Chemical cues released by predation increase the growth of yellow perch, *Perca flavescens*

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Background – the Nose Knows

- **Fish use sense of smell for important information**
- **“Odors” induce physiological and behavioral responses**

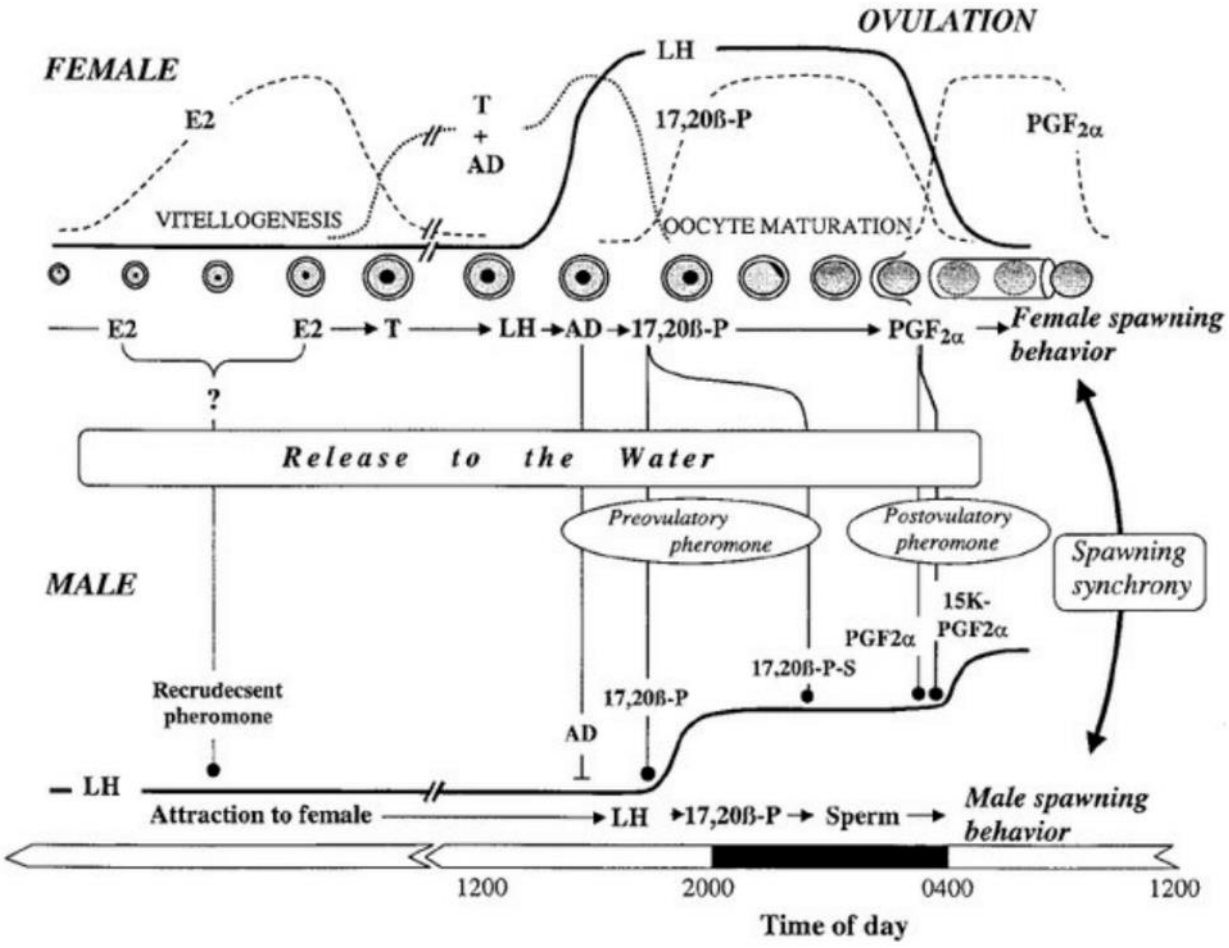
Finding food
Nucleotides, ATP/ADP

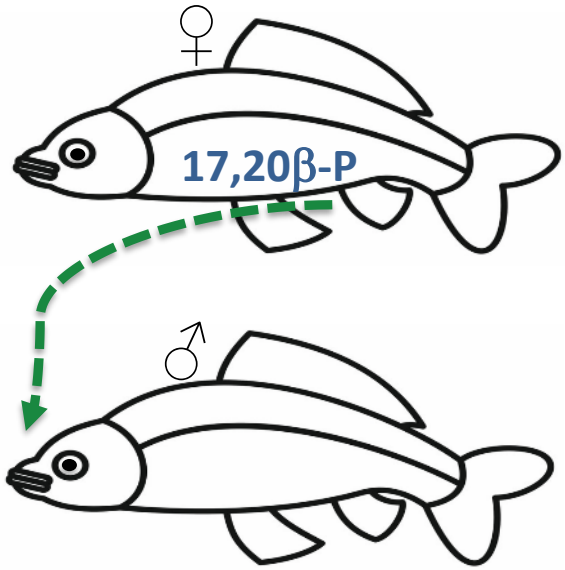
Spawning
17α, 20β-P, PGF2α, 4-Androstene-3,17-dione (4-AD)

Migration
Amino acids, bile acids, fatty acids

Predator avoidance “Alarm substance”
Hypoxanthine-3 N-oxide (H3NO)
