Responses of Alaskan groundfishes to ocean acidification

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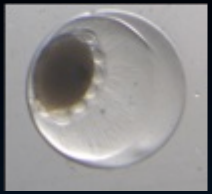
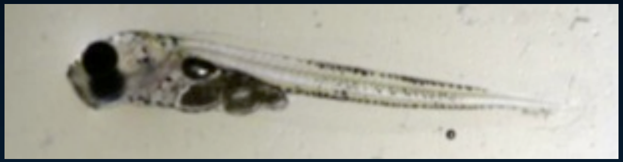
Objectives



Evaluate the potential effects of OA on the early life stages of critical Alaskan resource species



1. Show specific work on Alaskan fishery species.
2. Illustrate emerging patterns from observations in other species.
3. Point out gaps in knowledge / emerging areas.

Laboratory experiments conducted in AFSC lab at Hatfield Marine Science Center, Newport, Oregon

Laboratory system for the culture of marine fish larvae under controlled CO_2 conditions.

OA effect pathways – initial view

Direct effects

Indirect effects

Metabolism,
acid-base balance

Lower trophic levels

Growth,
development

Survival,
productivity

Basic methodology

Field collecting

Juvenile exposure experiments

- Ambient CO_2
- Low CO_2
- Medium CO_2
- High CO_2

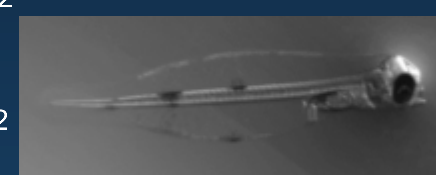
Laboratory broodstock

Larval exposure experiments

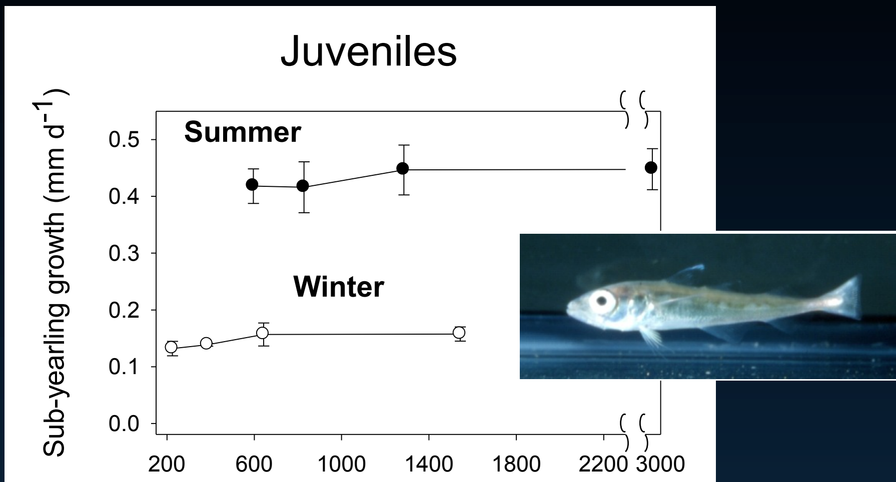
- Ambient CO_2
- Low CO_2
- Medium CO_2
- High CO_2

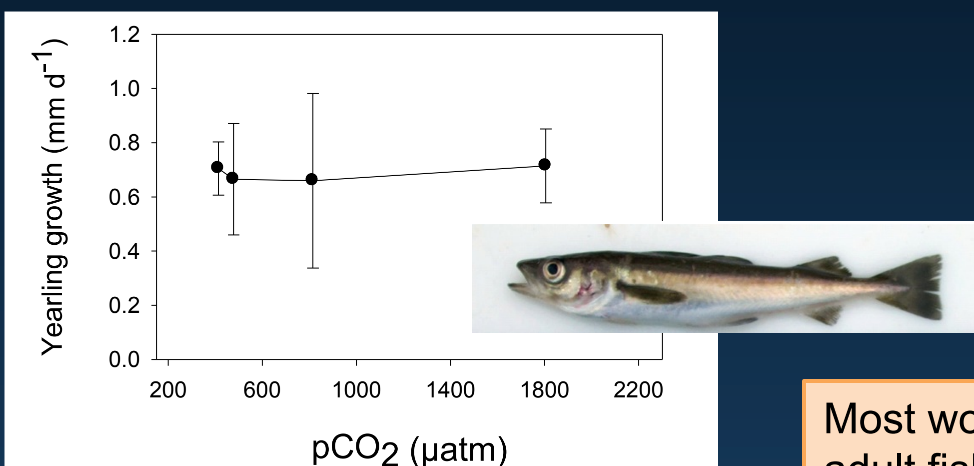
Egg incubation experiments

- Ambient CO_2
- Low CO_2
- Medium CO_2
- High CO_2



Juvenile pollock resilient to direct OA effects





Hurst et al. (2012)

