Are there too many or too few round gobies in Lake Huron?
Round Goby

*Neogobius melanostomus*

- Native to the Black and Caspian seas
- Lake St Clair River in 1990, Lake Huron in 1994
- Deepwater fish community
- Small, < 130 mm total length in Great Lakes
Why are round gobies important?

• Impact on native fishes
  – Predation on eggs and fry (lake trout, lake sturgeon, darters)
  – Competition for habitat and benthic invertebrates (sculpins)
  – Consumes dreissenids, accumulates toxins
  – Now feed on by predators so new transfer route for toxins

• Bioenergetics models consumption estimates
  – Primary prey used to be alewife and rainbow smelt
  – Diet shift to include goby in 2002
  – Increasing diet proportion for lake trout and walleye
  – Lake whitefish began feeding on round goby
No gobies consumed before 2001

After 2001, gobies comprised 30-40% of consumption by lake trout and walleye

Whitefish diet after 2002 included

- 16% (mean)
- 39% (max)
Prey biomass estimated from USGS bottom trawl

Estimated prey consumption

Goby bottom-trawl biomass estimates substantially less than consumption estimates

Mean = 17.6 million g

Mean = 497,500 g
Why do the estimates differ?

• Bottom trawl considerations
  – Round gobies prefer rock, sand, cobble, gravel, and macrophyte habitats and hide in crevices
  – Males guard nests (differences in proportions and size-at-age)
  – Trawls may occur after most of consumption occurs

• Bioenergetic models assumptions
  – Diet proportions, energy density, growth, etc.
  – Only key predators in offshore areas
Goby population model

• Create population model for Lake Huron round goby
• Use food web study consumption estimates to elicit S-R relationship
• Not a lot of Lake Huron data so borrow from other lakes, mostly Lake Michigan
Goby population model

- Ages 0 – 5, \( a \)
  - Ages 5+ often not found in studies
- Numbers at age 1+
  \[ N_a = N_{a-1} \times e^{-Z_{a-1}} \]
- Total mortality, \( Z_a \)
- No S-R relationship
- For recruitment at age-0, we constructed numbers-at-age using estimates of mortality
- Find \( R \) that sustains a goby population that could support the estimated consumption of gobies
Model – Mortality sources

\[ Z_a = M_a + Mp_a \]

- \( M_a \) is natural mortality-at-age
  - \( M_0 = 0.95 \) \( (\text{Kovtun, 1979, Sea of Azov}) \)
  - \( M_{1+} = 0.42 \) or 0.81 \( (\text{Pauly 1980, Huo et al. 2014 W,K,T}) \)
    \[ \log(M) = -0.2107 - 0.0824 \times \log(W_{inf}) + 0.6757 \times \log(K) + 0.4627 \times \log(T) \]
  - Age 1+ same mortality

- \( Mp_a \) is predation-at-age
  - \( Mp_0 = 0 \)
    - Small size and lack of habitat overlap with predators
  - \( Mp_{1+} = 0.2 - 1.7 \)
    - Predation same on all ages
    - Similar range to Lake Michigan \( (\text{Huo et al. 2014}) \)
**Model – Numbers consumed**

- Gobies consumed-at-age, \( Cn_a \), estimated using Baranov’s catch curve
  \[
  Cn_a = \frac{Mp_a}{Z_a} * N_a * (1 - e^{-Za})
  \]

- Bioenergetics estimates of consumption reported as total biomass

- Need to convert numbers consumed from model to biomass to compare “observed” to “expected”

- Use length-at-age and weight-length relationship to convert numbers to biomass

- Assumed no differences between genders
Model – length and weight

Length-at-age

\[ L_a = 120.86 \times (1 - e^{0.369(a+0.138)}) \] Waukegan

\[ L_a = 132.85 \times (1 - e^{0.263(a+0.275)}) \] Sturgeon Bay

Huo et al. 2014
Model – length and weight

Length-at-age

- Waukegan:
  \[ L_a = 120.86 \times (1 - e^{-0.369(a+0.138)}) \]
- Sturgeon Bay:
  \[ L_a = 132.85 \times (1 - e^{-0.263(a+0.275)}) \]

Weight-length relationship

- Waukegan:
  \[ W_a = 0.000008 \times L_a^{3.261} \]

References:
- Huo et al. 2014
- MacInnis & Corkum 2000
Model – Biomass consumed

\[ Cb_a = Cn_a \times W_a \]

- Expected = \( \sum Cb_a \)
- Observed = \( Ct = 2.32E+10 \text{ g} = 23.2 \text{ kt} \)
- Minimize difference between bioenergetics estimates and model estimates of biomass consumed

\[ SSdif = \left( \sum_{1}^{a} Cb_a - Ct \right)^2 \]

