Background

- Freshwater fish are most commonly understood to be active in the spring, summer, and fall, and dormant in the winter. ¹
- For overwintering fish, winter is typically defined as a period of ice cover and short day lengths. ¹
- Winter is associated with negative growth and high mortality with few studies focusing on the potential benefits of winter. ¹
- This study highlights how size and ice cover influence the outcome of cold-water overwintering freshwater fish.
- Explore how winter can be both positive and negative for cold-water freshwater fish.
- Understand the different ways size and ice cover can impact overwintering fish.
- Predict how climate change will impact these fish.

Objectives:

Methods

- Google Scholar was used to search key terms such as "fish AND winter AND mortality" or "fish AND winter AND size".
- Key findings from the studies were organized into a spreadsheet with the most common categories and species studied, which was used to find out which species were most successful under specific conditions.
- Ice cover and size were found to be the most positive topics with cold water species being the most popular for overwinter studies (Fig. 1).
- Data was extracted from Atlantic salmon studies that reported mean monthly wet weight and compared for overwinter studies (fig. 1).
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Reference Table:

<table>
<thead>
<tr>
<th>Label</th>
<th>Reference</th>
<th>Species</th>
<th>Focus of Study</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>Amundsen &amp; Knudsen, 2010</td>
<td>Arctic Charr, Brown Trout</td>
<td>Arctic charr interaction with brown trout</td>
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<td>B</td>
<td>Byström et al., 2006</td>
<td>Arctic Charr</td>
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<td>French et al., 2013</td>
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<td>E</td>
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<td>Cannibalism</td>
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</tbody>
</table>

Ice Cover

- Factors that can make ice cover beneficial:
  - Continuous feeding throughout winter, especially in small fish.³
  - Provides protection against aerial and terrestrial predators.³
  - Ice cover reduces resting metabolism and promotes proper energy budgeting.³
- Factors that can make ice cover disadvantageous:
  - Competition: Heightened competition under ice cover.³
  - Predator: Piscivorous feeding can be less efficient.³
  - Prey: Enhanced predation risk after moving to new feeding zones.³
  - Visual foraging: Ambient light conditions are darker under ice cover.³

Conclusions

- Overwinter success is highly dependent on the complicated interactions of overwinter conditions.
- Ice cover is often crucial for overwinter survival and positive outcome.
- Despite having synthesized the impacts of size and ice cover on overwintering fish, there are still many factors that remain unknown. Future studies should focus on how size and ice cover influence overwinter success paired with other common overwinter conditions.
- Winter is not an inherently negative period of time for freshwater fish as there are many benefits of the season that various species have evolved to take advantage of.
- Climate change is causing warmer, shorter winters with less ice cover which will be detrimental for these cold water fish that benefit from ice cover.⁴

Future Directions

- Draw connections between other factors identified in warm water species.
- Synthesize more topics into unifying winter outcomes and add more conditions to the flow chart.

References:

- Byström et al., 2006
- Hedger et al., 2013
- French et al., 2013
- Gallagher & Dick, 2015
- Amundsen & Knudsen, 2010
- Byström et al., 2006
- Hedger et al., 2013
- French et al., 2013
- Gallagher & Dick, 2015
- Amundsen, P. et al., 2010
- McMeans, 2022

Figures:

- Fig 1. (A) Number of studies with positive, negative, or mixed overwinter results by species organized by mean optimal growth temperature. (B) Number of studies with positive, negative, or mixed results by topic.
- Fig 2. Mean overwinter mass of Atlantic Salmon per month in meters, 2012.
- Fig 3. The effect of size and ice cover on fish species with a cold thermal preference based on lips, survival, energy, growth, and condition.