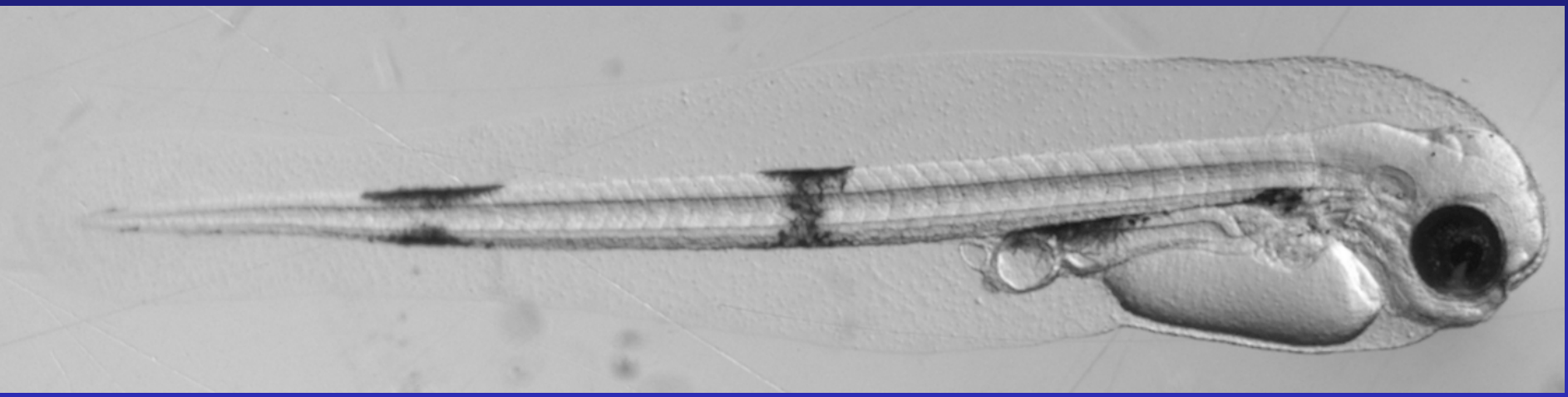
An experimental examination of temperature interactions in the 'match-mismatch' hypothesis for Pacific cod larvae



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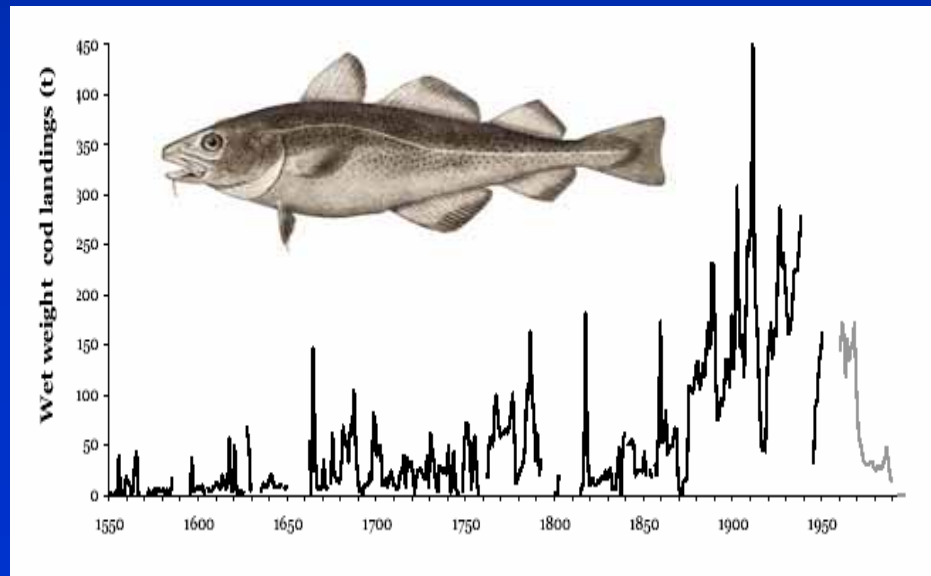
Pacific cod

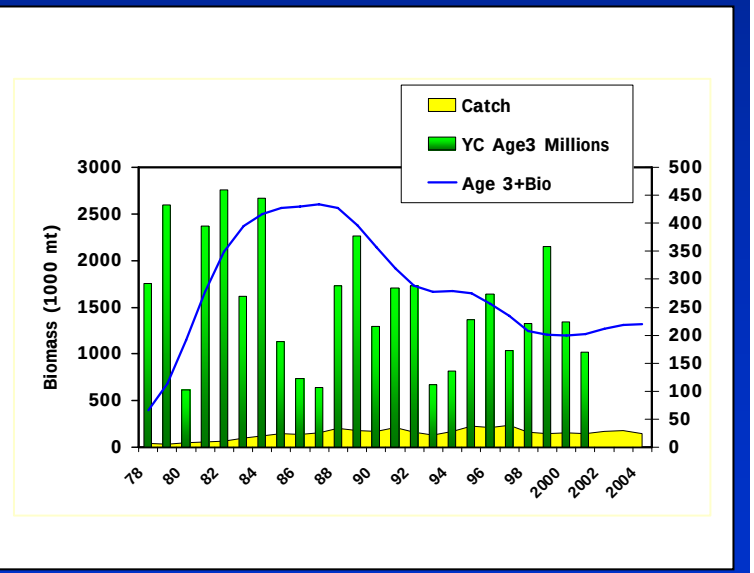
-Rank 2nd in catch and product value in the groundfish fishery in Alaska (much smaller relative component of fishery in Canada)

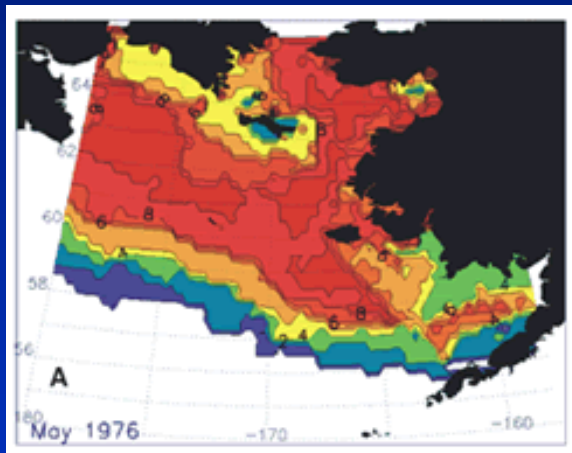
-Pacific cod has been examined in a multi-species framework e.g., regime shifts, climate change and North Pacific trophodynamics

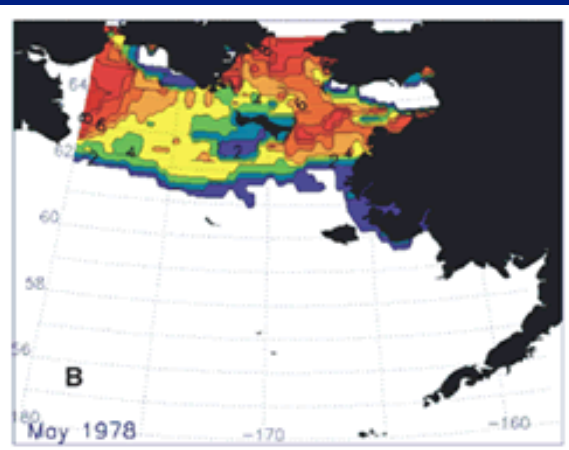
-Few studies have explicitly examined the ecology and life history of Pacific cod possibly because of assumed similarities between Pacific cod and their better-studied congener, Atlantic cod (*Gadus morhua*).

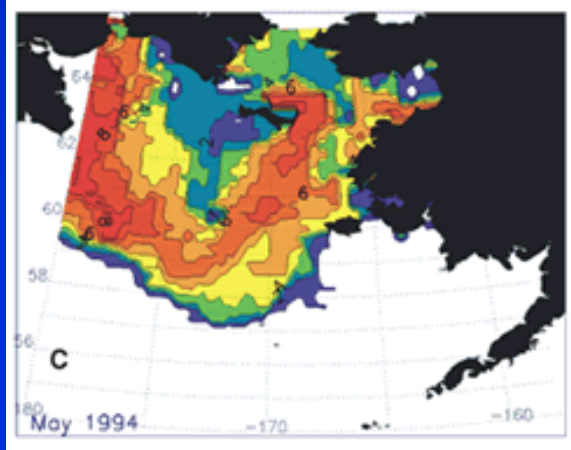


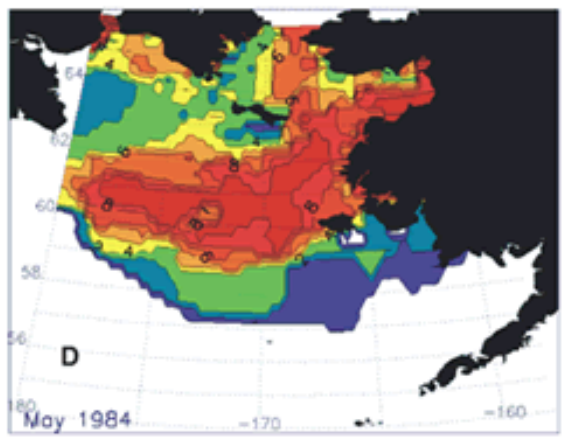
Sea ice coverage in the Bering sea has changed over the past 30 years