Glycosaminoglycans (GAGs)

Background – Spawning Pheromones





Kobayashi et al. 2012

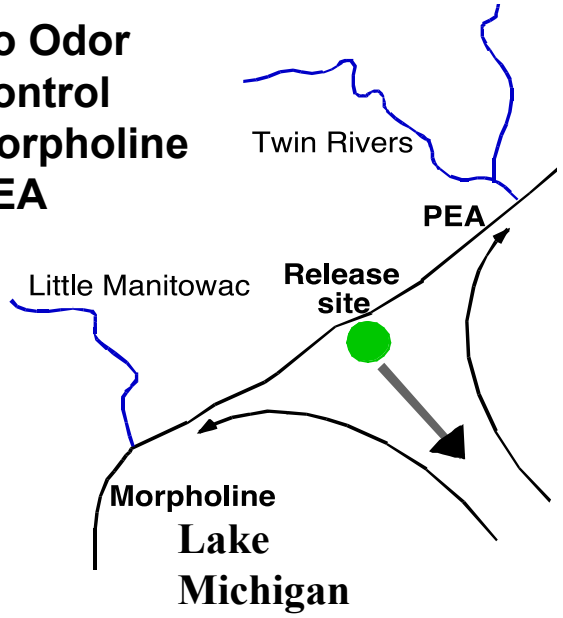
Fish use odors to return back to home stream

***Olfactory Imprinting Model* (Hasler and Wisby 1951):**

1) Streams differ in chemical characteristics that are stable over time.
2) Salmon can distinguish these differences using olfaction.
3) Salmon learn the chemical characteristics of their natal stream prior to or during their seaward migration and remember/respond to them as adults for navigation during their return migration.