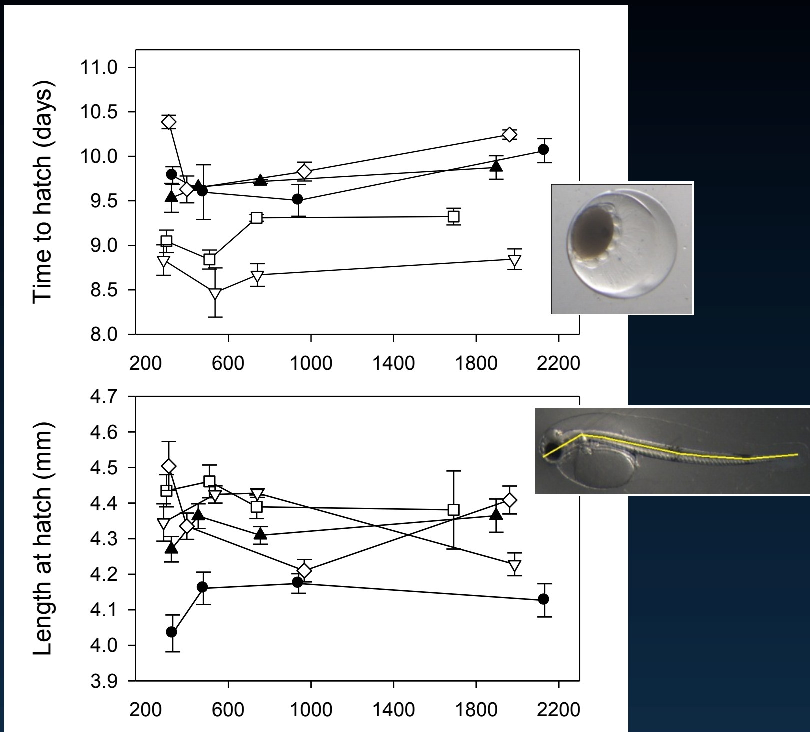
Expected resiliency based on active ion regulatory system.

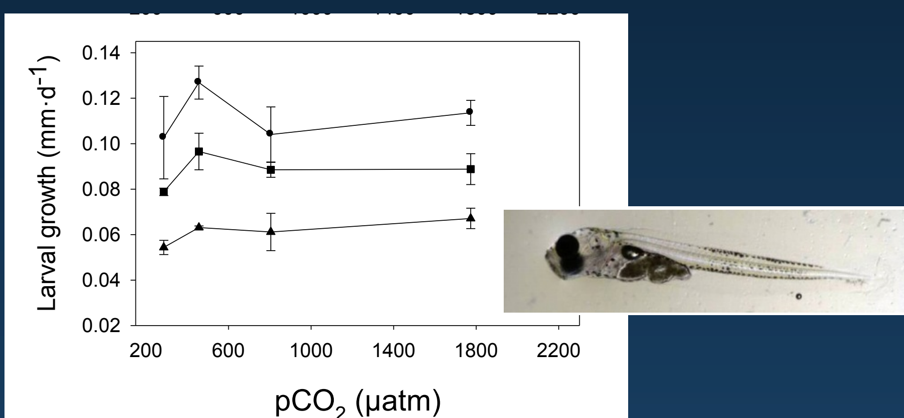
No negative effects of OA in short (6 week) or long (6 month) exposures with juveniles.

There was effect on consumption rate,
i.e. fish didn't consume more to maintain 'normal' growth rates.

Most work has suggested that energetics of juvenile/adult fish are resilient to OA
- feeding, metabolism, growth, condition factor
- swimming capacity

Pollock eggs & early larvae more sensitive?





Hurst et al. (2013)

No evidence of negative effects on growth

Trend toward faster growth at slightly elevated CO_2

These effects smaller than effects of temperature

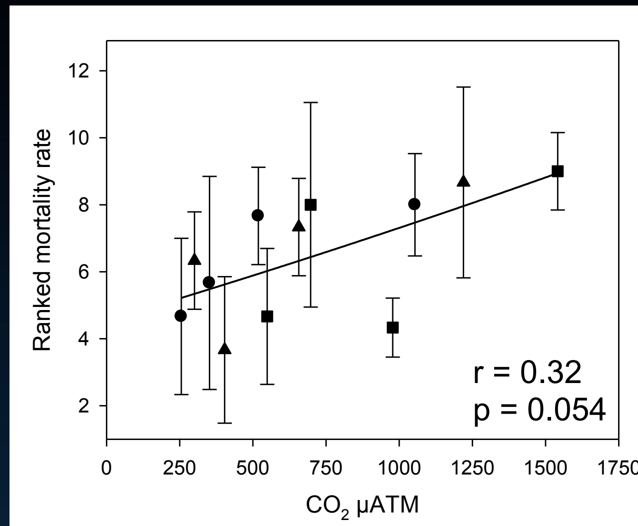
Results vary markedly across species.