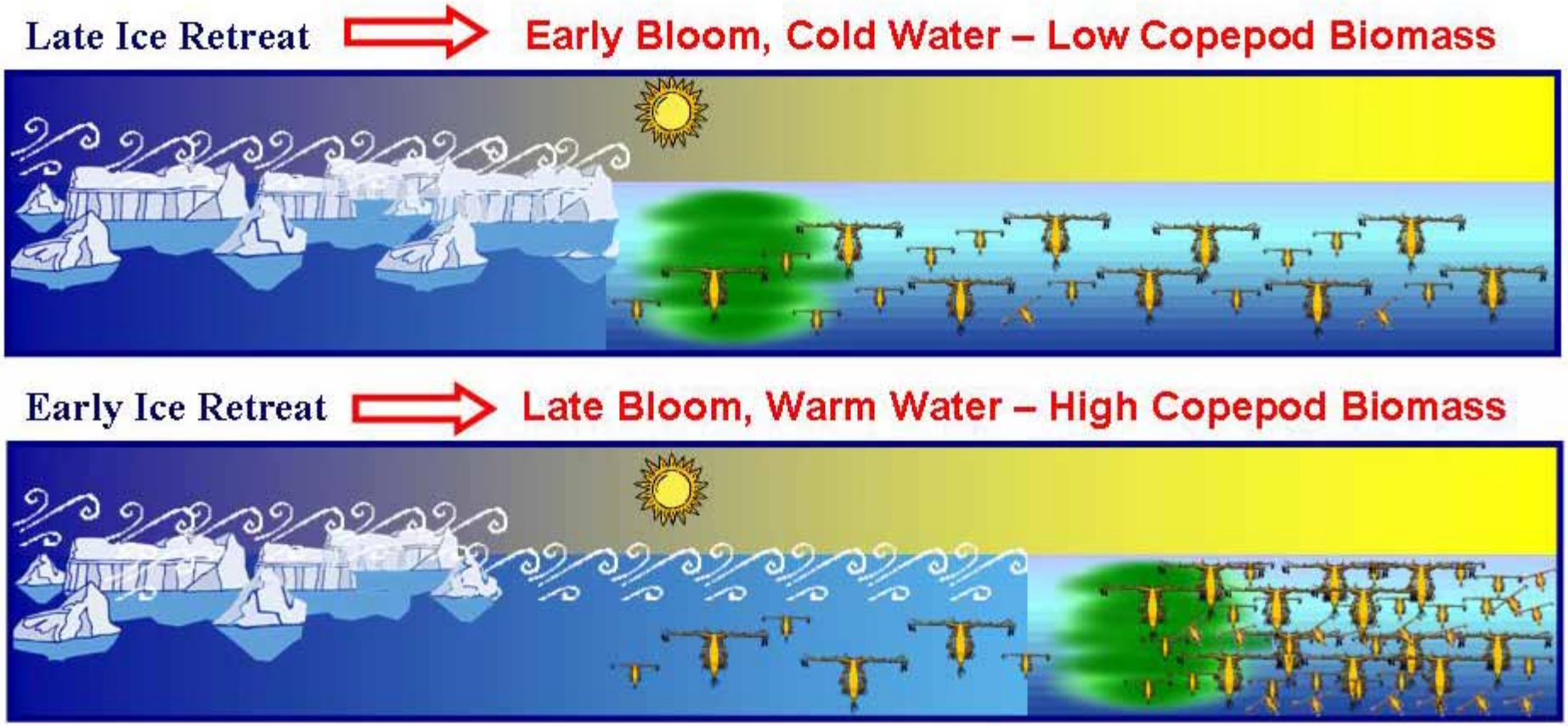








Climate affects the ecosystem through sea ice

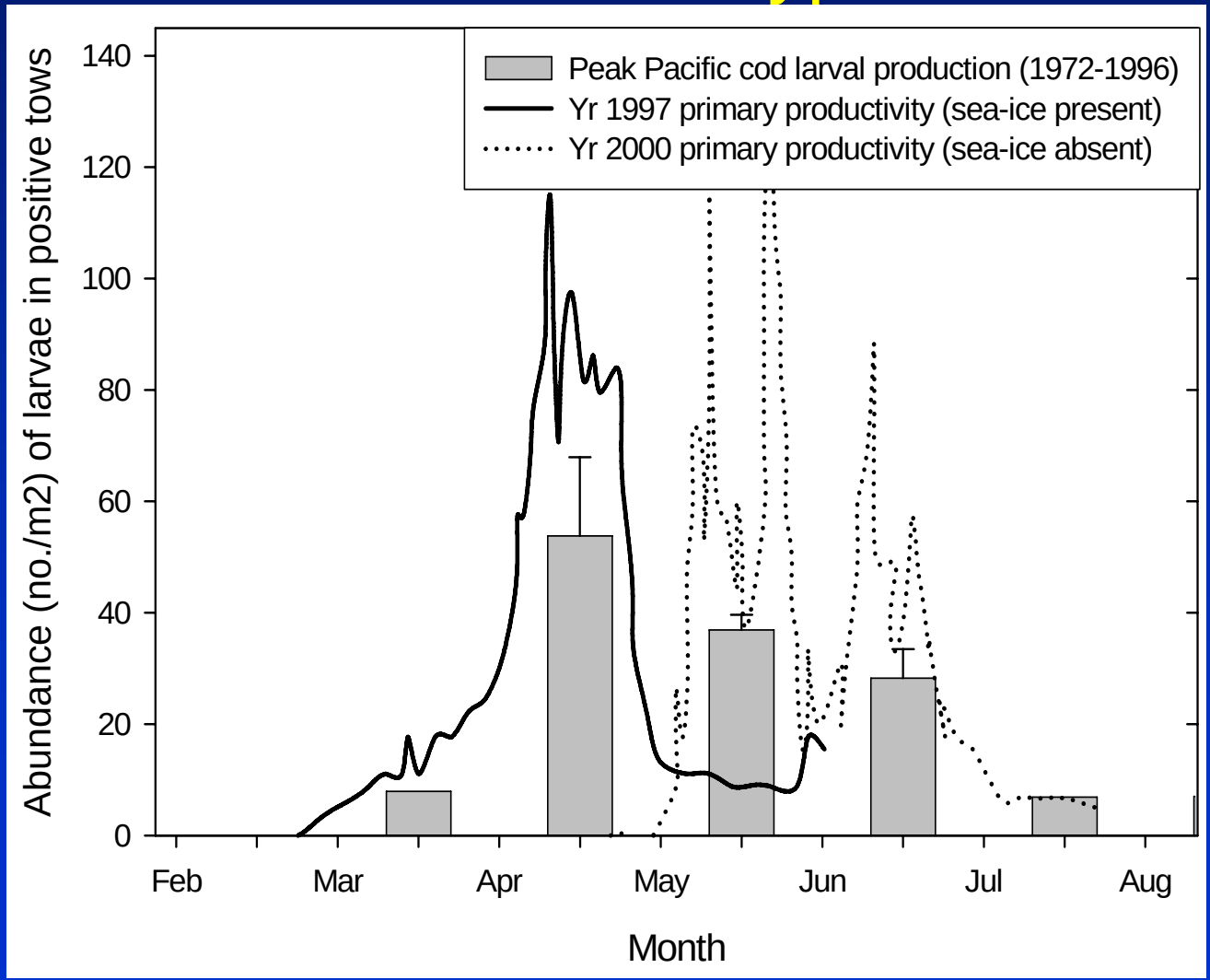


February March April May June

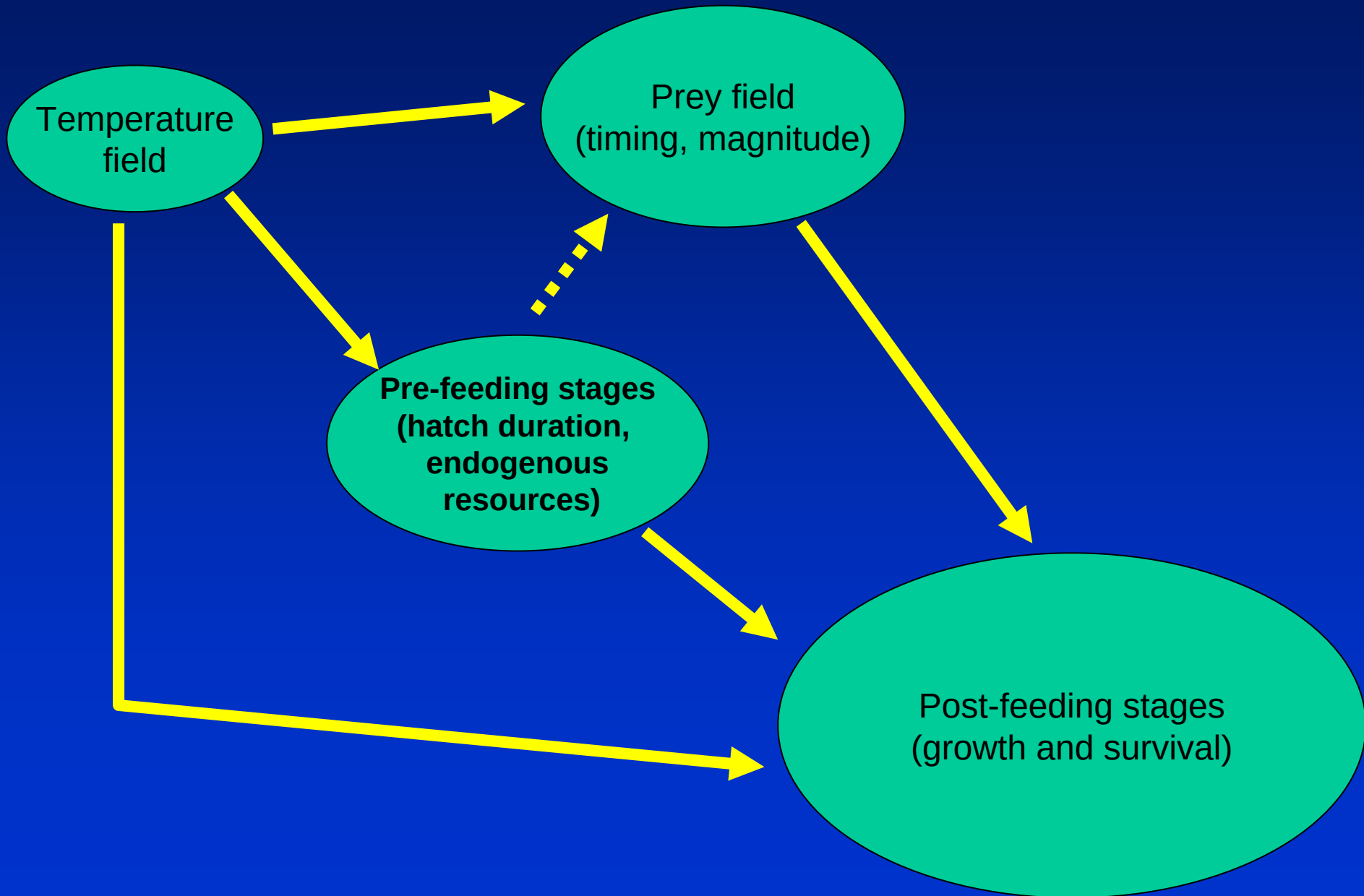
Hunt et al. 2002

Slide courtesy of Gary Shaw

The Oscillation Control Hypothesis contradicts predictions based on the 'Match/mismatch' hypothesis



OCH or match-mismatch? Complex interactions



Modeling growth and survival of Pacific cod eggs/larvae in response to climate-related changes in sea ice conditions in the Bering Sea

- Phase I: Vital rates of eggs and pre-feeding larvae in response to temperature
- Phase II: Vital rates of post-feeding larvae and juveniles in response to interactions in temperature and food availability
- Phase III: Development of spatially explicit models of early life survival of Pacific cod in the Bering Sea using laboratory validated data

Temperature control at the NOAA-FBEP laboratory at the HMSC in Newport, OR

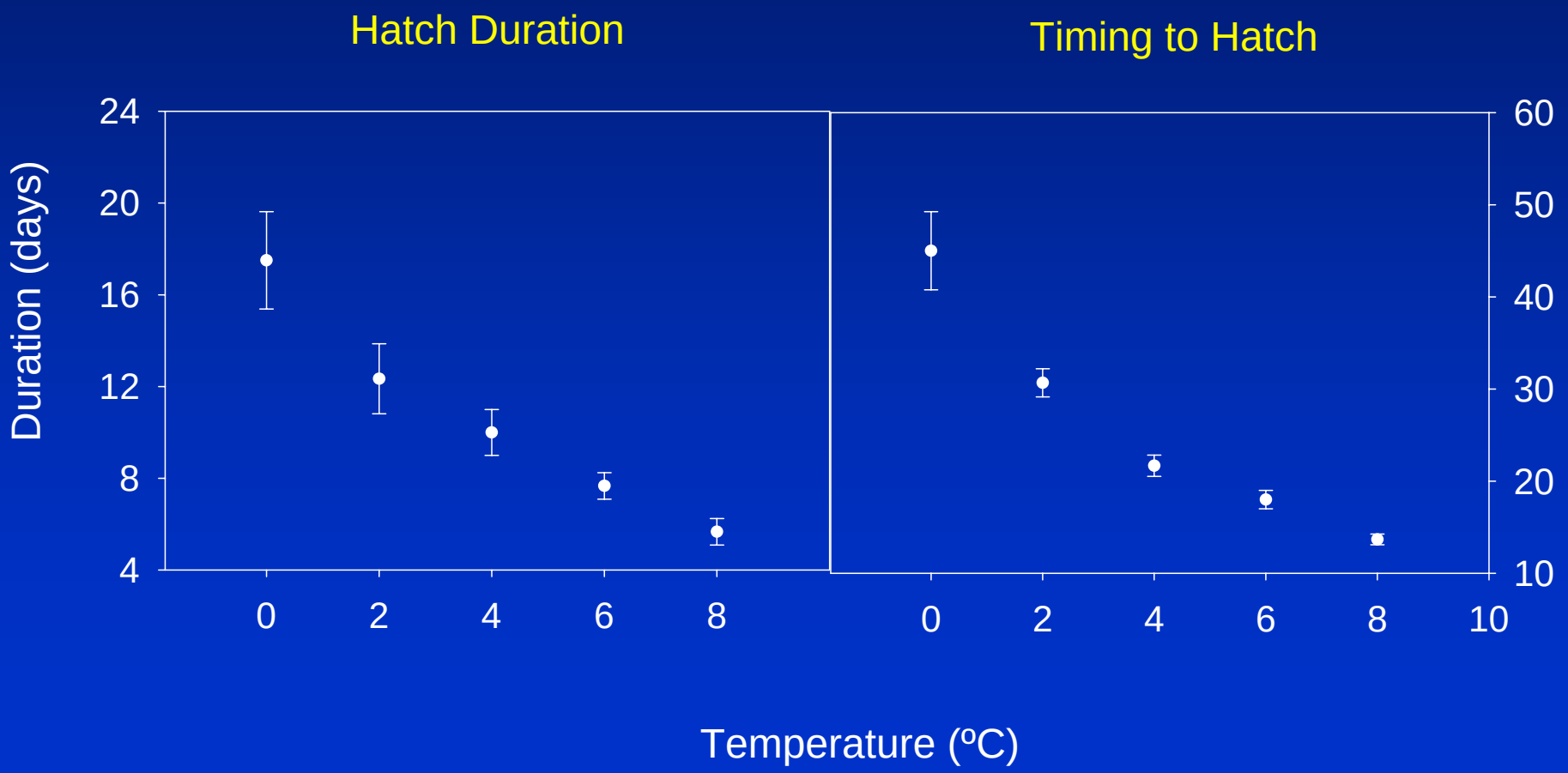
Flow-through, temperature controlled seawater system

Experiment #1: Pre-feeding larvae

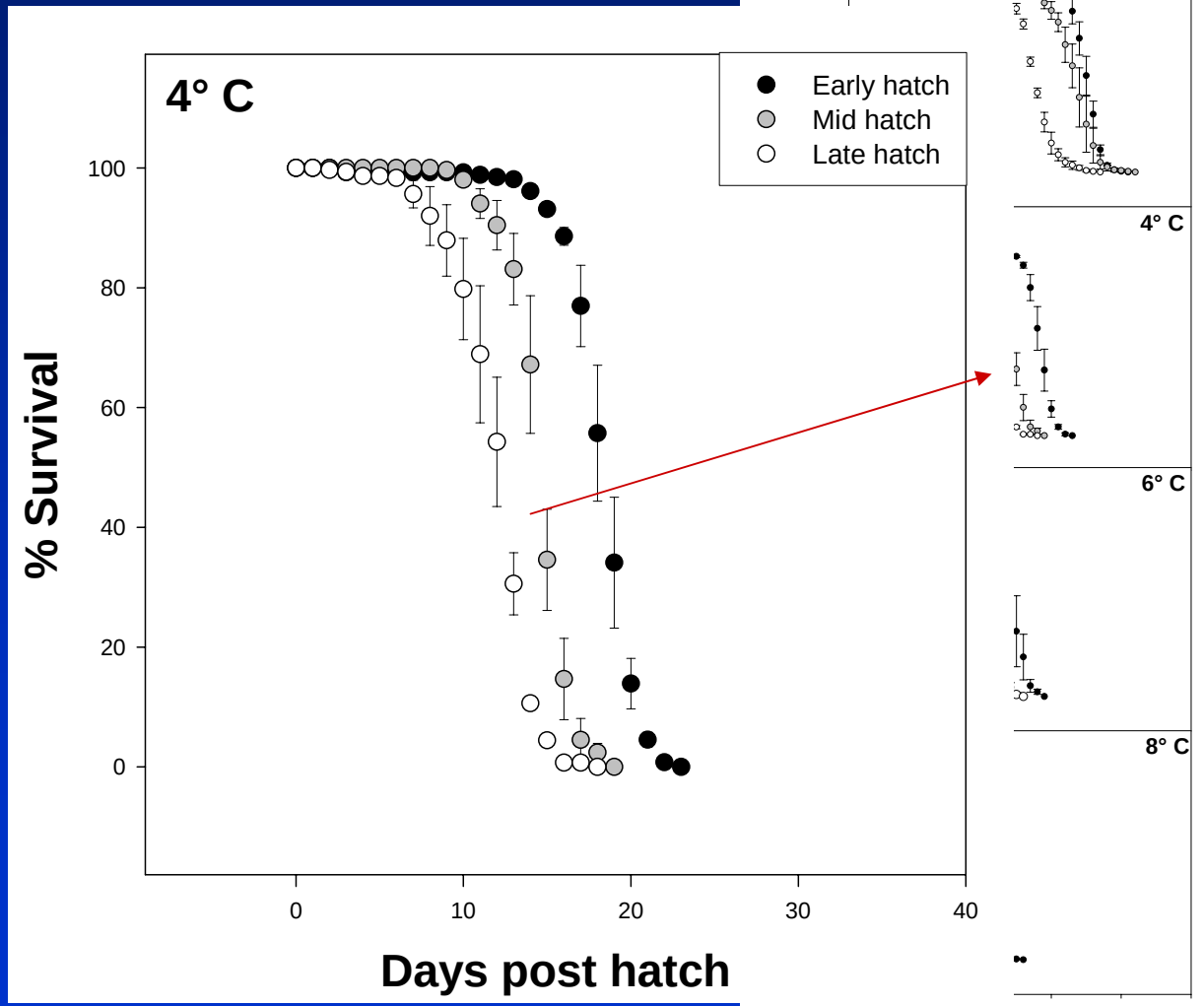
- 5 temperatures (0, 2, 4, 6 and 8ºC)
  - Larvae: 3 replicate containers for each hatching stage: ~25%, ~50% and 75% hatch (n=45 tanks)
    - Measured daily mortality and morphometric changes (yolk area, MH, SL and ED) every 3 days to ~50% mortality
    - Lipid/fatty acid characteristics measured at early, mid and late hatch for each temperature treatment