Art Hasler 1974

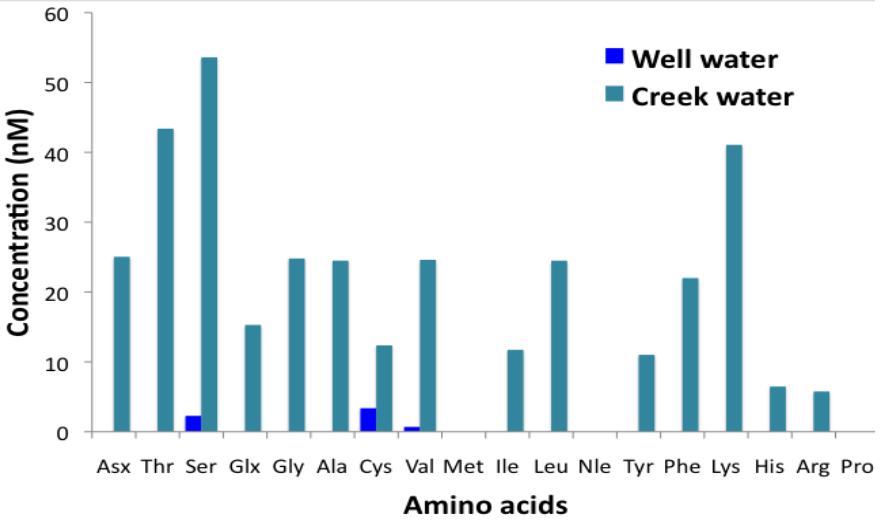
1. **No Odor Control**
2. **Morpholine**
3. **PEA**