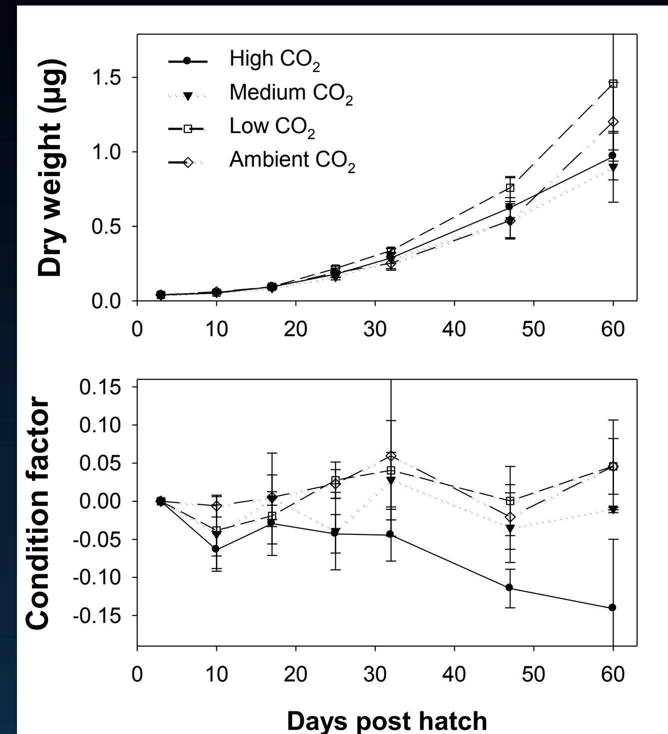
Negative – neutral – positive

No clear pattern to explain differences across studies

- Life history guilds
- Experimental approach
- Population history

Northern rock sole appear more sensitive to OA





Trend toward higher mortality rates at elevated CO_2

Lower growth rates and condition factors observed at high CO_2 levels.

Most studies examine OA independently or in conjunction with temperature.

Need to expand studies to consider OA in a multiple –stressor context.

- Pollution
- Hypoxia
- Nutritional stress

Hurst et al. (in review)

Alaska groundfish comparison

Based on laboratory experiments exposing eggs and larvae to elevated CO_2 in laboratory experiments.

Northern rock sole

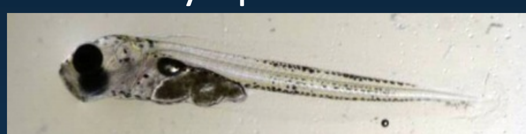
More sensitive

To 1600 µatm CO_2 ; to 60 days post hatch

- No effect on hatch success or size at hatch
- Reduced growth and condition in post-flexion fish
- Trend toward higher mortality at high CO_2 levels

Hurst et al. in review

Walleye pollock



Resilient

To 2100 µatm CO_2 ; to 28 days

- No effect on survival to hatch
- Slight growth improvement at intermediate CO_2
- No CO_2 effect on survival

Hurst et al. 2012 & 2013

Northern rock sole appear more sensitive to elevated CO_2 than walleye pollock tested in the same experimental setup.

OA effect pathways – step 2

Direct effects

Indirect

General patterns suggest that Alaskan fishes will be less sensitive to direct growth and survival effects from OA than calcifying invertebrates, such as some crab species. But, there is variation among species.

e.g. Mathis et al. Vulnerabilty Index Project

Lower trophic levels

Growth, development

Survival, productivity

Behavioral / Sensory responses in fishes

Studies have demonstrated that exposure to elevated CO_2 levels can lead to sensory and behavioral deficits in some coral reef fishes.

Olfaction (Munday et al. 2009; Dixson et al. 2010)
Hearing (Simpson et al. 2012)
Behavioral laterilization (Domenici et al. 2012)

These responses are hypothesized to result from a disruption of signal conduction in the GABA-A neurotransmitter (Nilsson et al. 2012)

Poster child – Orange clownfish

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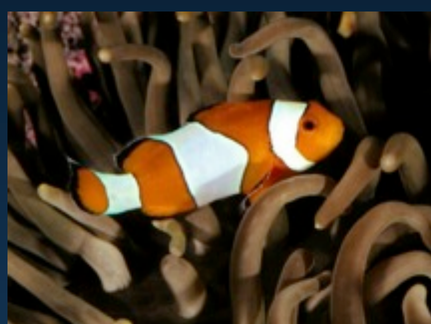