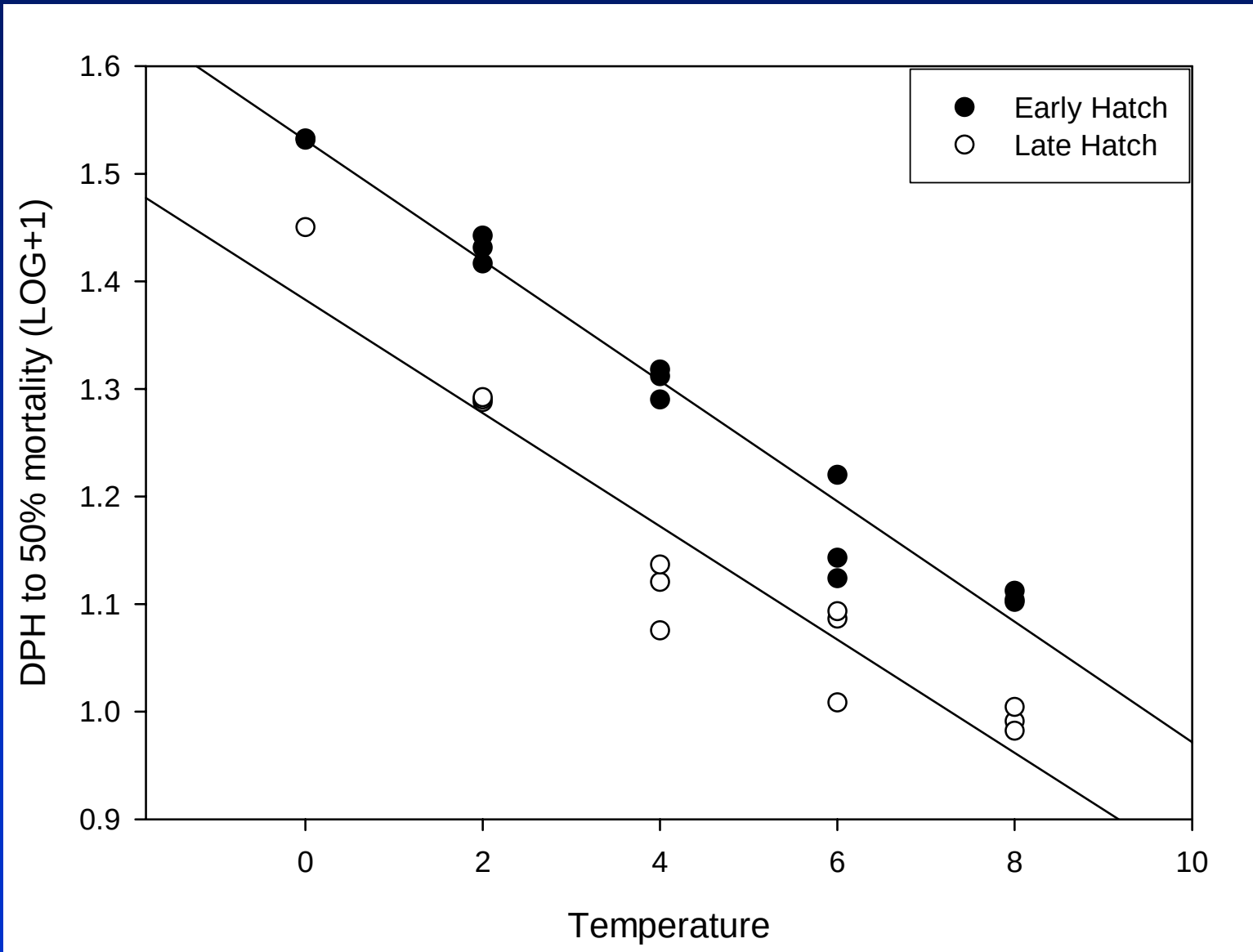

3-A

Hatching is temperature-mediated

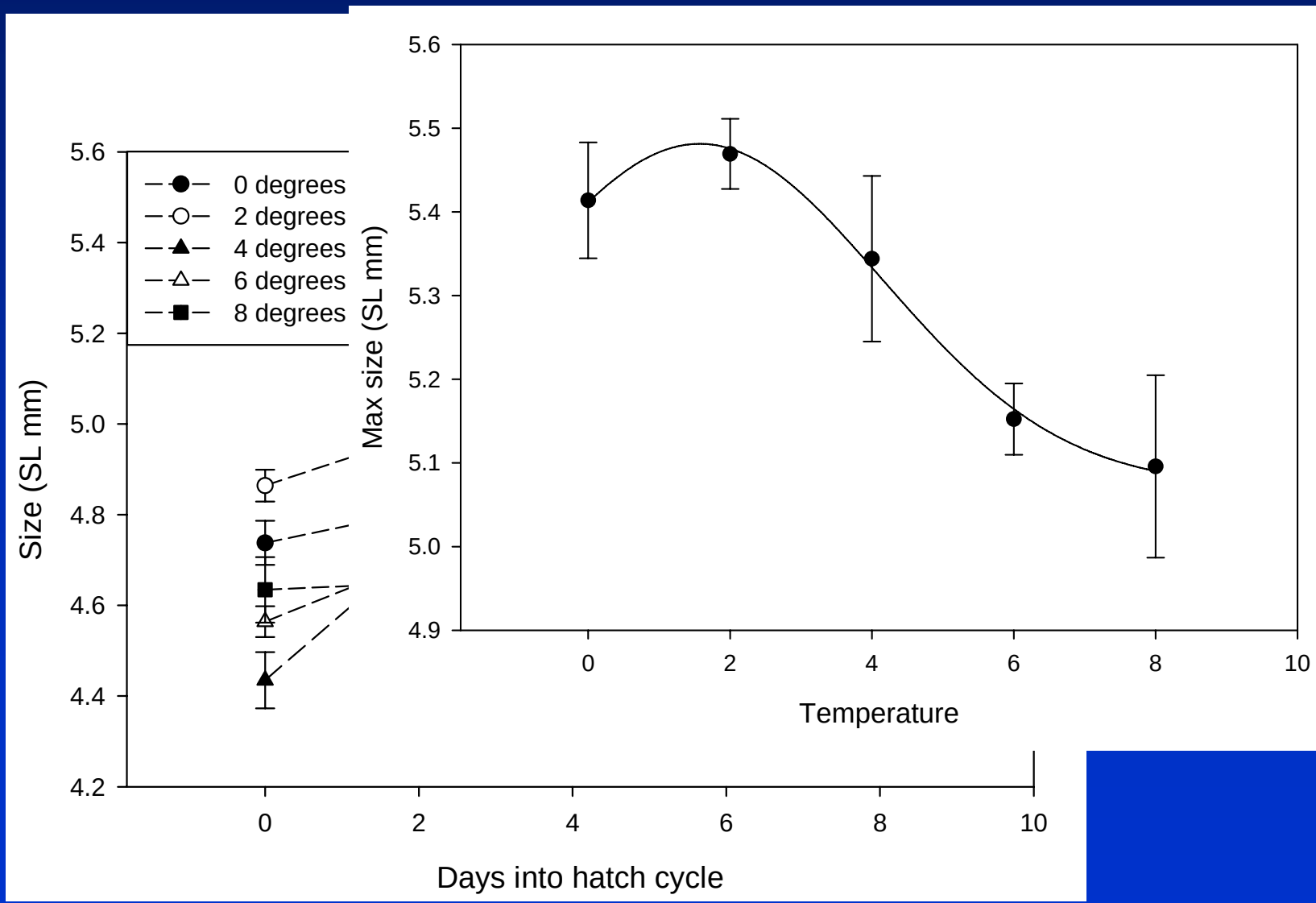


Early hatchers survive longer across all temperature treatments

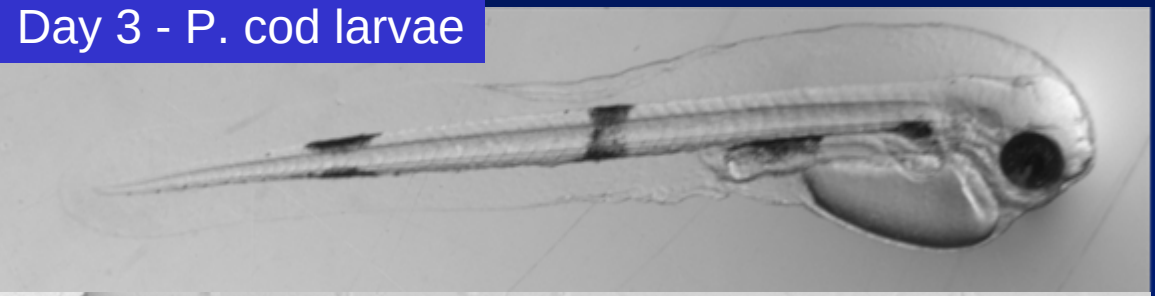



Early Hatch
Late Hatch
DPH to 50% mortality (LOG+1)
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0
2
4
6
8
10
Temperature