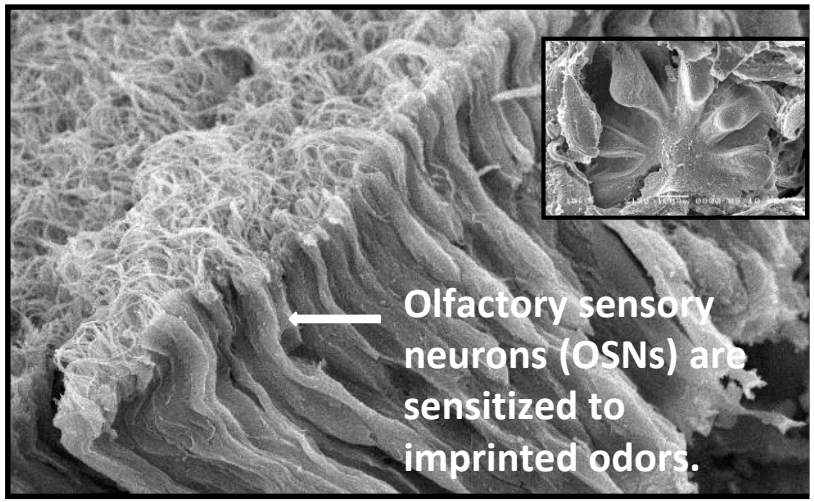


Scholz et al. 1976

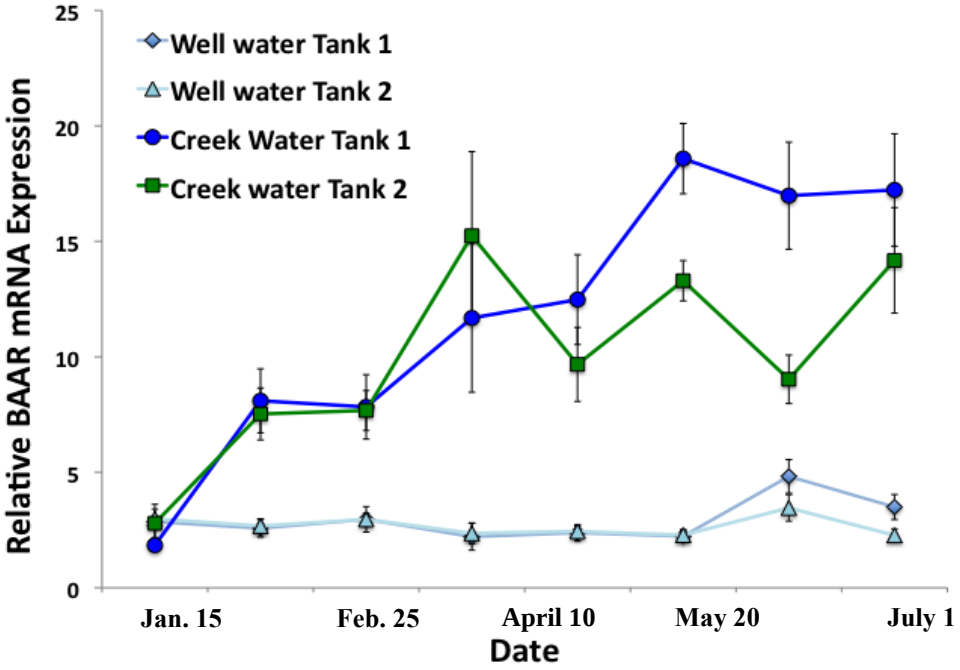
Background – Migration Pheromones

Juvenile salmon exposed to tributary waters with <u>different chemical compositions</u> will display <u>different patterns of olfactory receptor expression.</u>



