Ontogenetic niche separation and connectivity of fishes from the Kimberley region, Western Australia, using otolith geochemistry

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Background

• The Kimberley Marine Research Program (KMRP) was established to understand eco-connectivity of the Kimberley coastal marine environment;
• Understanding eco-connectivity is vital for the effective management of fish stocks (Sale et al. 2005 *TREE*);
• Otolith geochemistry has become a popular source of information for understanding population connectivity and movement of fishes (Campana et al. 2000, *Fish. Res.*).
Project Aims

• To determine if ontogenetic niche separation can be determined in two species of coral reef fishes through the study of otolith geochemistry;
• To establish whether the variation in trace elements found in fish otoliths produces geographic groupings for both species;
• To determine whether the data derived from the geochemistry is comparable to genetically derived information for the same species across a similar spatial scale.
• Otoliths grow throughout the life of the fish

• Deposition of calcium carbonate, is regular so when the otolith is sectioned they show a concentric time-series.

• Trace elements and isotopes from the environment are deposited at the same time.

• Analyses of these chemicals can be used to determine the habitat the fish inhabited during that period of its life. (Campana 1999, MEPS)
Target Species

- *Lutjanus carponotatus* (stripey snapper)
- *Pomacentrus milleri* (miller’s damselfish)
  - Key ecological species – abundant and common, good indicators of a healthy environment
  - Important for fishing (*L. carponotatus*)
  - Samples collected by Fisheries and on WAMSI research trips
Ontogenetic Niche Separation

Juveniles inhabit coastal waters, particularly mangroves and seagrass beds.

Adults move offshore which is where spawning takes place.

Planktonic larvae make their way to the coast as they grow.
Larvae migrate from the open ocean to the coast but it is not known how they distribute along the coast:

- As one population with movement along the coast during the juvenile phase
- As several populations with some connectivity
- As discrete populations with no connectivity at all
Lutjanus carponotatus

Available otoliths:  
335 female  
374 male  
93 sites

Sampled otoliths:  
64 female  
64 male  
45 sites
Pomacentrus milleri

Available otoliths: ●
67 female
51 male
72 unclassified
18 sites

Sampled otoliths: ♠
20 female
20 male
12 sites
Trace Element Analysis

• A suite of trace elements including B, Ba, Cr, Mg, Mn, Pb, Sn will be measured to refine location signatures.

• Past work has demonstrated that fish habitats can be geographically separated by the combination and proportion of different trace elements (Thorrold et al. 2007, Oceanog.).

• Otoliths are embedded in resin, sectioned and polished then undergo laser-ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) which can be analysed as a transect or a element map.
Strontium Isotopes

• Strontium abundance (measured as Sr/Ca, below) is correlated with salinity, with higher Sr with increasing salinity (Campana 1999, *MEPS*).

• Fluctuations in strontium stable isotope ratios $^{87}\text{Sr}/^{86}\text{Sr}$ are also associated with changes in salinity.

• Both parameters are measured using multi-collector inductively coupled plasma mass spectrometry (MC-ICP-MS) through a sectioned otolith, in order to measure an ontogenetic time-series.
Oxygen Isotope Analysis

- Oxygen isotopes ratios ($\delta^{18}O$) also vary with salinity (Elsdon & Gillanders, 2002, *Can J. Fish. Aquatic. Sci.*).
- Oxygen isotopes can be measured using secondary ion mass spectrometry (SIMS).
- SIMS is a very precise technique, using laser spots of 5 or 15$\mu$m in size.
- Comparing Sr and O ratios measured by different techniques provides an independent test of the results – if they corroborate we can be sure that they are accurate.
## Geochemical Analyses

<table>
<thead>
<tr>
<th></th>
<th>Set 1 64 L. carponotatus 18 sites</th>
<th>Set 2 40 P. milleri 12 sites</th>
<th>Set 3 64 L. carponotatus 27 sites</th>
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<td>(Set 3 at University of Adelaide)</td>
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</table>

* 19 trace elements: 7-Li, 23-Na, 24-Mg, 25-Mg, 42-Ca, 43-Ca, 48-Ca, 55-Mn, 60-Ni, 63-Cu, 65-Cu, 66-Zn, 85-Rb, 86-Sr, 87-Sr, 88-Sr, 137-Ba, 138-Ba, 208-Pb

** SIMS is only planned for use on a subset of the otoliths due to limitations of cost, time and machine availability. Six otoliths from Set 1 (*L. carponotatus*) underwent SIMS analysis in January 2017. This will act as a proof-of-concept and should the analysis be successful then a subset of otoliths from *P. milleri* will be analysed at a future date. Only after this time will further SIMS analysis be planned.
Data Analysis

- Margin analysis – compare geochemistry from the margins to determine if the fish can be differentiated by site
- Core analysis – compare geochemistry from the cores to determine if spawning populations can be distinguished
- Comparison with genetics results – does the geochemistry tell the same story as the genetics?
- Transect analysis – time series analysis of geochemistry to see if movement can be inferred (ontogenetic movement)
- Population analysis – compare the life-histories of the individual fish from the same and different sizes to determine if there are commonalities (this will be complex work due to the extended sampling period of the otoliths)
Preliminary Results – *L. carponotatus*

- Statistically significant differences between north and south

**PERMANOVA**

- **Core**: $p = 0.0108$
- **Margin**: $p = 0.0014$
Preliminary Results – *P. milleri*

- No population differentiation (yet)
Preliminary Results – *P. milleri*

- With outliers removed

![Graph showing preliminary results with locations and elements plotted on a PCA diagram.](image-url)
Future Work

• Is there the same north/south divide present in *P. milleri*?
• Is there evidence of exchange of fish between north and south?
• Is there evidence of nursery grounds? If so, can they be located?
• Is SIMS a good method?
Thanks To:

• Everyone in the otolith sectioning lab at Fisheries, particularly Mark and Jan, for teaching me how to prepare and section otoliths
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• Laure Martin for her help with SIMS
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REFERENCES