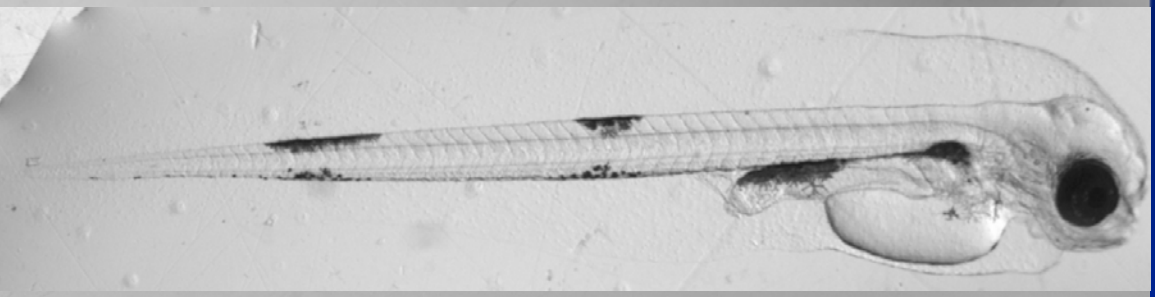
Size and growth



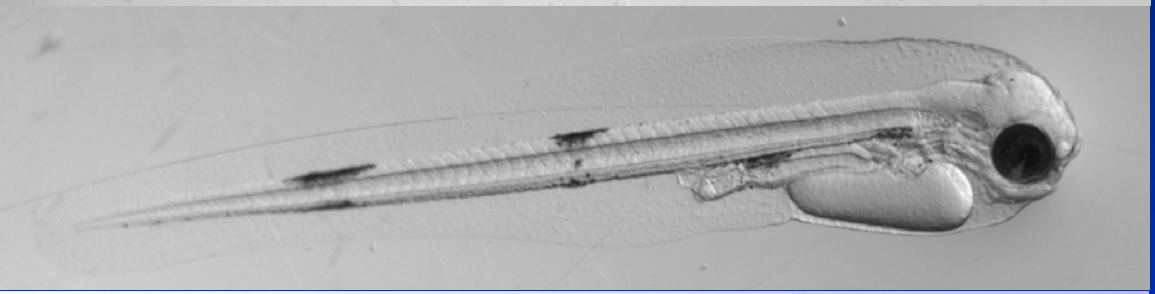
Day 3 - P. cod larvae



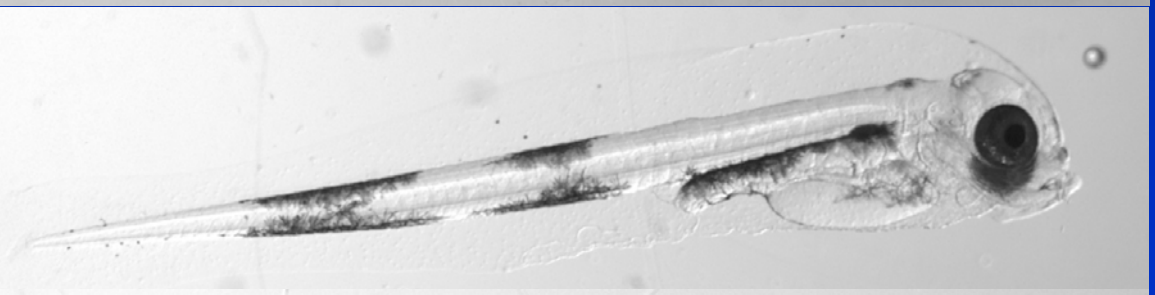
0°C



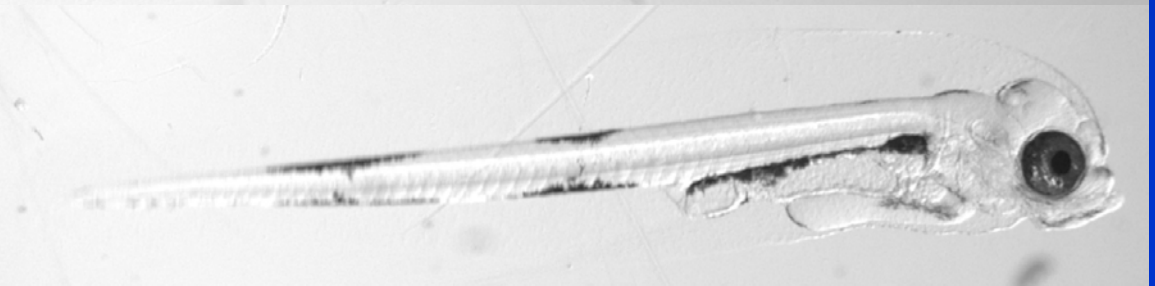
2°C



4°C

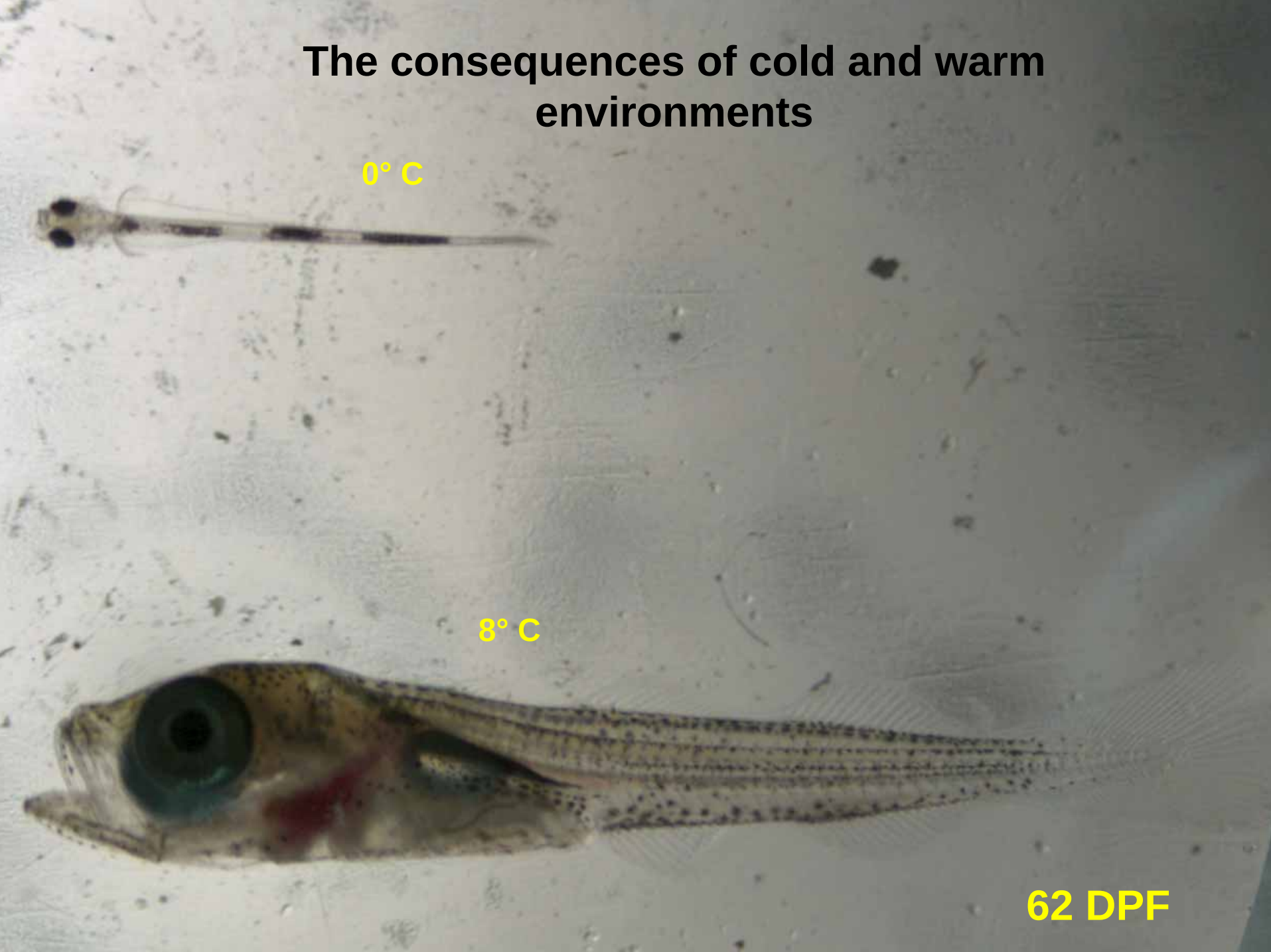


6°C



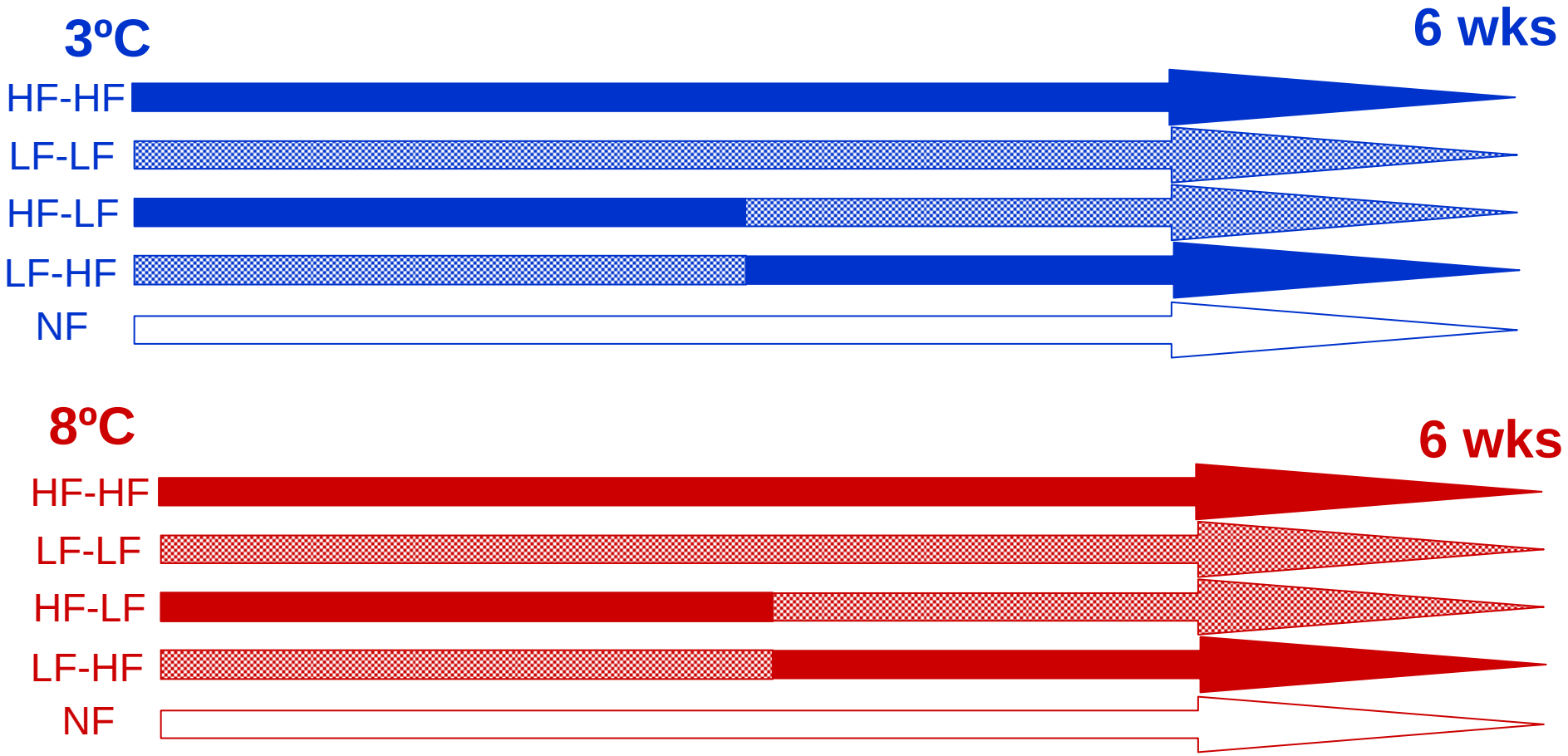
8°C

The consequences of cold and warm environments



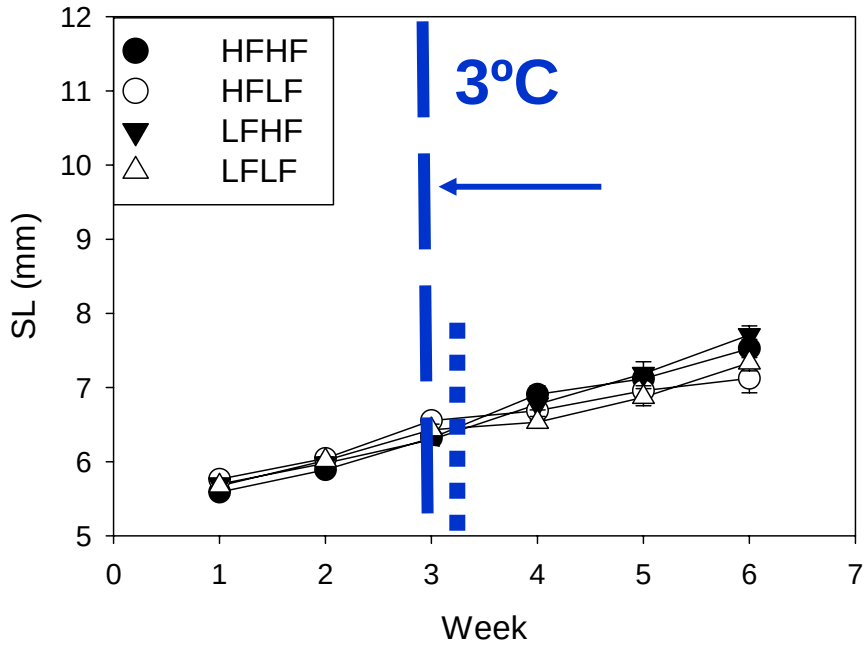
Experiment #2: Post-feeding larvae

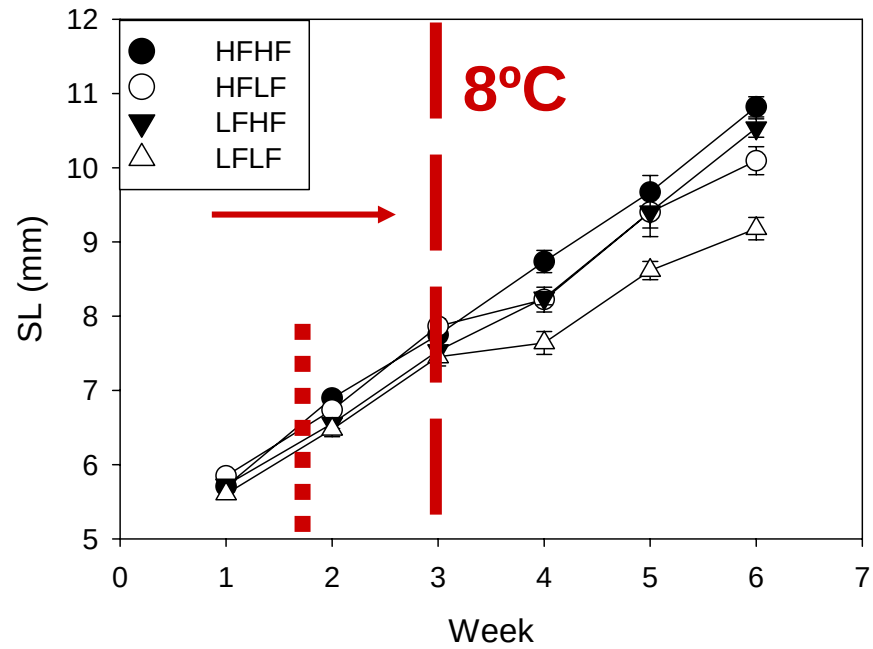
Temperature mediated
match-mismatch experiment



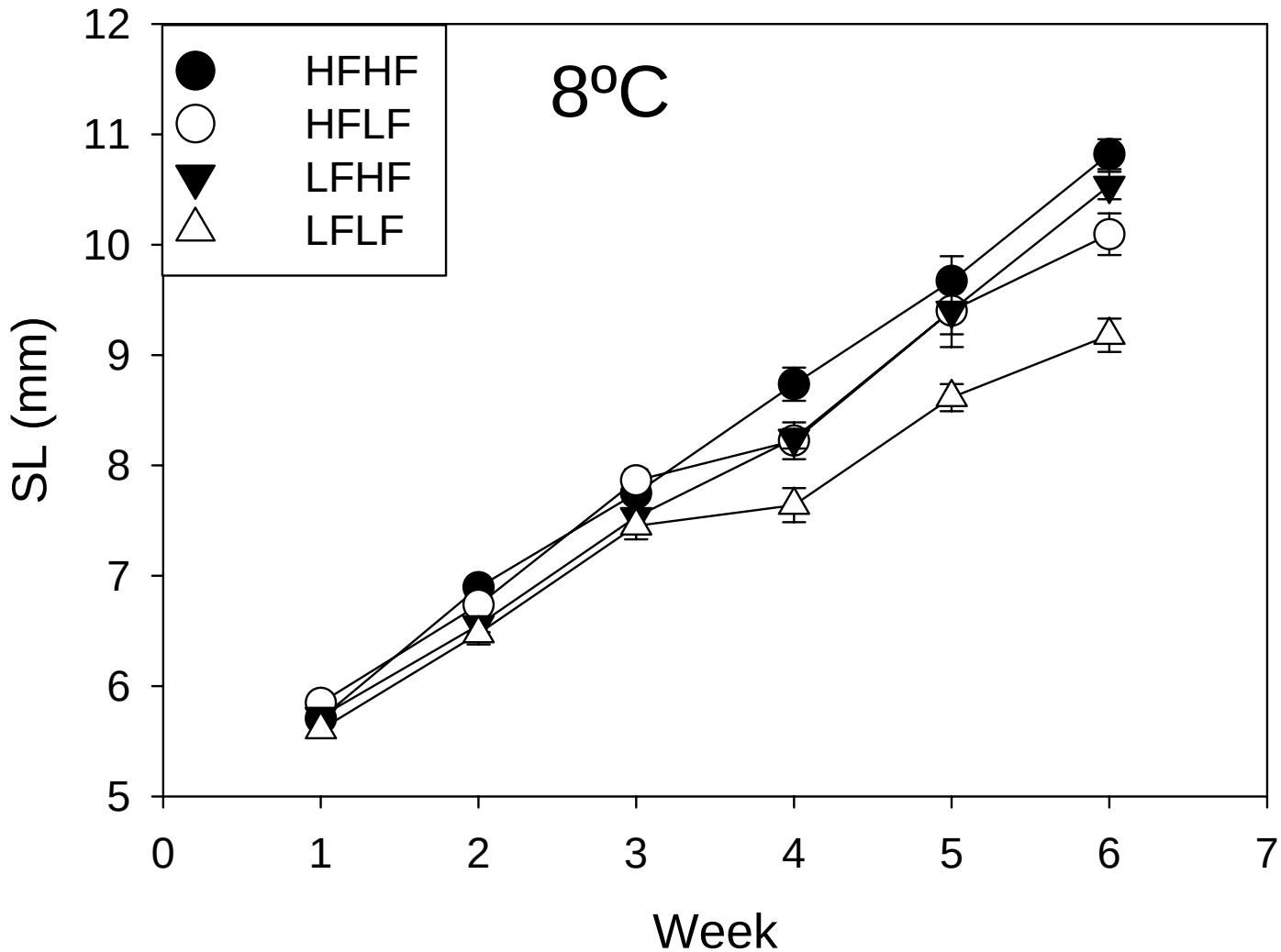
Match-mismatches in prey at two temperatures

- Temperature explains the most variance in growth
- Fish at cold temperatures survived longer in the absence of prey
- The relative timing of match-mismatches in prey therefore differed between temperature treatments





Growth consequences of early and late mismatches of prey



Conclusions

- Time of hatch and hatch cycle duration are negatively correlated with temperature—early hatchers survive longer in the absence of prey but may have a limited ability to feed on certain sizes and types of prey relative to late hatchers.
- Optimal conversion efficiency using endogenous reserves occurs at colder temperatures (≤4ºC). Larvae grow larger and survive longer in the complete absence of prey at colder temperatures
- (3ºC) Mismatches in food availability at cold temperatures are relatively inconsequential at low temperatures except in the complete absence of food. However, early and late mismatches in food have measurable effects on growth
- (8ºC) Mismatches in food availability are very important to growth, especially when mismatches occur after 3 wks post-hatch.
- Temperature ultimately drives growth when sufficient prey for survival are present

Future and ongoing work

- Further integration into Bering sea models (Phase III)
- The behavioral consequences of early and late hatching in a predator and feeding environment

Acknowledgements

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North Pacific Research Board (NPRB - Grant#: R0605, NOAA Fisheries – Alaska Fisheries Science Center RACE Division

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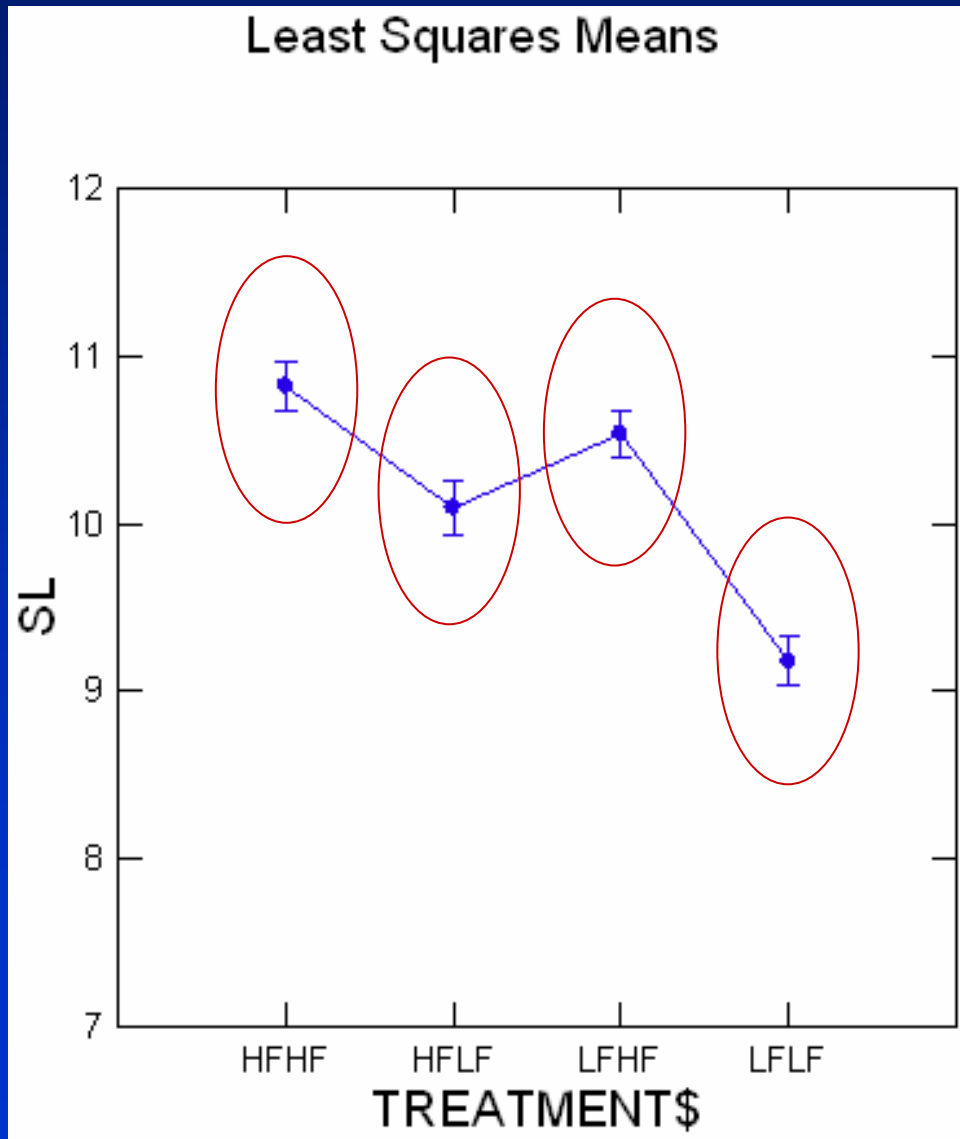
Personnel
Field assistance: Alisa Abookire and Brian Knoth