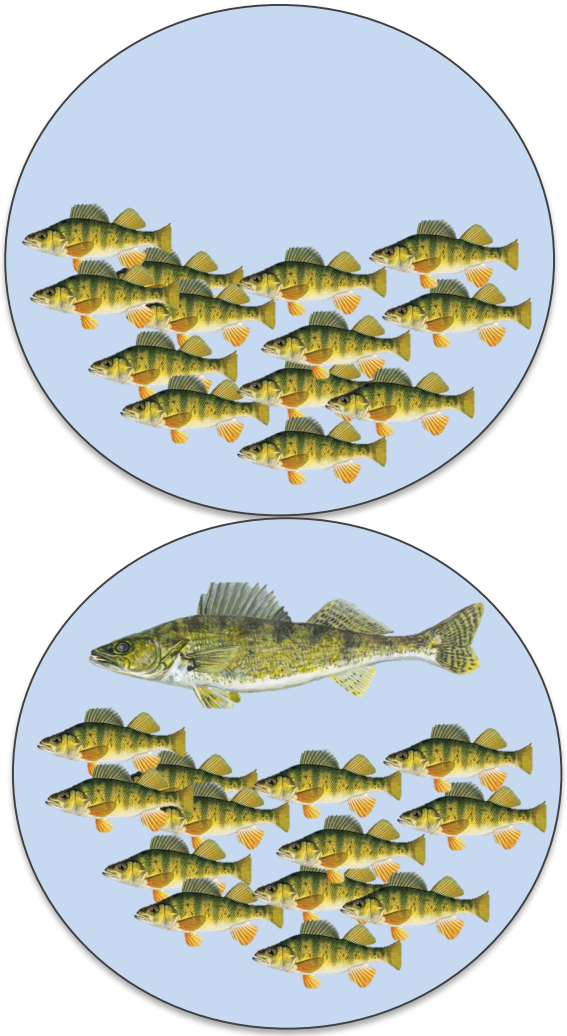


Olfactory Epithelium



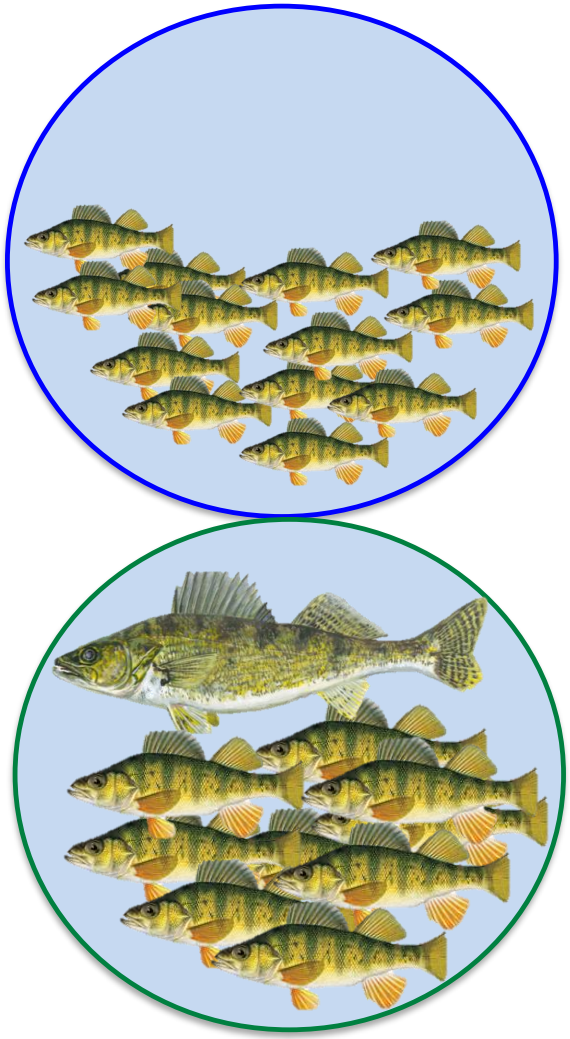
Background – Accelerated Perch Growth

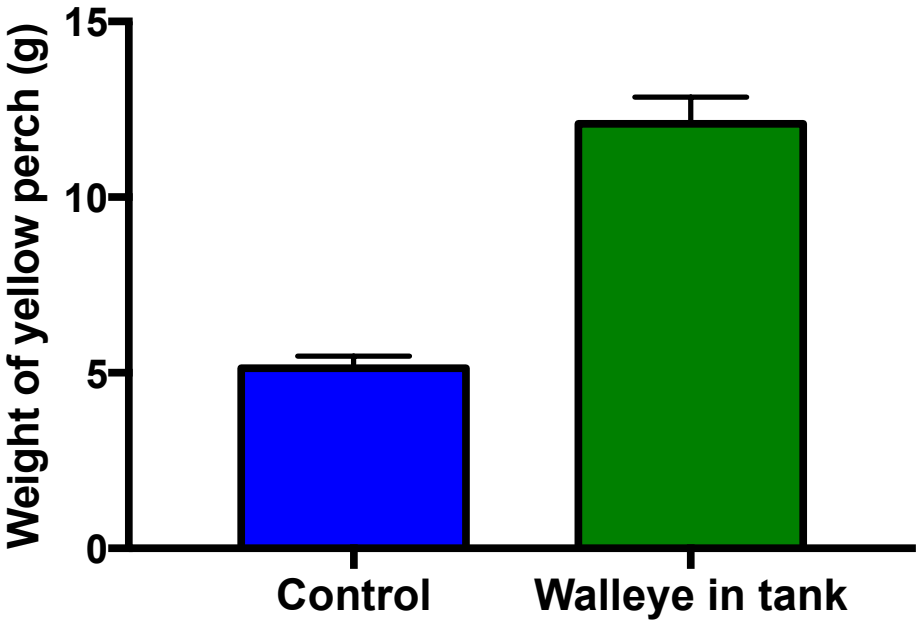
A serendipitous discovery



Background