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These responses have been observed in species which did not exhibit negative responses to OA in growth or survival

OA effect pathways

Direct effects

Indirect effects

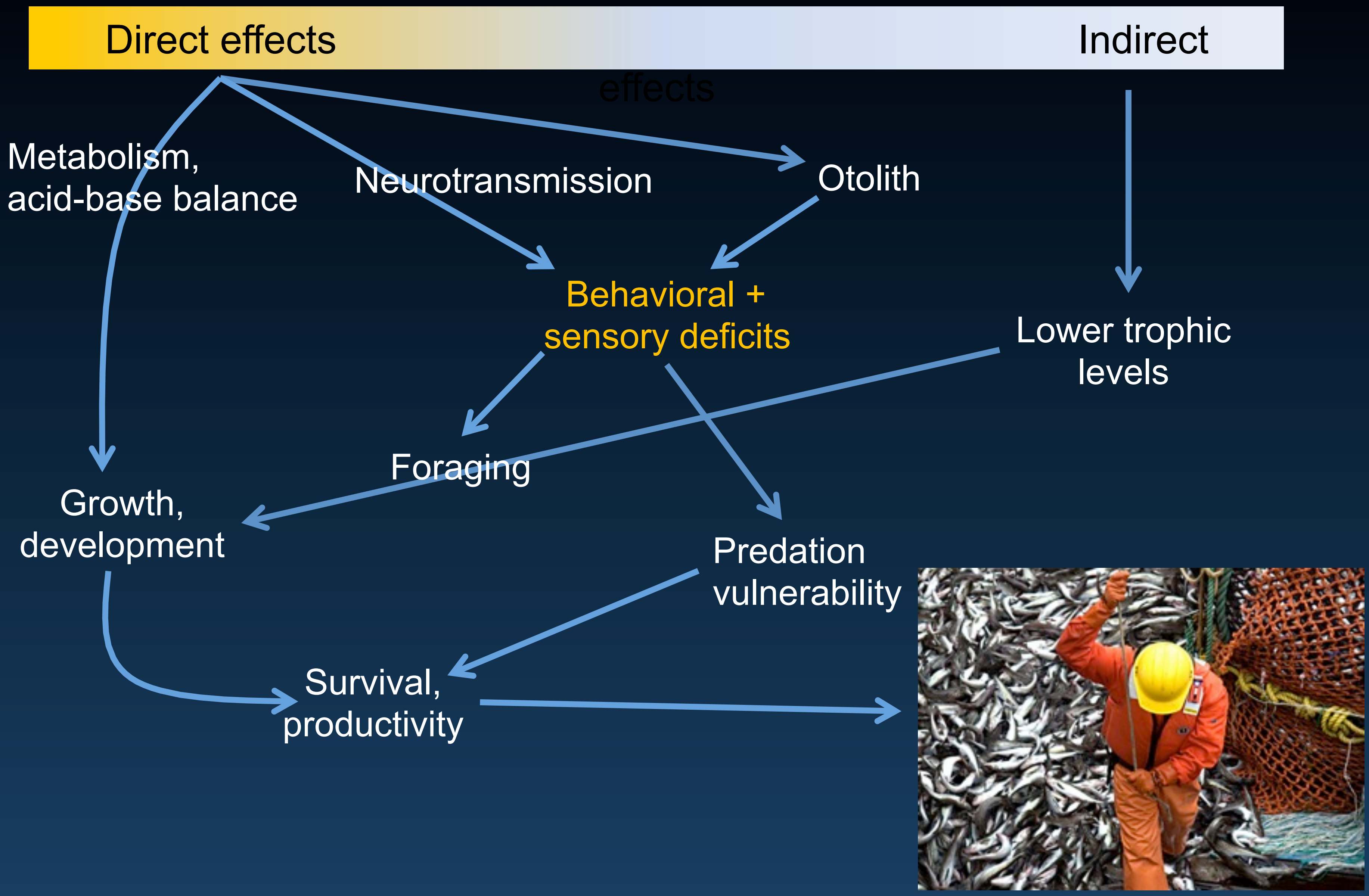