Boat charters: Tim Tripp and Jan Axel

Laboratory experiments: Scott Haines, Michele Ottmar and Paul Iseri

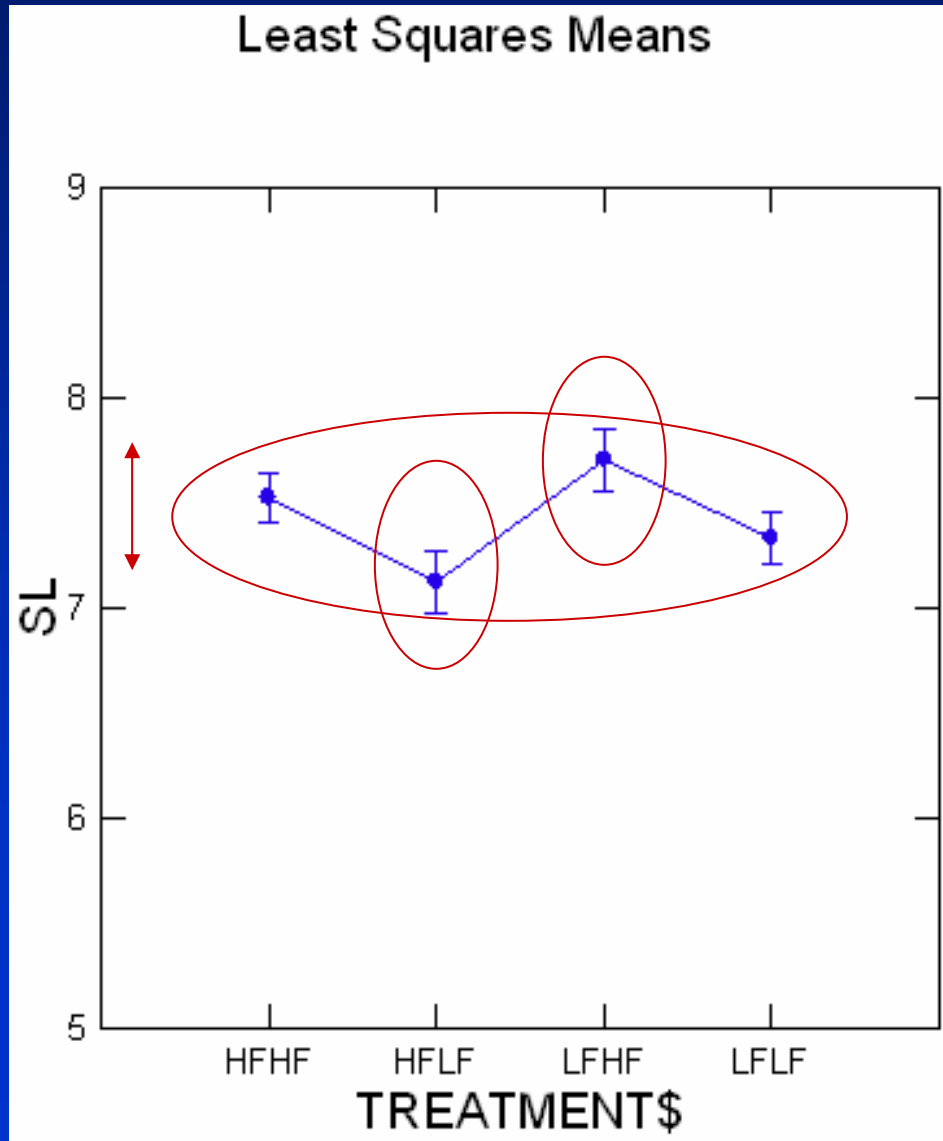
Match-mismatch results wk 6 at 8ºC

- Optimal feeding conditions contribute to highest growth
- Late mismatches in food are more consequential to growth than early mismatches.

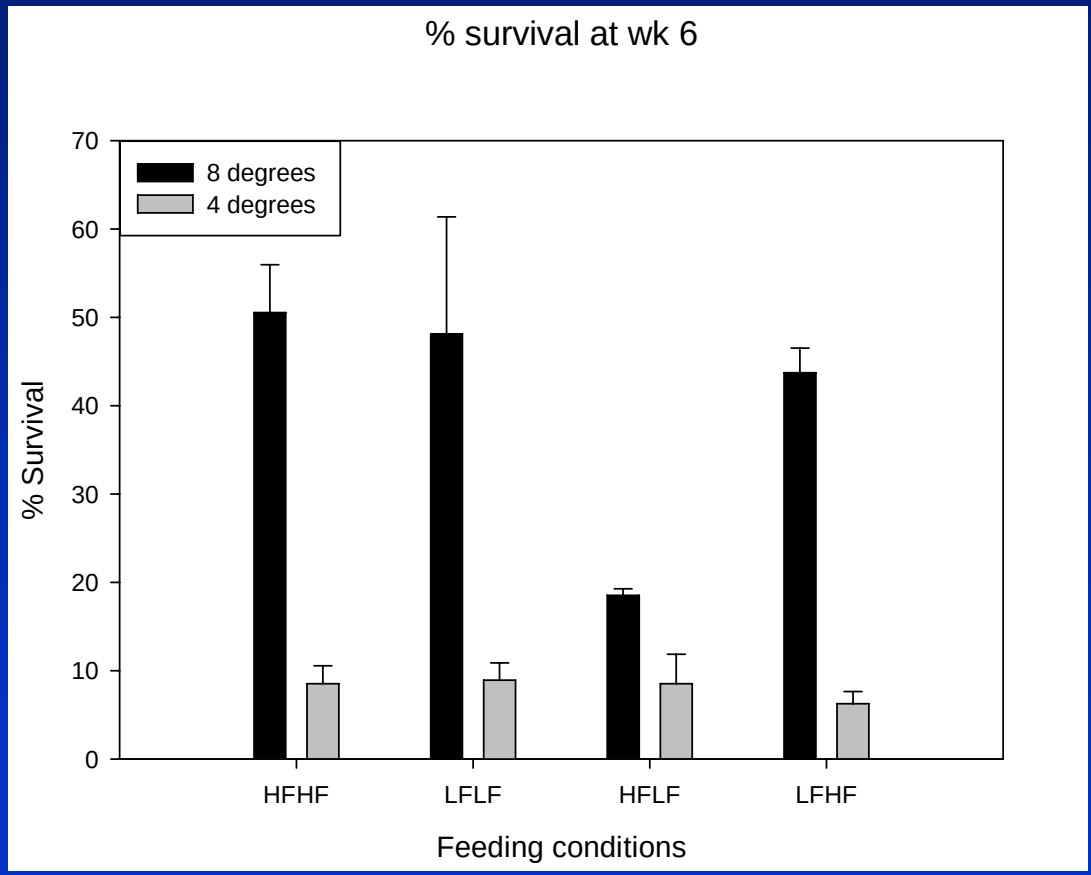


Match-mismatch results wk 6 at 3ºC

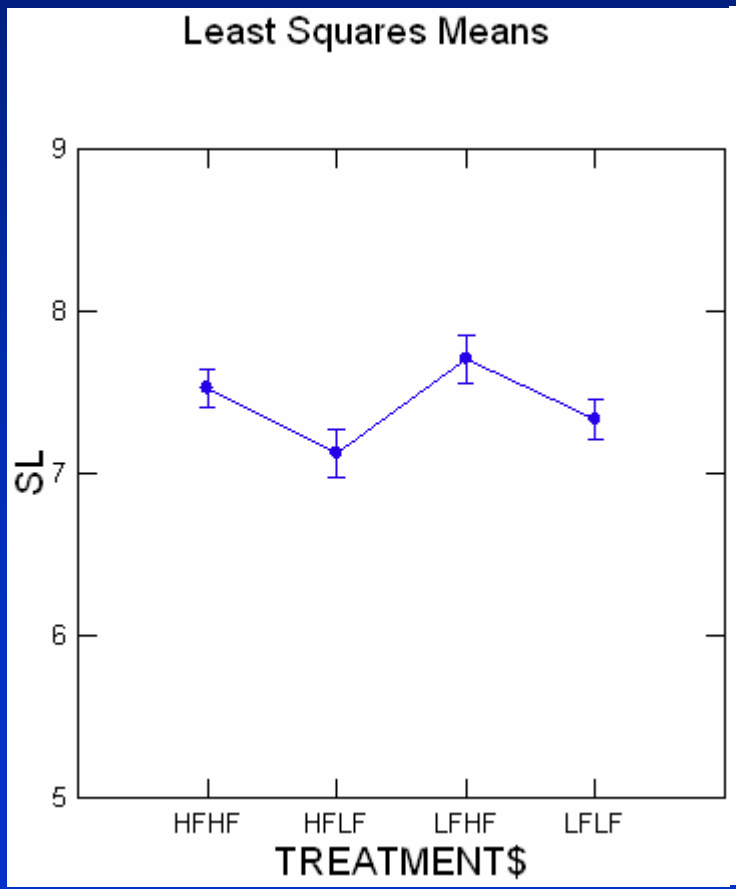
- Optimal feeding conditions matter little in terms of growth
- Late mismatches still appear to be consequential to growth compared to early mismatches.

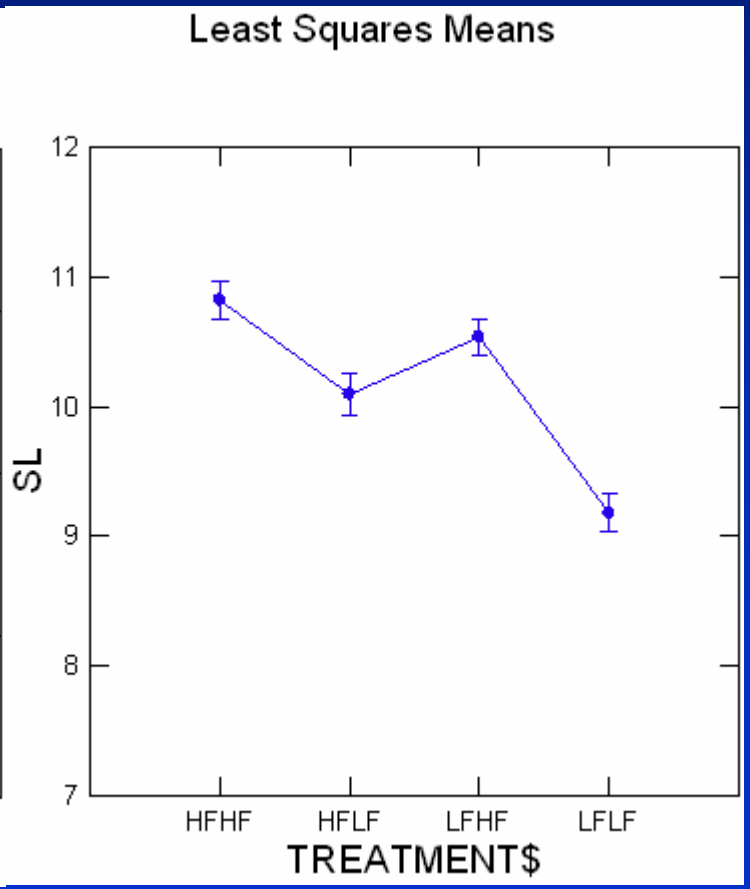


Survival


% survival at wk 6
8 degrees
4 degrees
% Survival
70
60
50
40
30
20
10
0
HFHF
LFLF
HFLF
LFHF
Feeding conditions

Match-mismatch results wk 6 at 3ºC

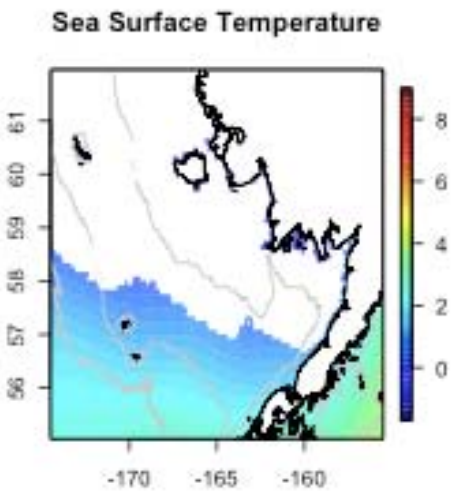


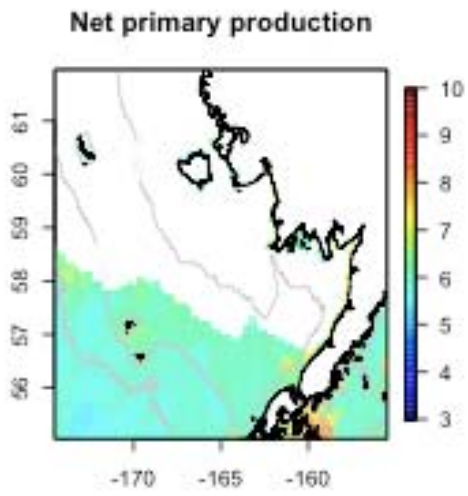


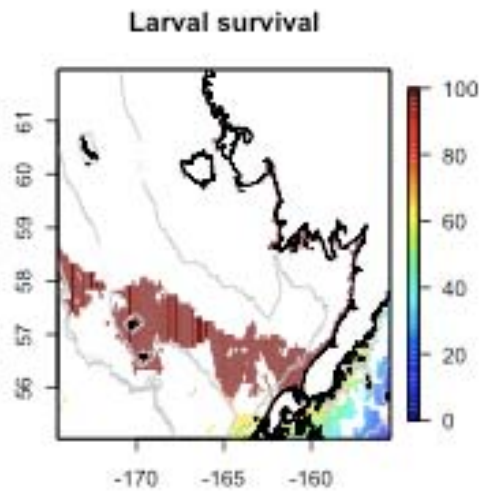
Preliminary model runs

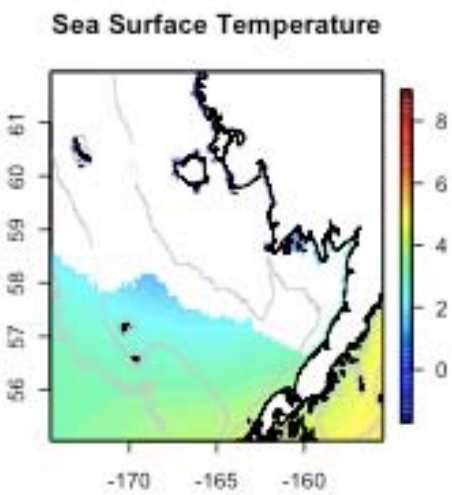
1999
(coolest)

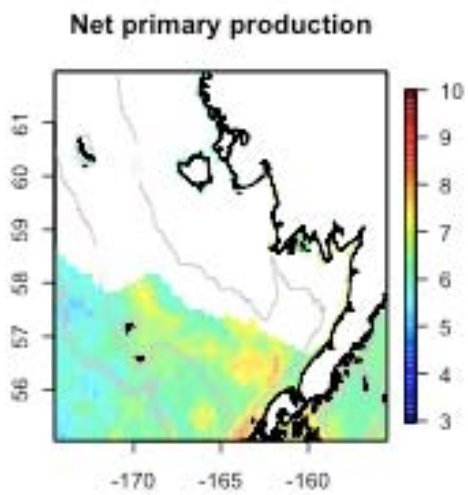
2005
(warmest)

