaviour off West Coast (WC).
- Explore “on-shelf” interactions between LC (Capes Current?) and spawning behaviour, and the effect on recruitment variability for key WC scalefish (WC A. herring, dhufish, tailor).
- Quantify the origin of spawning A. herring (exploitable biomass) for both WC and SC fisheries.
- Further study underlying mechanisms for SB scallops and prawns.
- Update the LC whitebait relationships.
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