Metabolism, acid-base balance

Lower trophic levels

Growth, development

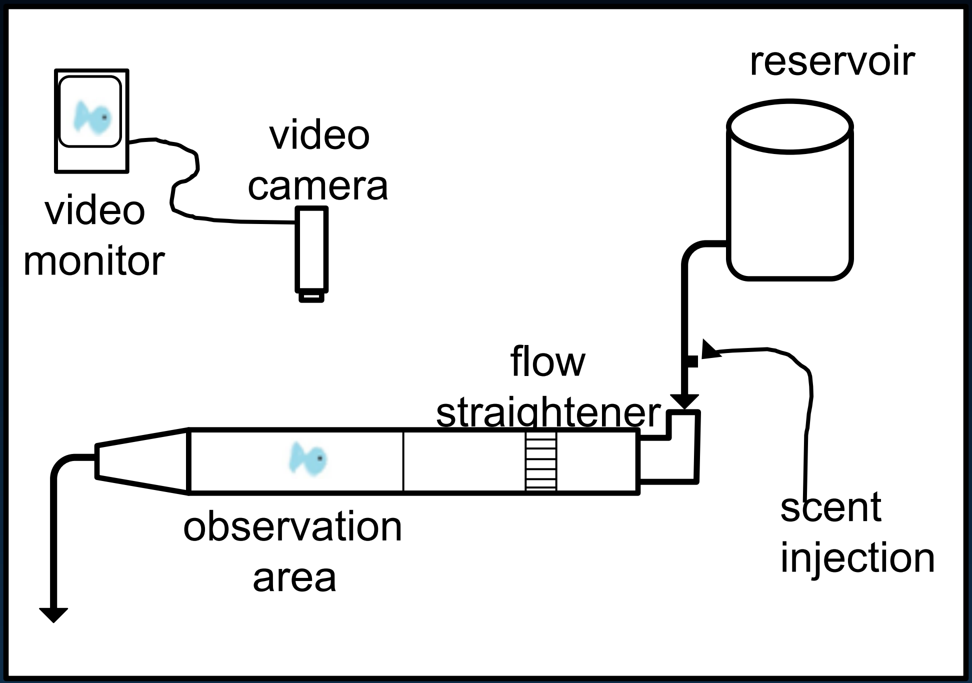
Survival, productivity

OA effect pathways

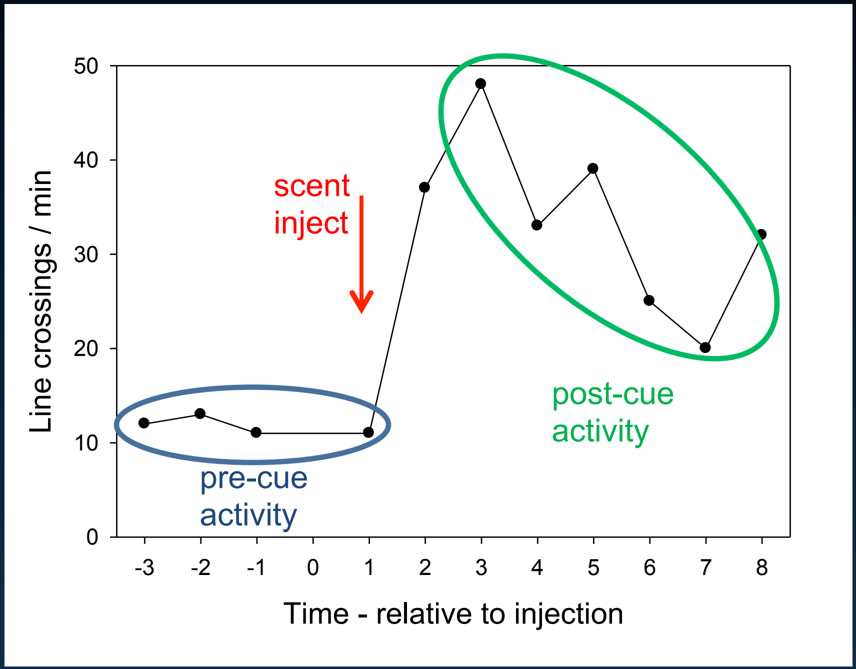


Walleye pollock– prey scent detection

Experimental set-up