- Adjust recruitment \( N_0 \) until observed and predicted biomass consumed matches
Scenarios

- Base
- MaxAge7
  - Increased maximum age from 5 to 7 to match Lake Michigan
- hiNatural
  - Use higher estimate of background natural mortality of 0.81
- AlternateLAA
  - Use Sturgeon Bay LAA instead of Waukegan
  - Sturgeon Bay fish smaller in the age range we modeled
- $Mp_{1+}$ varied in all scenarios: 0.2, 0.7, 1.2, 1.7
Base

- 200-250 billion age-0 required to support consumption

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<th>$M_{p1+}$</th>
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<th>$C_{n1+}$</th>
<th>Population consumed</th>
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<tr>
<td>0.2</td>
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Base

- 200-250 billion age-0 required to support consumption
- Numbers of age 1+ is 14.5 - 21.1 billion fish
  – Lake Erie estimates for central + western basin was 14.1 billion

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## Base scenario

- 200-250 billion age-0 required to support consumption
- Numbers of age 1+ is 14.5 - 21.1 billion fish
  - Lake Erie estimates for central + western basin was 14.1 billion
- Density in numbers is 0.24 - 0.65/m$^2$ for ages 1+
  - Bay of Quinte density estimates are 0.14 – 3.88/m$^2$

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Changing predation rates

- **Mp=0.2**, biomass consumed-at-age concentrated on ages 2-4 at nearly same proportion
- **As Mp increases**, age composition is increasingly truncated and consumption occurs predominately at ages 1 and 2
- **Mp=1.7**, 88% of the consumption occurs at age 1
Other scenarios

With the higher natural mortality, $N_0$ increased by 56-93% to provide the same consumption over Base.
Other scenarios

Changing the LAA relationship to smaller gobies (from Sturgeon Bay data), $N_0$ increased by from 26-35% over Base.
Other scenarios

Increasing max age from 5 to 7 decreases $N_0$ at $M_p=0.2$ by 14% and is almost the same as Base at $M_p=1.7$.
Model assumptions and interpretation

• Assumes steady-state population
• Applicable if gobies were
  – experiencing heavy predation pressure
  – or mortality rates were in the ranges we used
  – and no expansion in goby population
• Consumption by predators ≠ production
• Bioenergetics estimates include critical assumptions
  – Includes only key offshore predators (lake trout, Chinook salmon, walleye, and lake whitefish)
• Nearshore goby population and predation not accounted for but could represent substantial proportion of overall goby abundance
Too many or too few?

- Too many
  - Non-native species
  - Invasive nature changing food web dynamics
  - Direct harm to some native species
Too many or too few?

• Too many
  – Non-native species
  – Invasive nature changing food web dynamics
  – Direct harm to some species

• Too few
  – Lake Huron’s alewife population is uncertain
  – Becoming important prey fish
    • Impacts commercial and recreational stocks
  – Little is known about goby life history in Lake Huron
Next steps

• High variability in measurements within a lake and measurements between lakes
  – Changes with location, temperature, season, diets, spawning habitat, overlap with predators, etc.

• Need to improve understanding of goby populations in Lake Huron
  – Abundance and mortality
  – Age and gender based length and weight
  – Changes in predator diet composition

• Predator-prey model similar to Lake Michigan
Acknowledgements

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Lake Huron Food Web Project

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* Round goby population model
Variability among studies

- **Gender proportions**

<table>
<thead>
<tr>
<th>Lake</th>
<th>%F</th>
<th>%M</th>
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</thead>
<tbody>
<tr>
<td>Erie</td>
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<td>36.67</td>
</tr>
<tr>
<td>Michigan</td>
<td>54.26</td>
<td>45.74</td>
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<tr>
<td>Detroit River</td>
<td>55.95</td>
<td>44.05</td>
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<tr>
<td>Huron</td>
<td>40.32</td>
<td>59.68</td>
</tr>
<tr>
<td>Ontario</td>
<td>25.09</td>
<td>74.91</td>
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</table>

- **Length-at-age (age 3)**

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<th>Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huron</td>
<td>67.1-69.0</td>
</tr>
<tr>
<td>Huron</td>
<td>100.5 - 105.2</td>
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<tr>
<td>Erie</td>
<td>114.5-148.0</td>
</tr>
<tr>
<td>Michigan</td>
<td>73.6-87.4</td>
</tr>
</tbody>
</table>

- **Age-0 natural mortality**

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<tr>
<th>Lake</th>
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<td>0.95</td>
</tr>
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<td>Ontario</td>
<td>0.99</td>
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