Large pelagic squids, mid-level trophic gateways?

Trophic ecology of two pelagic squids, revisited

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Why study the trophic ecology of these squids?

• They are a food source for many large pelagic predators- billfish, sharks, tunas, cetaceans etc.
• They feed heavily on mesopelagic fishes and squids
• Historical fishery (300,000 mt/yr), troubled fin-fish fisheries, new Hawaiian fishery
• Trophic interactions are fundamental to ecosystems and animal behavior
Background

*Sthenoteuthis oualaniensis*- purple squid

*Ommastrephes bartramii*- red squid
Background on squids
Sampling area
Methodology (stomach contents)

- Correlate what is found with identifiable parts, beaks/otoliths.

Benefits
- species identification
- actual consumption
- low tech

Limitations
- bias
- snapshot of feeding
- labor intensive
- reference dependent
Methodology (stable isotopes, $\delta^{15}N$)

$\delta^{15}N = [(R_{sample}/R_{standard})-1] \times 1000$, $R = ^{15}N/^ {14}N$

$\delta^{15}N$ value gets larger with trophic level (add on 3.4‰ each TL) (Mingawa&Wada, 1984; Peterson & Fry, 1987)

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Limitations</th>
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<tbody>
<tr>
<td>• non-biased</td>
<td>• 3.4‰ average</td>
</tr>
<tr>
<td>• assimilated material</td>
<td>• where is the baseline?</td>
</tr>
<tr>
<td>• historical data</td>
<td>• does not identify prey</td>
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<td>• time component (turnover)</td>
<td>• isotopic routing</td>
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<td>• less time consuming</td>
<td>• less tested in open ocean</td>
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</table>
Otolith abundance (family level):

- **O. bartramii**, n=264
- **S. oualaniensis**, n=210

**Fish Family**

- Myctophidae
- Unidentified
- Gonostomatidae
- Melamphaidae
- Sternoptychidae
- Photochthiidae
- Evermannellidae
- Chauliodontidae
- Gempylidae
- Scopelarchidae

% of total otoliths
Otolith abundance (myctophids):

O. bartramii, n= 264

S. oualaniensis,
n=210

% of total otoliths

Myctophid species

- O. bartramii
- S. oualaniensis
Beak abundance (family)

O. bartramii, n= 264
S. oualaniensis, n=210

Cephalopod family

% of total beaks
Beak abundance (lowest taxon)

O. bartramii, n= 264
S. oualaniensis,
n=210

% of total beaks

Cephalopod taxa

O. bartramii
S. oualaniensis
Feeding indices - breadth + overlap

(Hurlbert, 1978; MacArthur and Levins, 1967)

Feeding indices - breadth + overlap

Red squid feeding

Purple squid feeding

Overlap > 0.7 considered substantial

(Macpherson, 1981; Ellis et al., 1996)

Red squid feeding is a subset of red squid feeding but also shows differences in % and patterns

<table>
<thead>
<tr>
<th>Squid</th>
<th>Breadth</th>
<th>Overlap</th>
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<tbody>
<tr>
<td>Red</td>
<td>0.56 (0.22)</td>
<td>0.22 (0.46)</td>
</tr>
<tr>
<td>Purple</td>
<td>0.086</td>
<td>1.16 (0.93)</td>
</tr>
</tbody>
</table>

narrow 0 ≤ B ≥ 1 wide

No parentheses - otolith data
Parentheses – beak data

Purple squid feeding is a subset of red squid feeding but also shows differences in % and patterns
Stable isotopes: all categories

\[ \delta^{15}N_s = 0.65 \]

TL-5, TL-4, TL-3, TL-2, TL-1

POM, Plankton, S. oualaniensis paralarvae, O. bartramii paralarvae, O. bartramii juveniles, S. oualaniensis (subadults), myctophids, C. hippurus, Thunnidae, other mesopelagics, O. bartramii adults
Trophic complexity

Red = red squid prey
Purple = purple squid and red squid prey
Pink = mostly red squid prey some purple squid
$\delta^{15}$N increase with size

Purple squid, n = 167

$\delta^{15}$N (muscle)