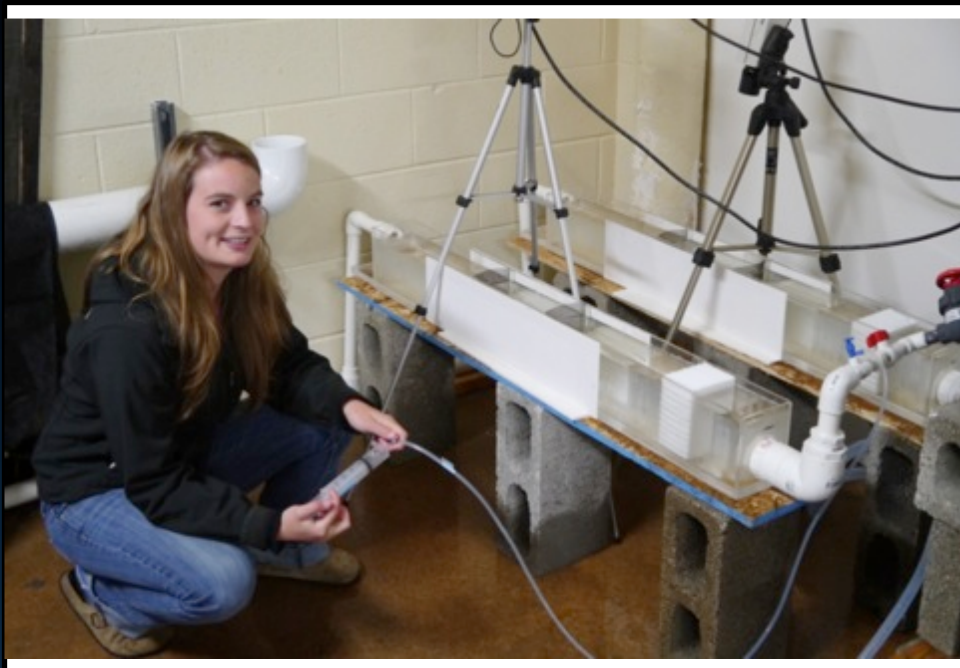
Behavioral response to prey scent

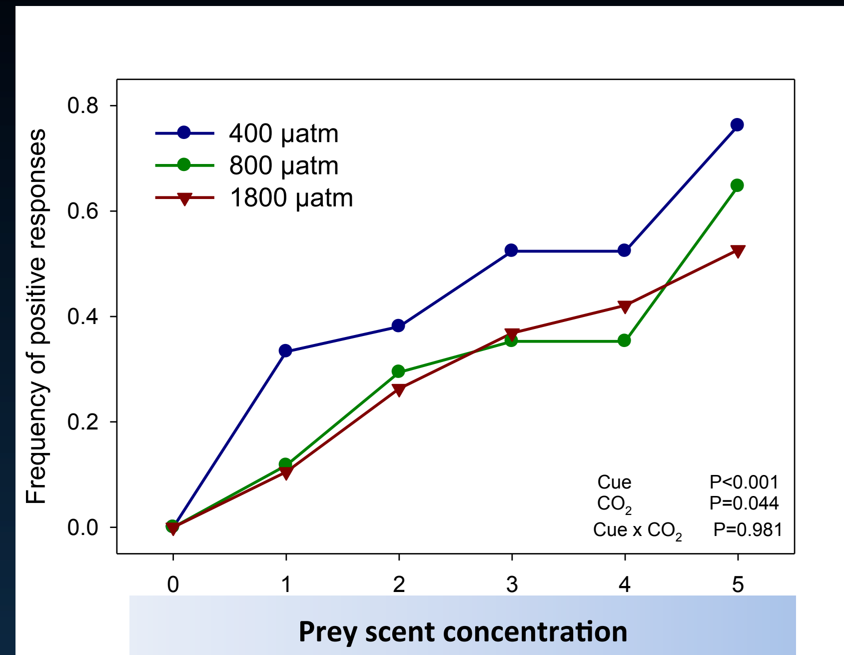


Prey scent injected in pulses into flow through the flume.

Allowed us to test each fish at multiple levels of prey scent concentrations.