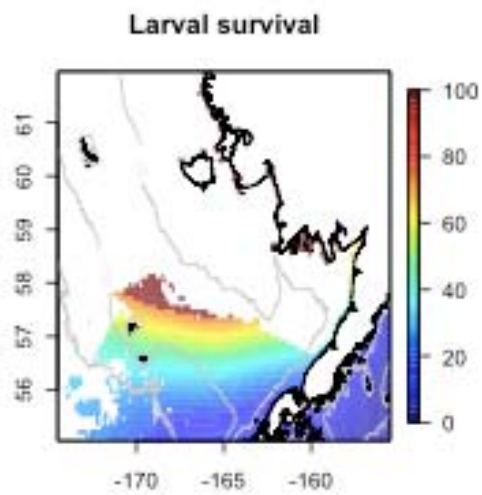










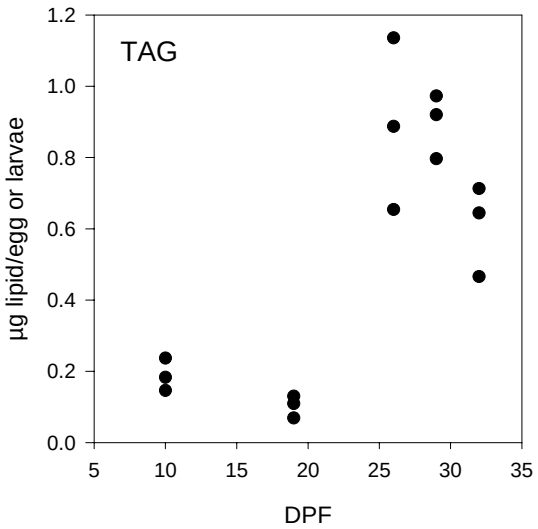


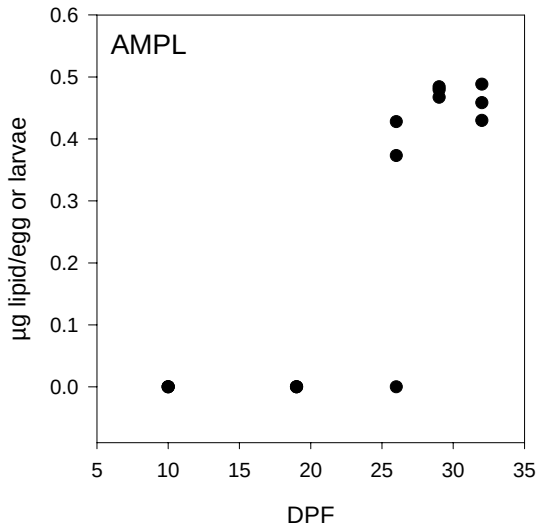
Experiment #2: Post-feeding larvae

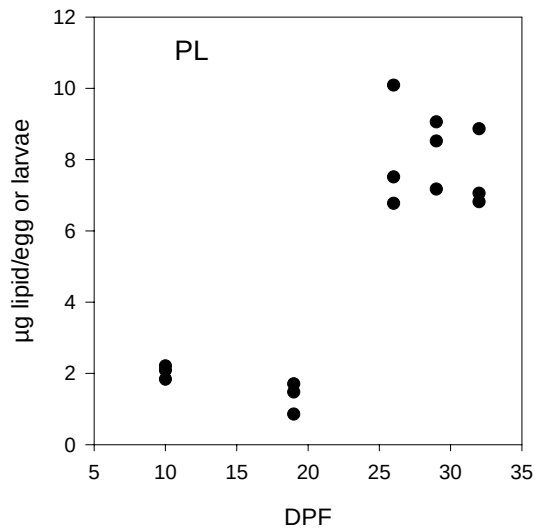
- 2 temperatures (3 and 8ºC)
- 6 wk experiment with 5 feeding treatments per temperature: HF-HF, LF-LF, HF-LF, LF-HF and no food. Three replicate incubators per food-temperature treatment (n=30 tanks)
- Morphometric measurements using image analysis taken every wk (SL, MH, ED, Yolk area)
- % survival measured at the end of the experiment in the food treatments. Daily mortality recorded for the no food treatments

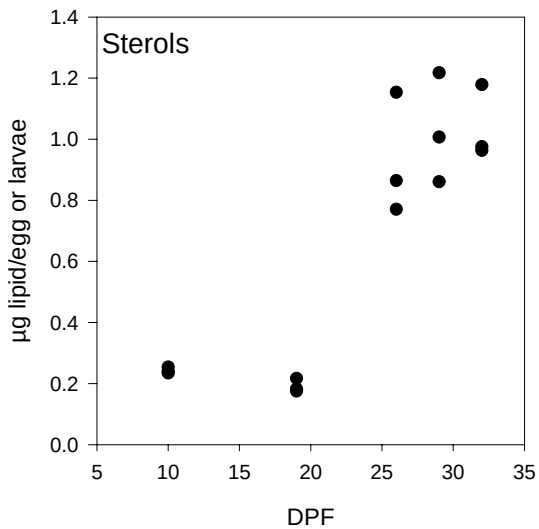
Questions?

Changes in lipid classes at 2ºC

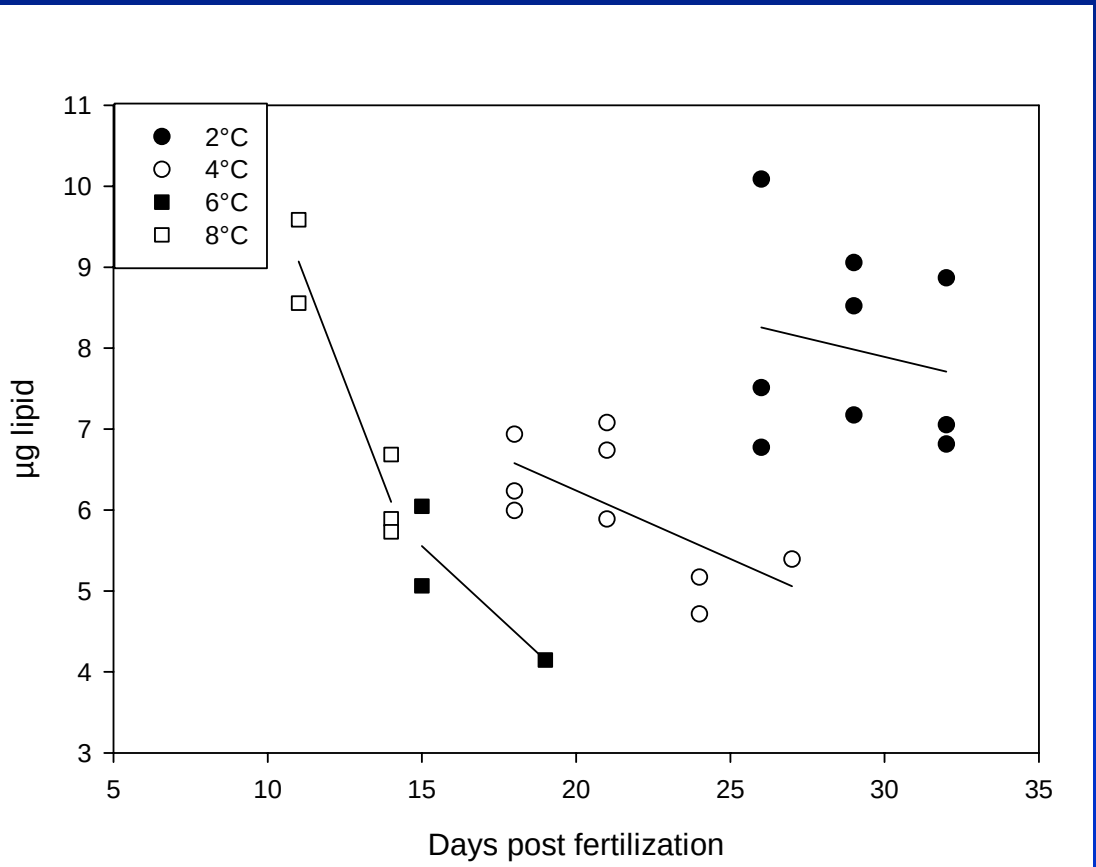




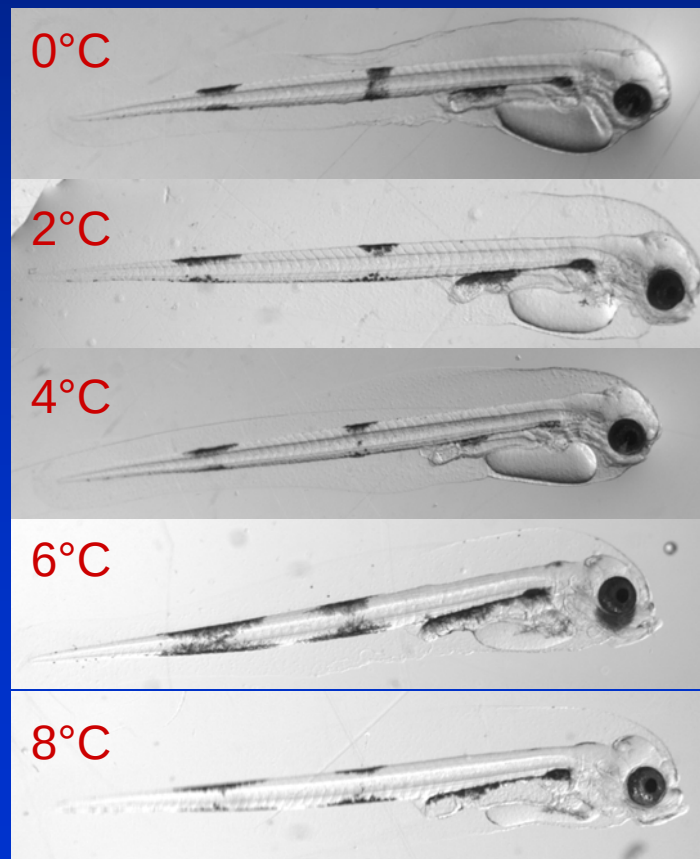




Changes in total lipid composition of early and late hatching eggs as a function of temperature



Day 3 - P. cod larvae

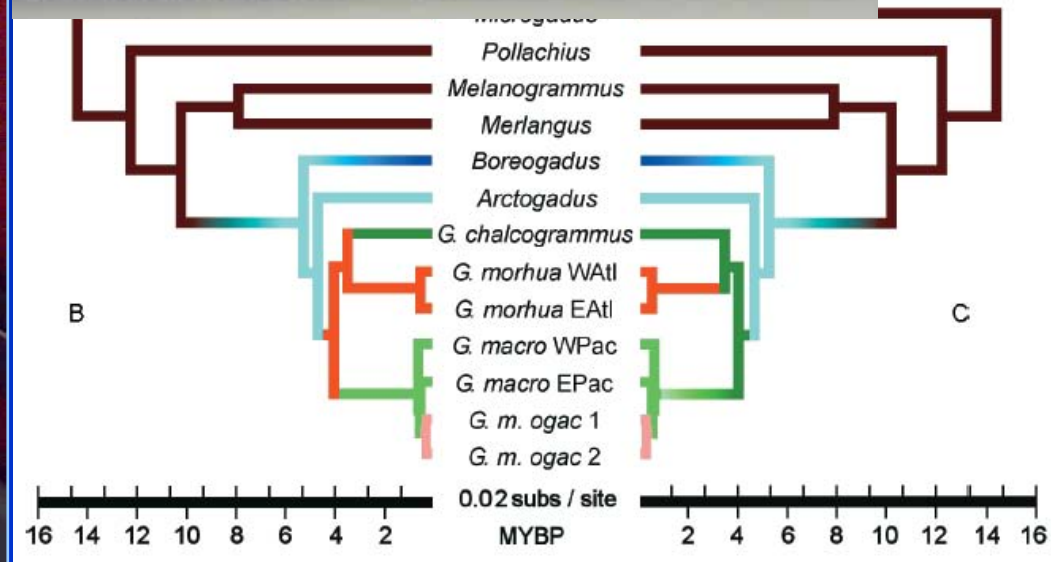


Egg collection March 2006

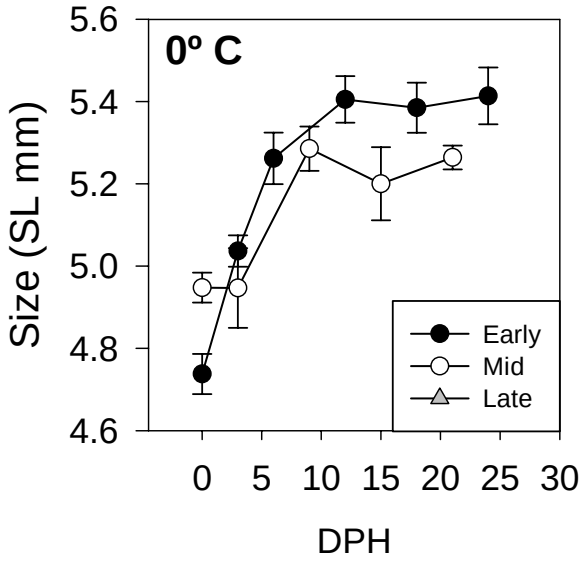
Similar but perhaps not as similar as was previously thought……