Mantle length (mm)

Unusually heavy individuals

$r^2 = 0.56$
$\delta^{15}N$ increase with size

Red squid, $n = 174$

$r^2 = 0.83$
Historical $\delta^{15}\text{N}$ signal

Purple squid eye lenses

\[ r^2 = 0.79 \]

\[ r^2 = 0.68 \]

\[ r^2 = 0.56 \]
Historical $\delta^{15}N$ signal

Red squid eye lenses

The graph shows the relationship between mantle length (mm) and $\delta^{15}N$ values for Red squid eye lenses. The data points are color-coded to indicate muscle and eyes. The x-axis represents mantle length, while the y-axis represents $\delta^{15}N$ values.

Key:
- Muscle
- Eyes

The graph indicates that there is a trend where muscle $\delta^{15}N$ values are generally higher than those of eyes, especially at longer mantle lengths.
Conclusions

• Red squid generalist feeder, purple squid more specialized

• Using $\delta^{15}N$ to study trophic position in these squids yields reproducible results with a range of different tissues

• Purple squid increases trophic position throughout size ranges sampled, red squid increases trophic position rapidly and then reaches a relatively high plateau
Conclusions cont...

- *O. bartramii* vs *S. oualaniensis*...competition??

- Stomach contents vs stable isotopes
  - Stomach contents indicate differential feeding
  - $\delta^{15}N$ indicate very different trophic position

- Trophic position for these squids is highly dependent on size, however other factors (geography, individual feeding behavior, growth rate) can affect the shape of the $\delta^{15}N$ vs size curve

- Need experimental studies looking at feeding and $\delta^{15}N$

**IMPLICATIONS FOR ECOSYSTEM BASED MANAGEMENT??**
Individual variation in patterns? $0.78 \leq r^2 \geq 0.98$, n=13
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Comparisons with other studies (stable isotopes)

Purple squid

• Takai et al. (2000) 5 S. oualaniensis avg 10.0‰ (217mm) off Japan (26.30°N, 144.00°E).

• Todarodes pacificus avg 10.5‰ (207 mm) off Japan

• Takai et al. (2000) found large regional differences in δ¹⁵N values for S. oualaniensis throughout both the Pacific and other oceans.
Comparisons with other studies (stable isotopes)

Red squid

- Takai et al. (2000) 5 female *O. bartramii* = 11.8 to 12.1‰ avg ML of 360 mm off Japan.
Comparisons with other studies (stable isotopes)

Kline (1997) looked at range of groups from plankton up to fish in the Gulf of Alaska.

Kline et al. (1998) looked at different fishes in northern Alaska.
Frequency data (family level):

- Myctophidae
- unidentified
- Gonostomatidae
- Melamphacidae
- Photichthyidae
- Chaouliodontidae
- Sternoptychidae
- Evermannellidae
- Gempylidae
- Scopelarchidae
- Omosudidae

% of squid stomachs containing prey item

- O. bartramii
- S. oualaniensis
Frequency data (lowest taxon):

- M. lychnobium/spinosum
- L. tenuiformis
- C. warmingii
- S. evermanni
- H. proximum/rheinhardti
- M. selenoides
- E. risso
- D. perspiculatus
- T. minimus
- L. luminosa
- L. urophaos
- M. nitidulum
- D. fragilis
- Myctophid species

% of squid stomachs containing prey item

- O. bartramii
- S. oualaniensis
Isotopic complexity

Juvenile red squid eye lenses

\[ \delta^{15}N \text{ of juvenile } O. \text{bartramii eye lens segments} \]

\[ \text{Estimated mante length (mm) from eye lens radius} \]
Plot of $\delta^{15}\text{N}$ vs Mantle length

$r^2 = 0.77$

Mantle length (mm)

$\delta^{15}\text{N}$ (muscle)

purple squid
red squid
Recent history of $\delta^{15}\text{N}$?

Purple squid blood

$\delta^{15}\text{N}$ of S. oualaniensis blood

Mantle length (mm)
Recent history of $\delta^{15}$N?

Red squid blood