Walleye pollock– prey scent detection

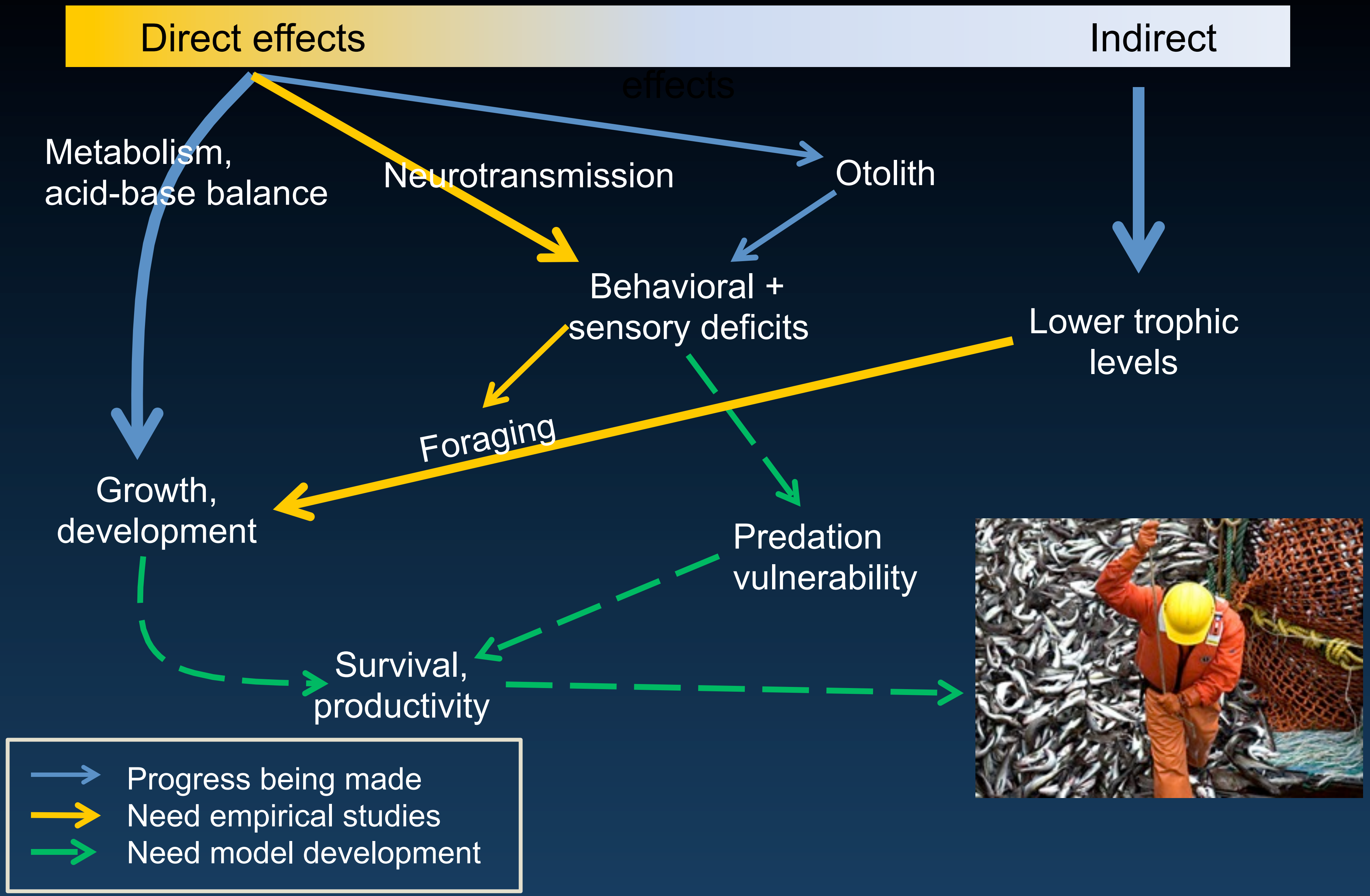




Preliminary experimental observations:
Behavioral / sensory impairment does not appear limited to tropical reef fishes.

Need experimentation on more species and across a wider range of ecologically relevant behaviors to evaluate the impact of this impairment.

OA effect pathways



Summary & Conclusions

The direct effects of OA on growth energetics of walleye pollock and northern rock sole appear to be minor, but are not equal.

Preliminary work indicates that OA may induce behavioral and/or sensory deficits, as demonstrated in some tropical species.

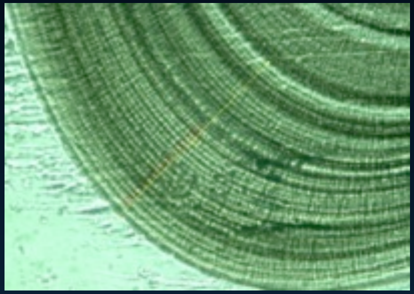
Future:

- Fuller evaluation of sensory / behavioral responses to OA
- OA-induced changes in prey availability and prey quality
- OA in context of multiple stressors

For commercially important species, these studies will require the development of collaborations between agency and academic researchers.

Primary funding support:

Otolith hypercalcification



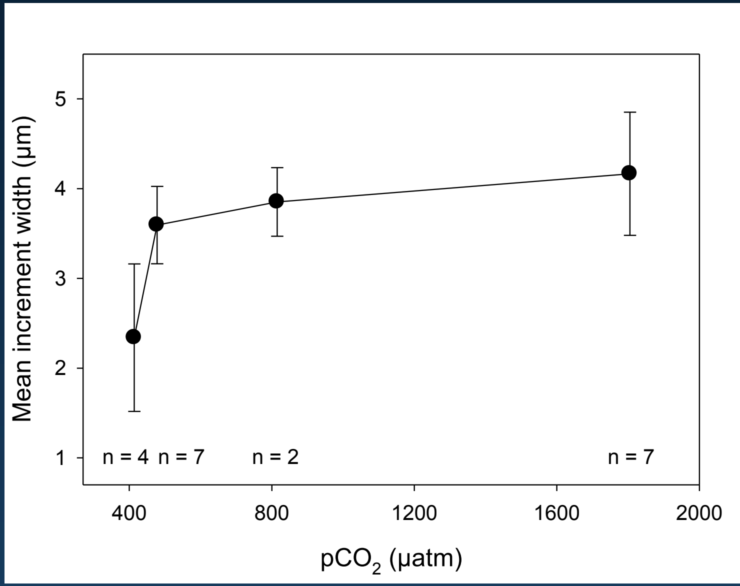
Ear bone – made of calcium carbonate, hearing & orientation

Hypercalcification – rapid accretion of calcuim carbonate matrix

Common effect: documented in > 5 unrelated species.