Accelerated growth when exposed to predator

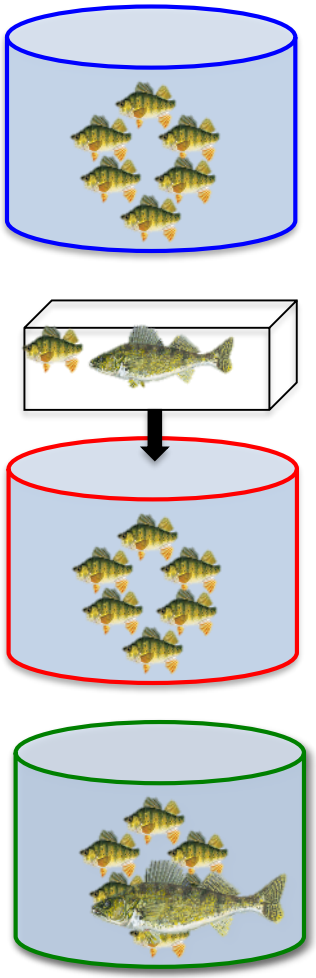


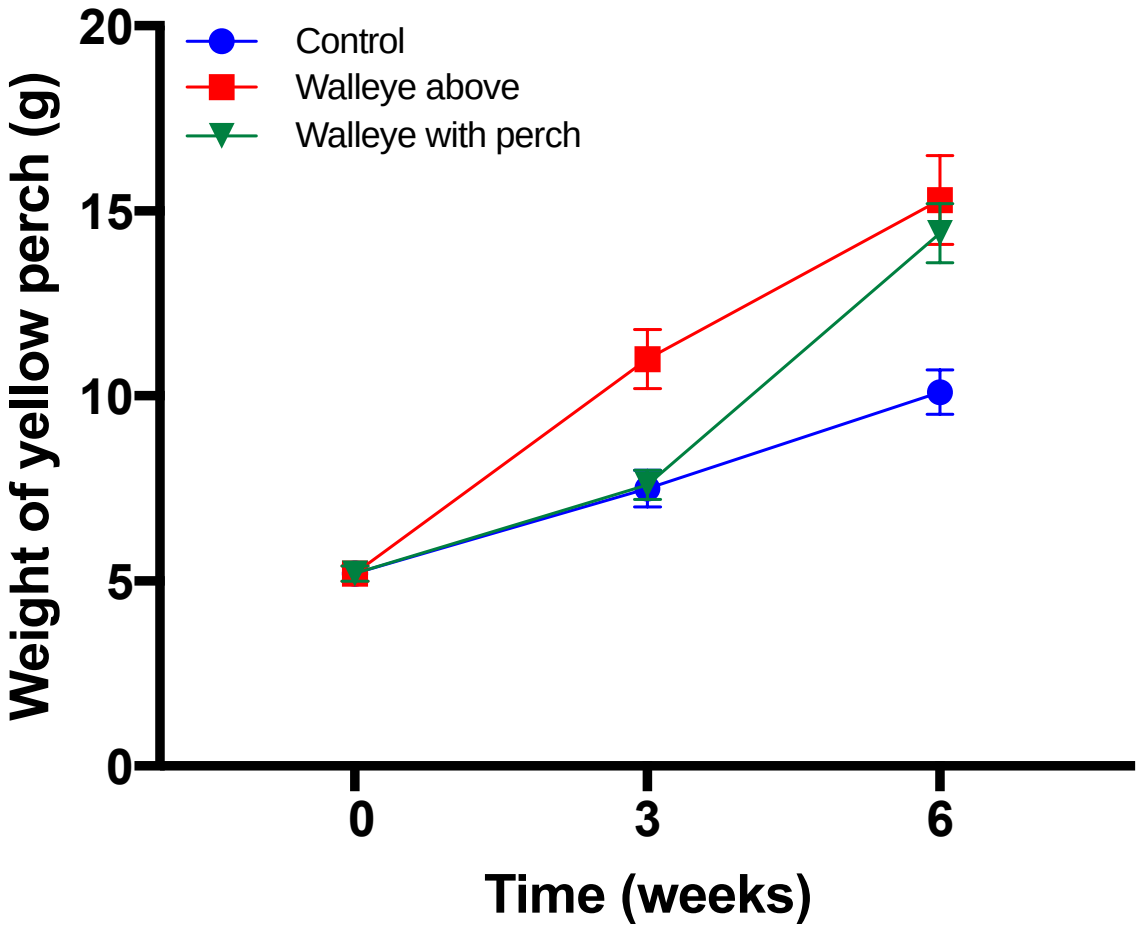


Hypothesis

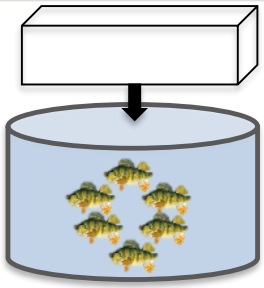
- Odor from predation responsible for increased growth

