Use of otolith chemistry to trace life history variability in barramundi

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Background

Understanding the life history of fishes is fundamental to their conservation and management.

Movement is a key aspect of the life history and drives important ecological processes.

Intra-specific variation in life history has important consequences for fish species and the fisheries they support (‘portfolio effect’, Schindler et al. 2010).
Barramundi *Lates calcarifer*

- High commercial, recreational and cultural importance
- Protandrous hermaphrodite
- Catadromous (spawns in salt water)
- Exhibits lots of intra-specific variation in behaviour
Barramundi life history model

1. Spawning occurs around river mouths and marine bays early in the wet season.

2. High spring tides wash eggs and larvae into coastal swamps.

3. Juveniles migrate upstream at the end of the wet season. 
   - Approximately
   - Age: 0-1 yr
   - Weight: 0.4 kg
   - Length: < 40 cms

4. Maturing males move downstream during the wet season. 
   - Approximately
   - Age: 3-4 yrs
   - Weight: 3-4 kgs
   - Length: < 60-80 cms
This presentation...

- Use otolith analysis to trace whole-of-lifetime salinity and growth histories of individual barramundi
- Revisit life history model and examine implications of movement behavior for food web and fishery productivity

  - Roberts et al. (in review). Migration to freshwater increases growth rates in a facultatively catadromous tropical fish.
A year in the life of a barramundi
101cm fish, tracked by acoustic telemetry Sep 2015 to Nov 2016
Otolith strontium isotope analysis

- Analysis of otolith $^{87}\text{Sr}/^{86}\text{Sr}$ allows us to hind-cast the entire salinity history of individuals
- $^{87}\text{Sr}/^{86}\text{Sr}$ is constant globally in marine waters (0.70916), but variable in freshwater
- Compare otolith and water $^{87}\text{Sr}/^{86}\text{Sr}$ to make inference about ambient salinity across life history
- Increment width is related to somatic growth rate
- We can align chemistry data with annual increments to examine effects of migratory strategies on growth rates
Methods

• Analysis of otolith $^{87}$Sr/$^{86}$Sr conducted on >200 Barramundi otoliths from Daly, Mary, Roper, Sth Alligator, Macarthur and Fitzroy (WA) rivers
• Laser-ablation multi-collector inductively coupled plasma mass spectrometry (LA-MC-ICPMS) operated by University of Melbourne
• Core-to-edge $^{87}$Sr/$^{86}$Sr transects, aligned with annual increments
Results – migration history

Water mixing model – South Alligator River

Salinity

Sr/86Sr

<1 ppt

1-3 ppt

3-36 ppt

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Results – migration history

Barramundi (89 cm TL), Mary River estuary

\[
\frac{^{87}\text{Sr}}{^{86}\text{Sr}}
\]

Distance from core (µm)
Results – migration history

Barramundi (122 cm TL), Mary River estuary

- 

\[ \frac{^{87}Sr}{^{86}Sr} \]

Distance from core (µm)

- <1 ppt
- 1-3 ppt
- 3-36 ppt
Results – migration history

Barramundi (103 cm TL, 6 years old), Yellow Water

Distance from core (µm)

$^{87}\text{Sr} / ^{86}\text{Sr}$

$< 1$ ppt

1-3 ppt

3-36 ppt
Results – migration history

Barramundi (103 cm TL, 6 years old), Yellow Water, Sth Alligator River

Mature female
Results – migration history

Barramundi (109 cm TL, 17 years old), Daly River

Stayed in freshwater until 10 years of age
Conclusions – migration history

From Crook et al. (2017)
Results - migration and growth rate

Daly, Mary, Sth Alligator, Roper, Macarthur
Migration and growth rate

Advantage versus estuarine/marine residence

<table>
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<th>Age</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<td>+17.26%</td>
<td>+12.59%</td>
<td>+9.10%</td>
<td>+6.33%</td>
<td>+4.04%</td>
<td>+2.09%</td>
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<tr>
<td>Mixed</td>
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<td>+8.63%</td>
<td>+6.86%</td>
<td>+5.50%</td>
<td>+4.41%</td>
<td>+3.49%</td>
<td>+2.71%</td>
</tr>
</tbody>
</table>

Roberts et al. (in review)
Conclusions – migration and growth rate

• Growth rates of barramundi tend to be greater when they are living in fresh water (access to productive floodplains)
• This is the opposite pattern to temperate anadromous fish (e.g., salmonids)
• Consistent with the ‘productivity hypothesis’ (Gross et al. 1988, Science)
  • Diadromy driven by productivity differentials between fresh and marine waters
  • This hypothesis suggests that diadromy is an intermediate evolutionary step between marine and freshwater residence
• If there’s such a big advantage, why don’t they all migrate?
• Environmental variability may allow different phenotypes to co-exist
• Demonstrates the importance of undisturbed floodplains for fishery productivity
Temporal stability of water Sr signatures

- Marine $^{87}\text{Sr}/^{86}\text{Sr}$ is temporally stable at a global scale over millennia.
- Freshwater $^{87}\text{Sr}/^{86}\text{Sr}$ is determined by catchment geology.
- It is often assumed that $^{87}\text{Sr}/^{86}\text{Sr}$ in rivers is stable because underlying geology is invariant.
- However, surface run-off and groundwater hydrology potentially interact with geology to influence local patterns of $^{87}\text{Sr}/^{86}\text{Sr}$.
- Temporal variation in freshwater $^{87}\text{Sr}/^{86}\text{Sr}$ has the potential to confound interpretation of otolith chemistry data.
Temporal stability of water Sr signatures

Daly River barramundi

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Temporal stability of water Sr signatures

$^{87}\text{Sr}/^{86}\text{Sr}$
Temporal stability of water Sr signatures

$^{87}\text{Sr}/^{86}\text{Sr} – \text{longitudinal main channel}$

![Graph showing the temporal stability of water Sr signatures](image-url)
Temporal stability of water Sr signatures

Sr concentration
Temporal stability of water Sr signatures

- There is potential for strong temporal variation in water Sr signatures, especially where there is significant groundwater input.
- Caution is needed when interpreting otolith chemistry data.
- Need data on water chemistry over time.

![Graph showing temporal stability of water Sr signatures.](image)
Acknowledgments

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