Hypothesized to be side-effect of extracellular pH regulation.

Consequences for hearing and orientation are still unknown.



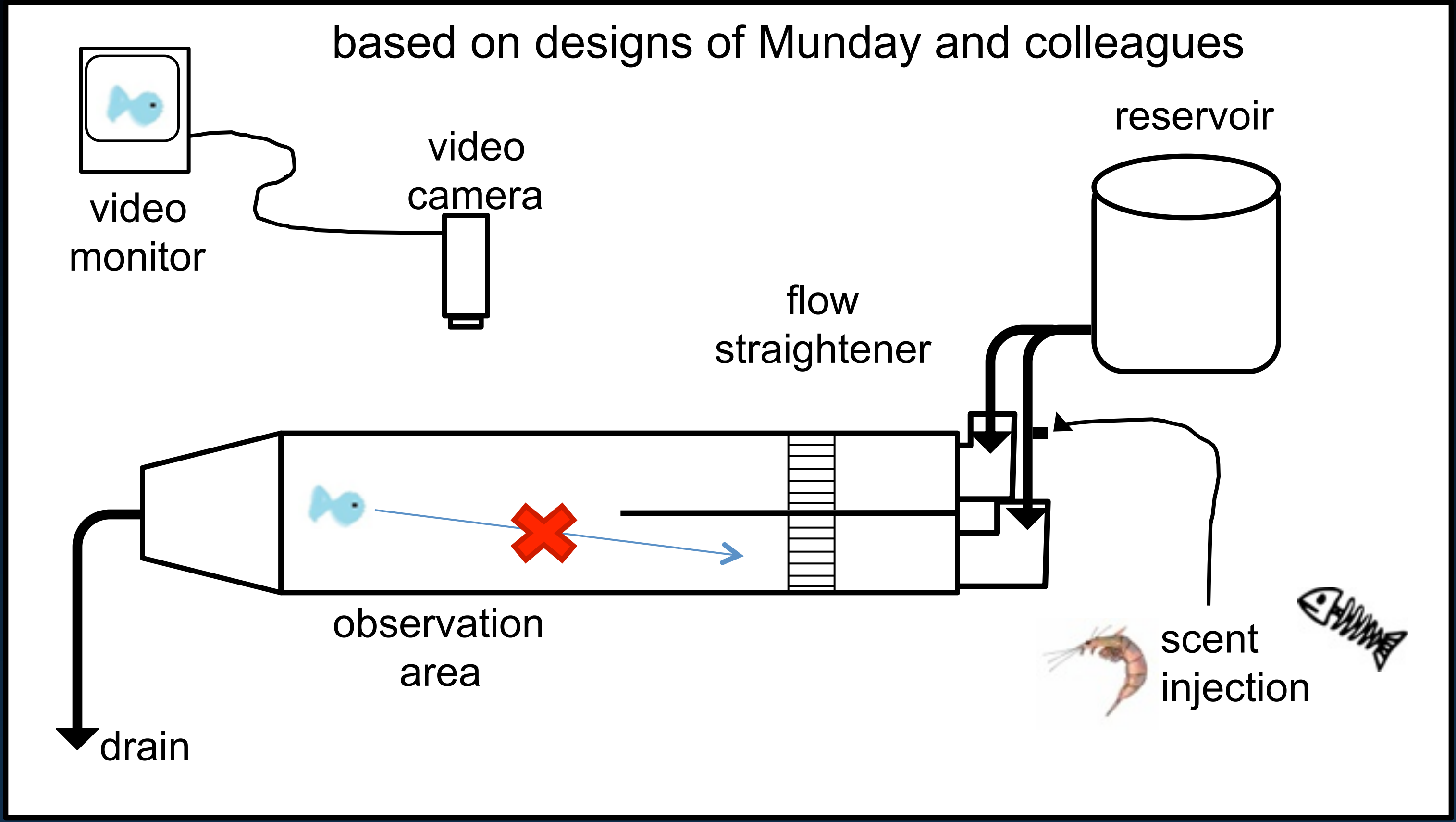
Hurst et al. (2012)

Otolith accretion in yearlings was more rapid at higher CO_2 levels.

The effect is not restricted to larvae.

Still do not know if the effect would persist over long-term exposures.

Flume schematic – scent attraction/repulsion



Walleye pollock showed no consistent attraction to "channel" with prey scent cues.

Also tried response to "damaged conspecific cues" – again no reliable response.