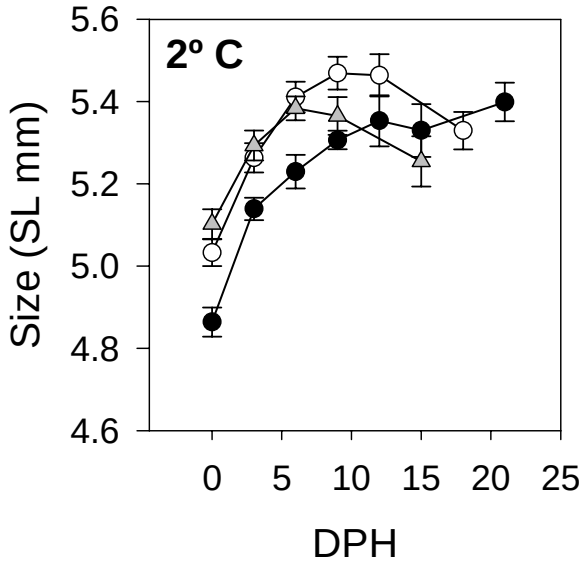
Pacific cod

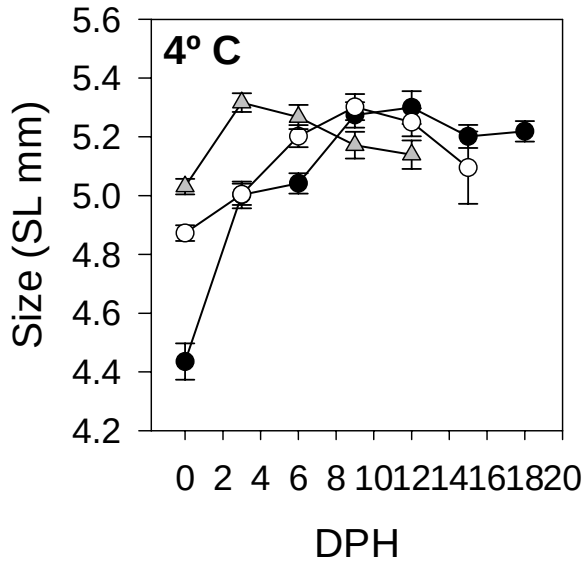
Atlantic cod

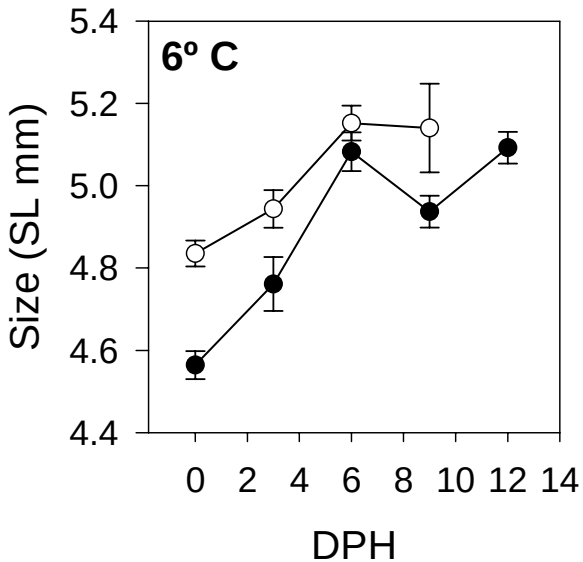


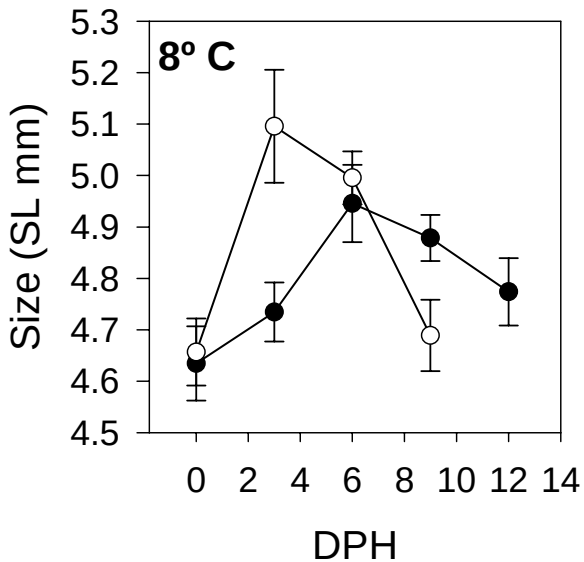
Length

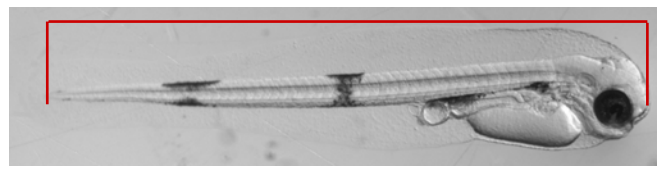

0º C
Size (SL mm)
DPH
Early
Mid
Late


2º C
Size (SL mm)
DPH

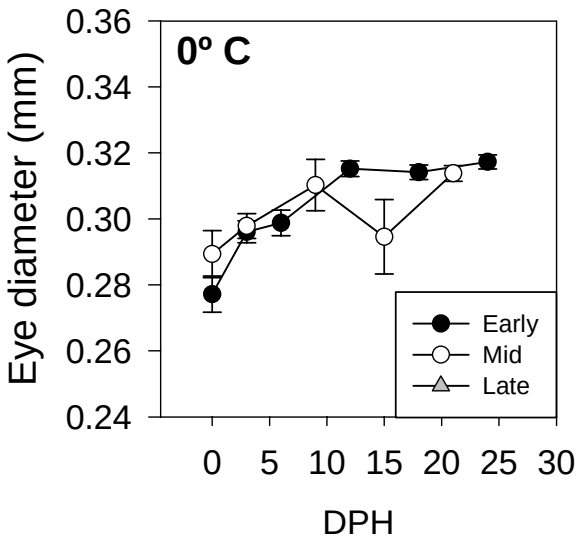

4º C
Size (SL mm)
DPH

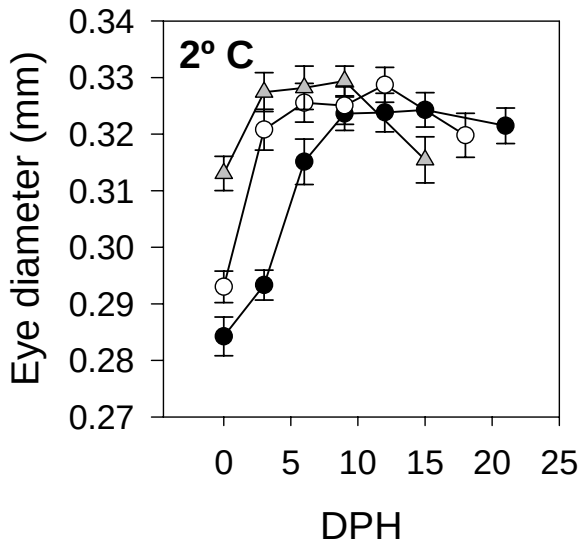

6º C
Size (SL mm)
DPH

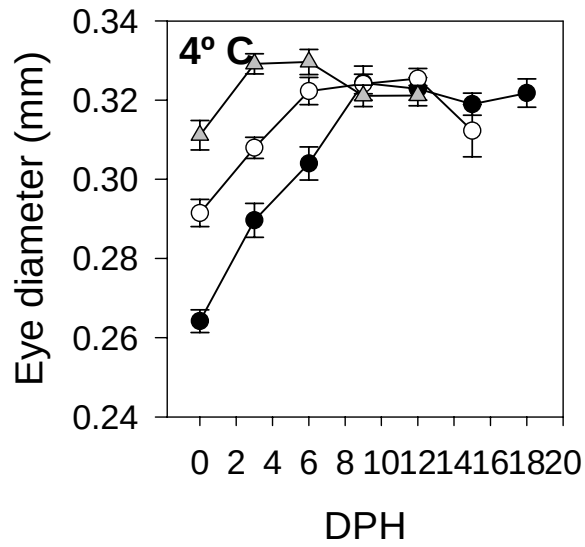

8º C
Size (SL mm)
DPH

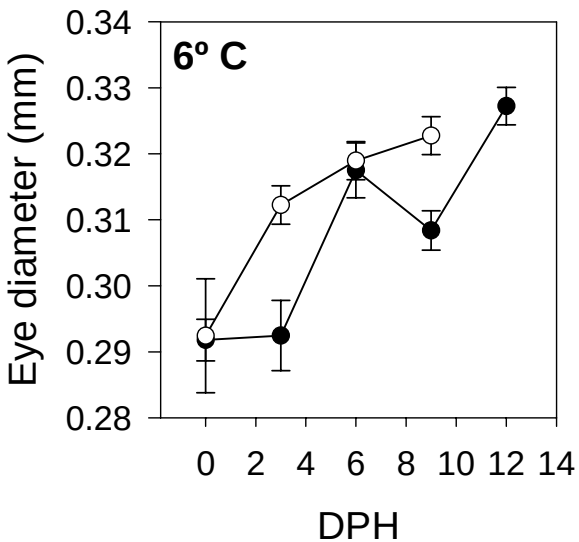


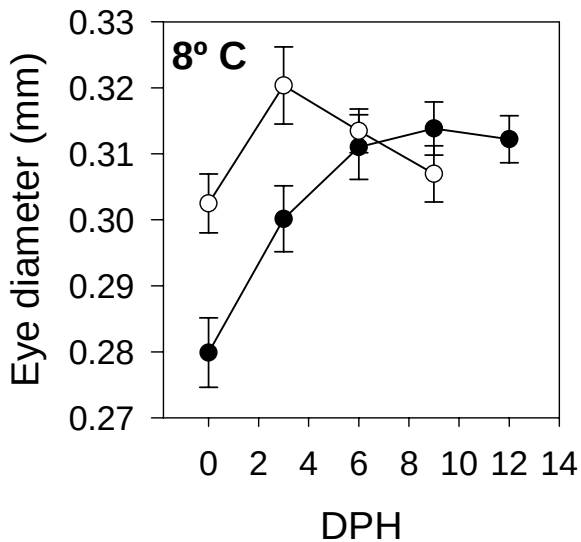
Eye diameter











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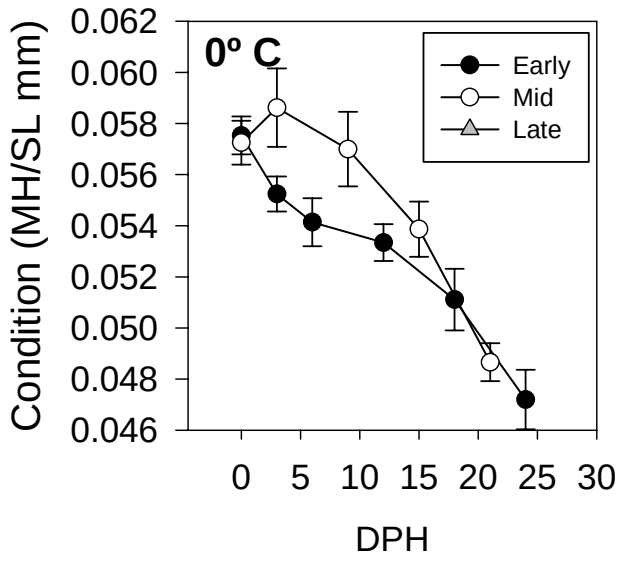
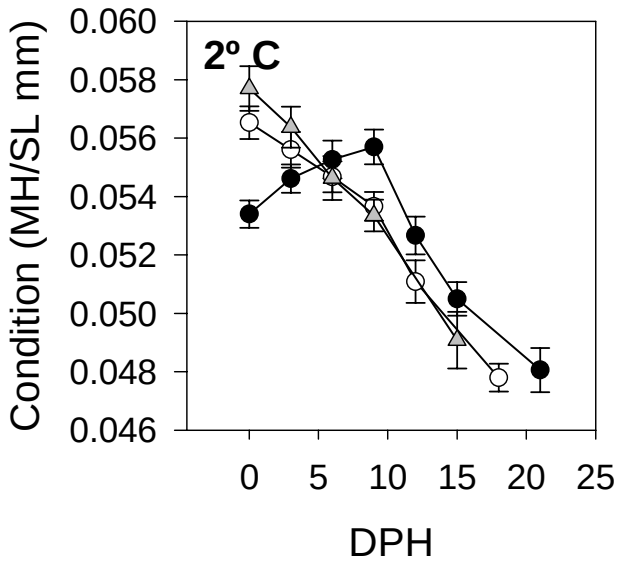
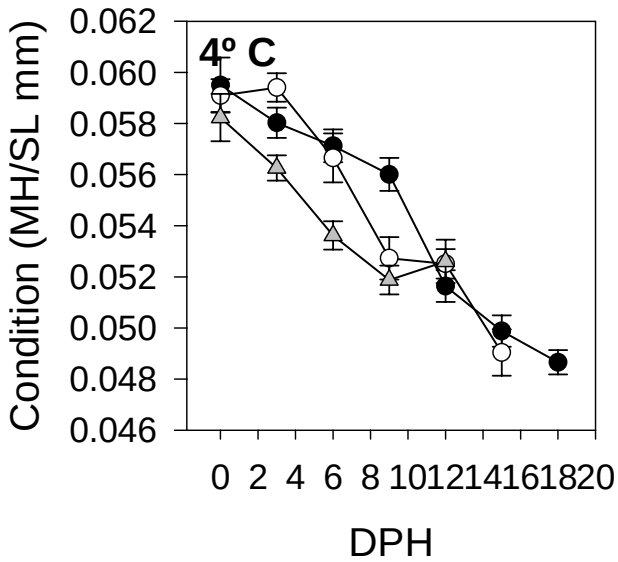
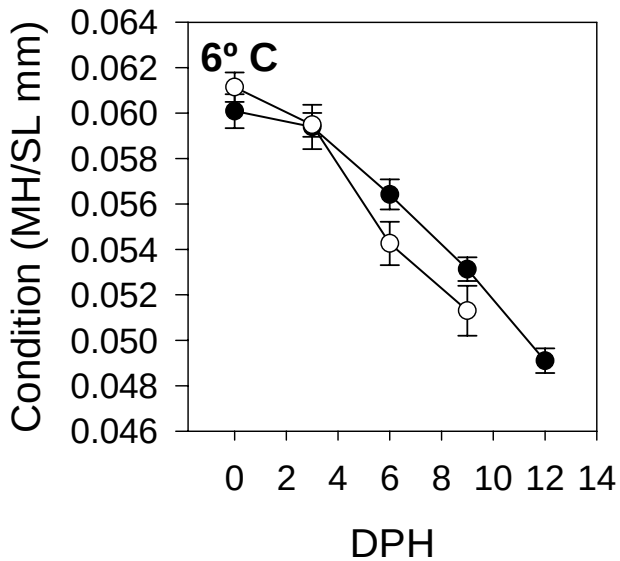
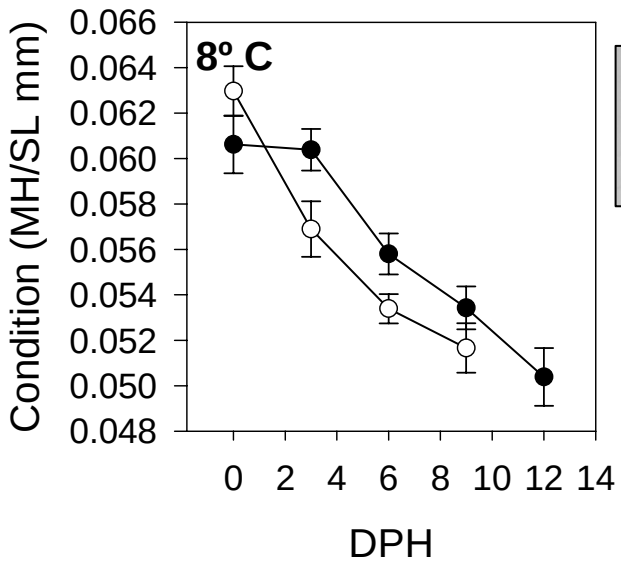
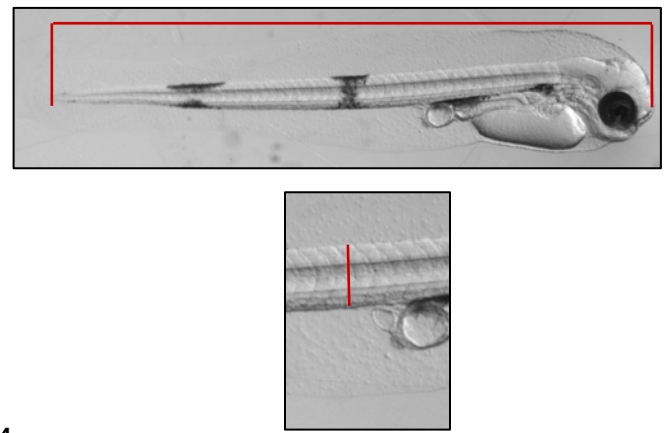




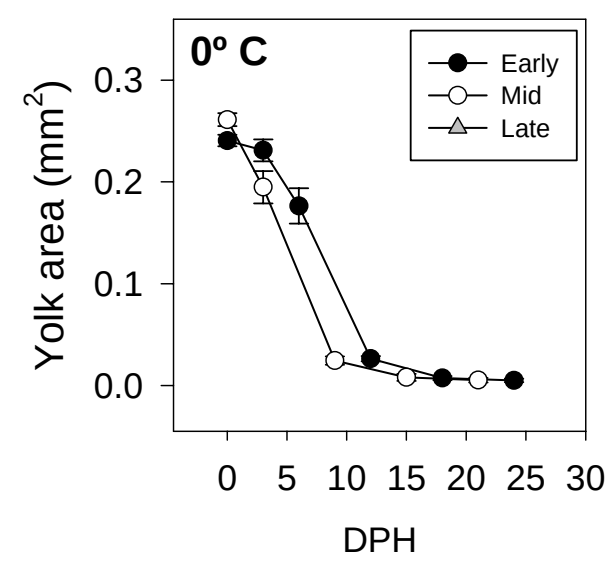


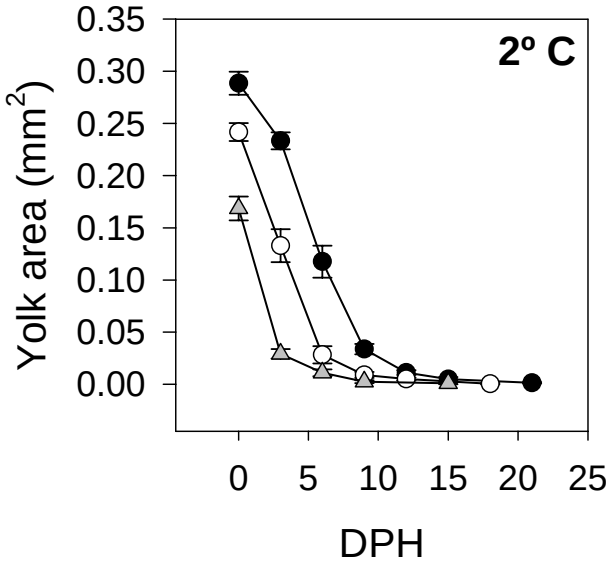


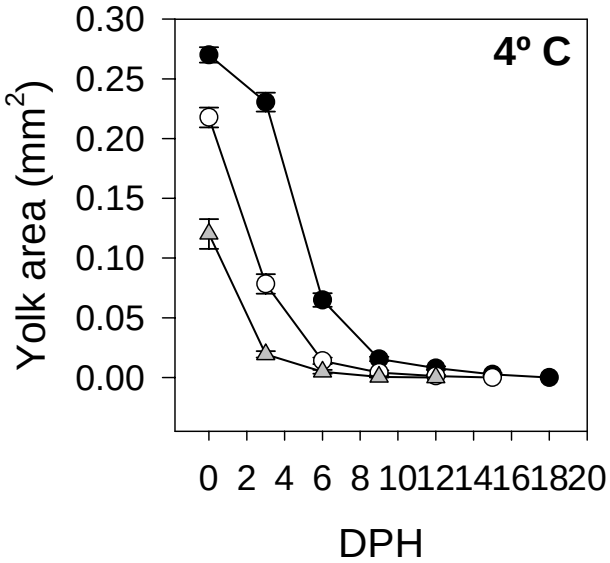


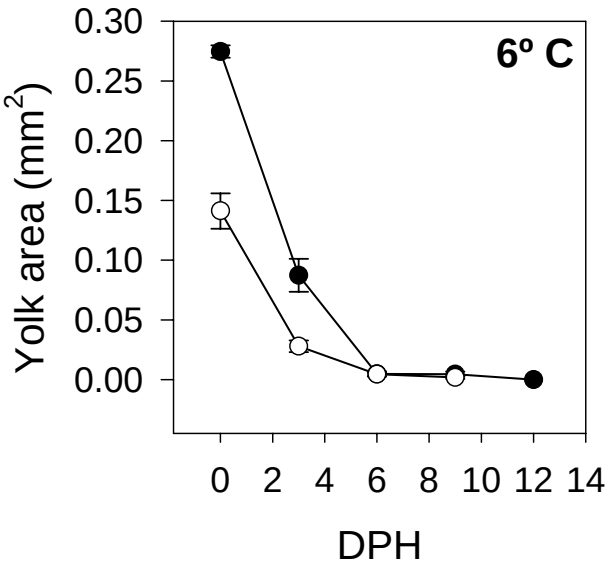


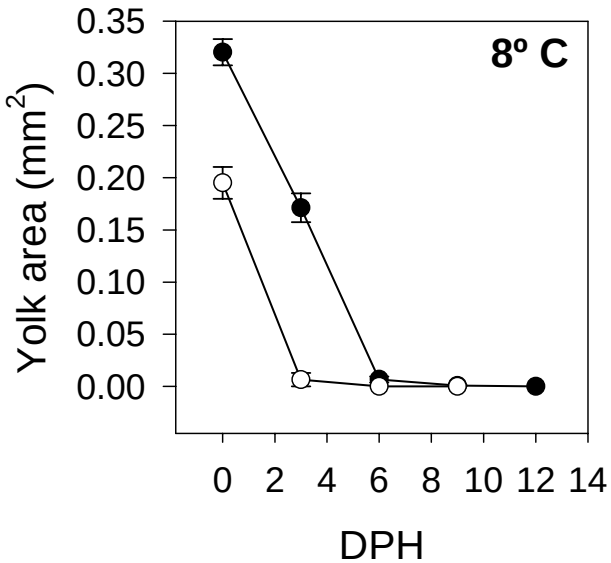
Yolk depletion

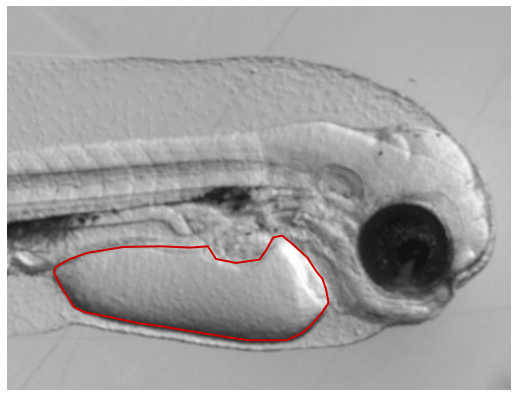




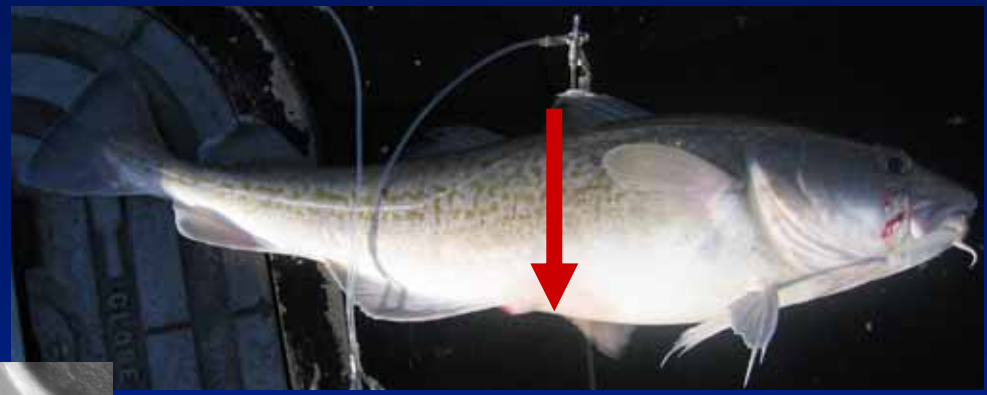








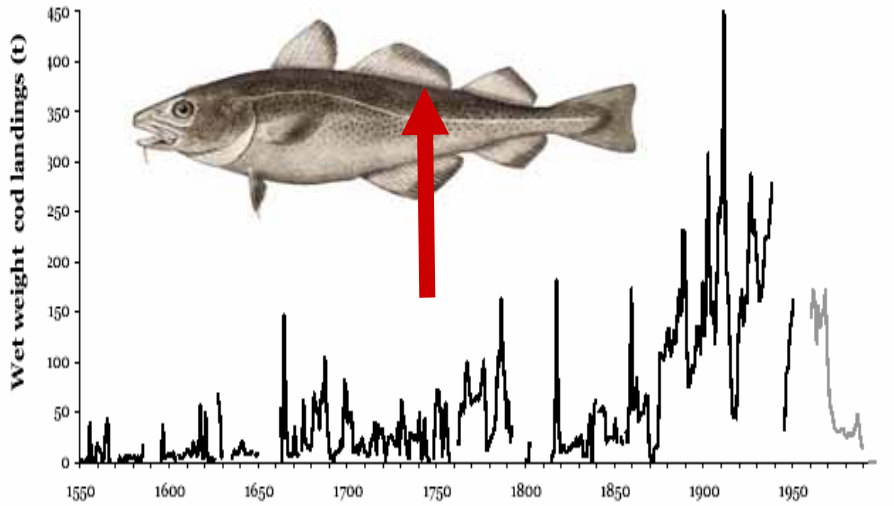
Pacific cod



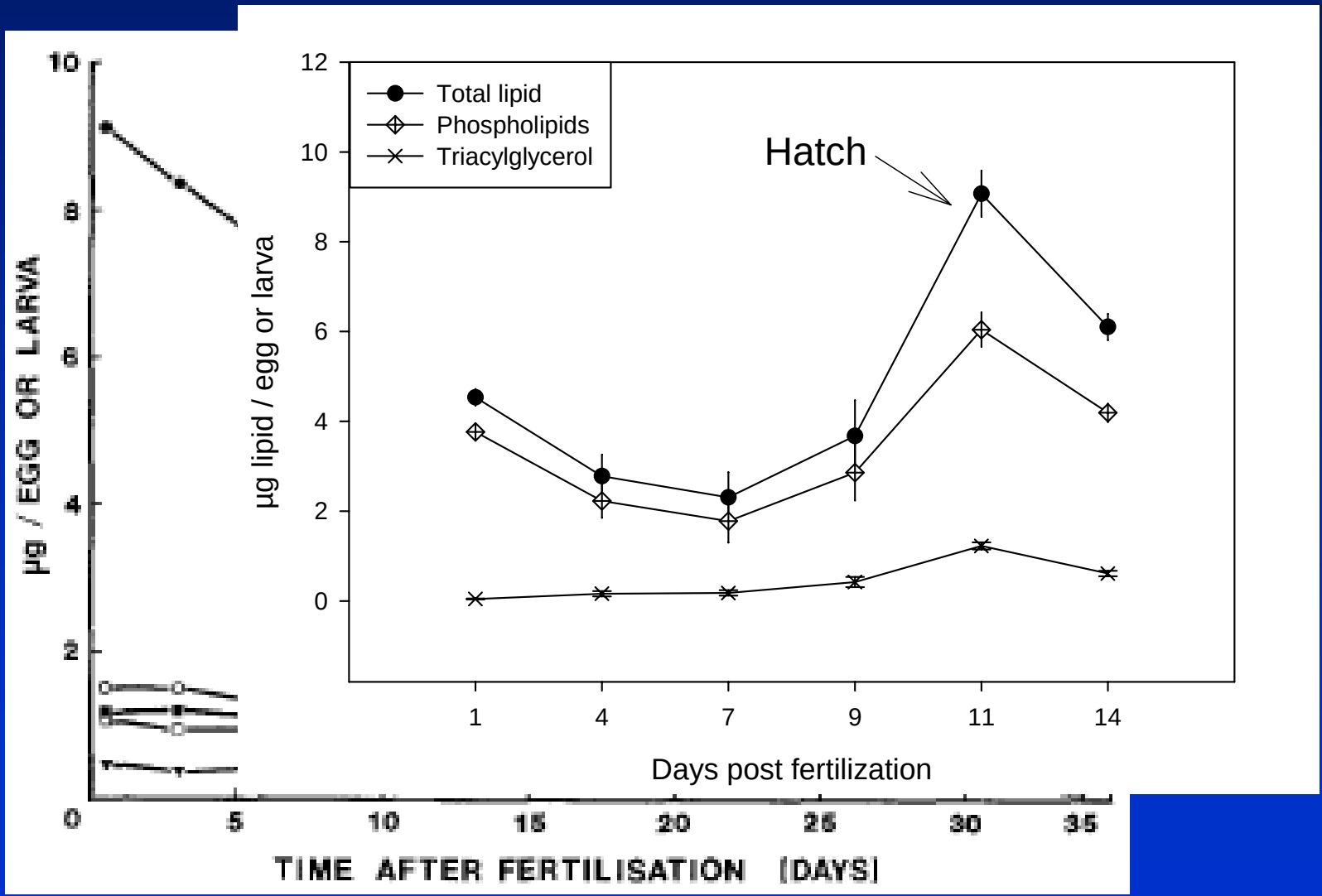
groundfish fishery in Alaska (much Canada)

pecies framework e.g., regime trophodynamics

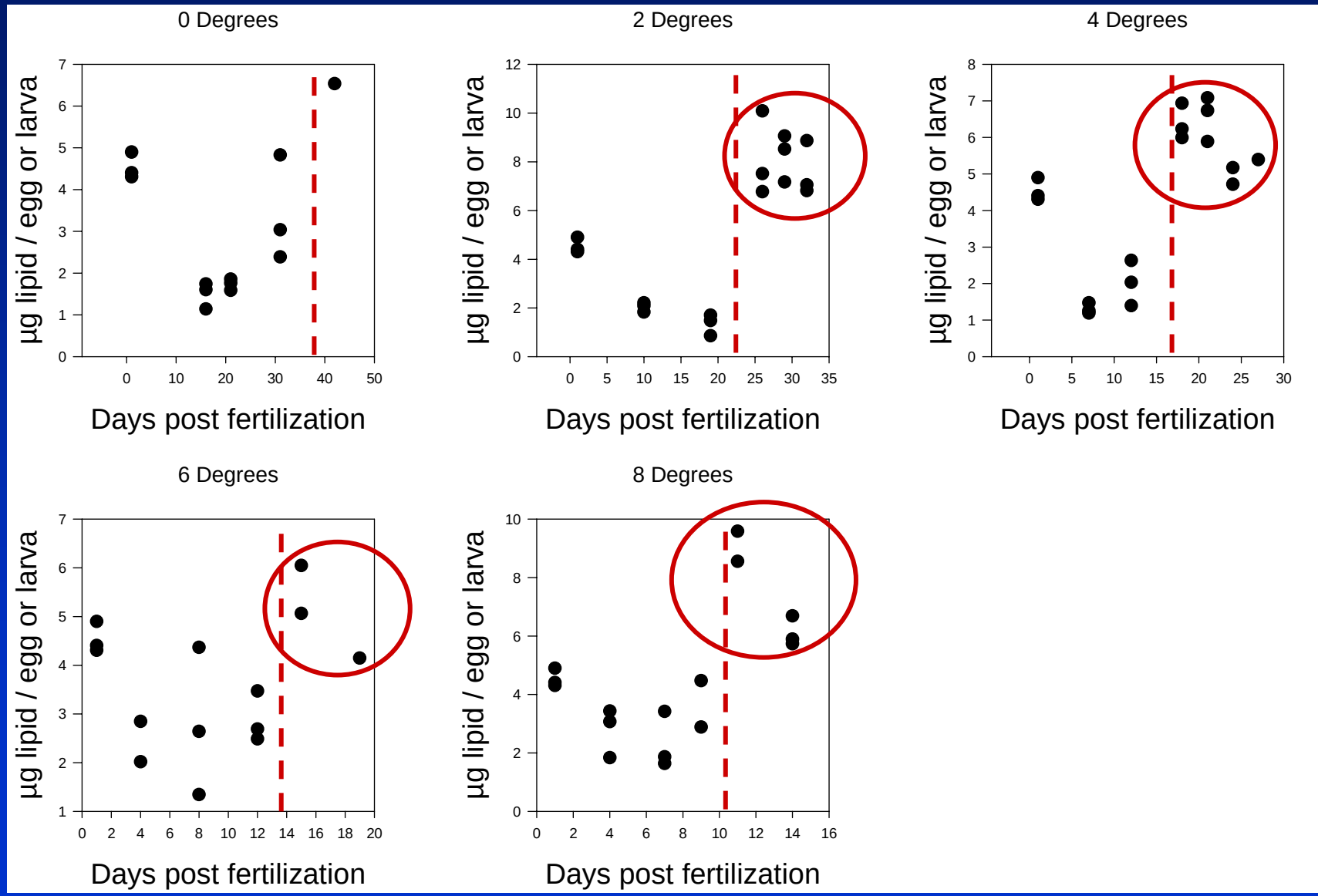
history of Pacific cod possibly because of assumed similarities between Pacific cod and their better-studied congener, Atlantic cod (*Gadus morhua*).



Lipid catabolism in Atlantic cod eggs and pre-feeding larvae



Lipogenesis in Pacific cod eggs/larvae across all temperature treatments



Changes in total lipid composition of early and late hatching eggs as a function of temperature