Experiment 1

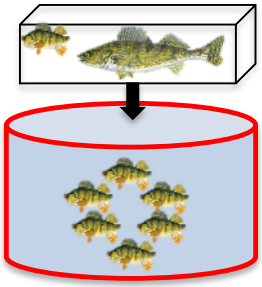




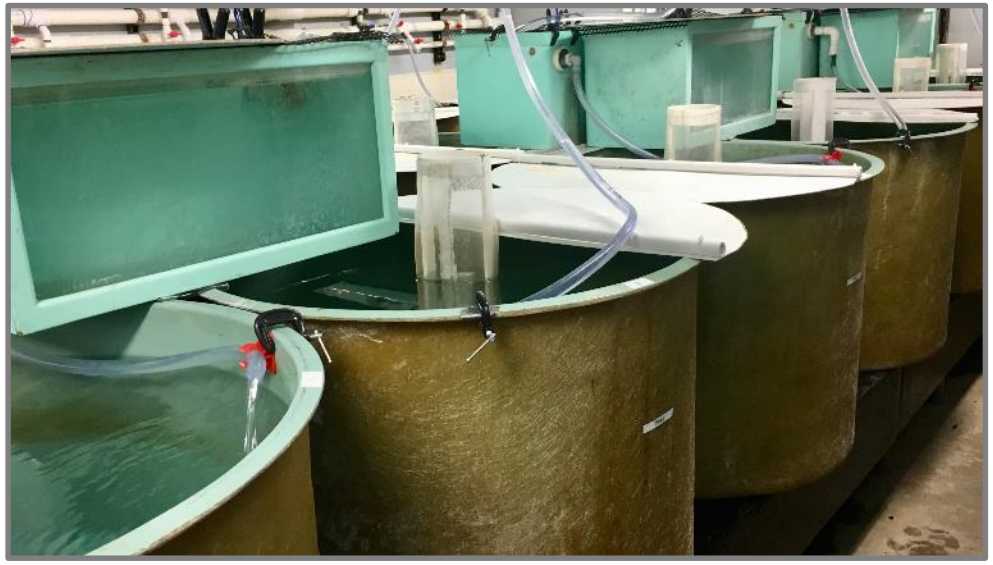
Experiment 2

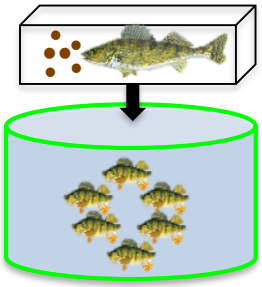


1. Control

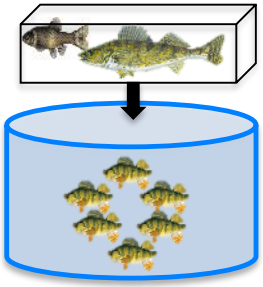


2. Yellow perch



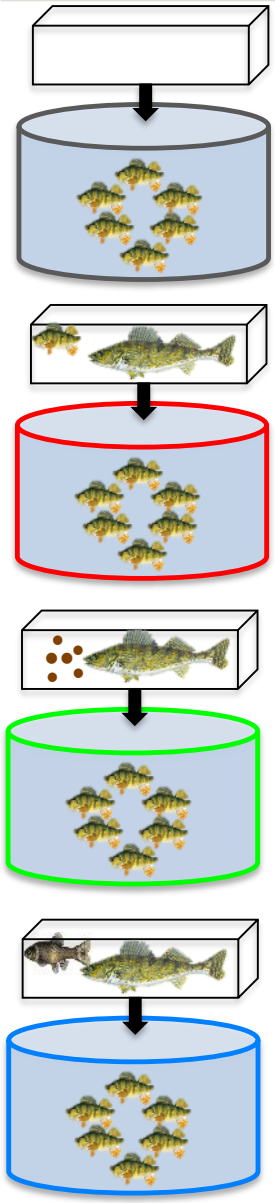


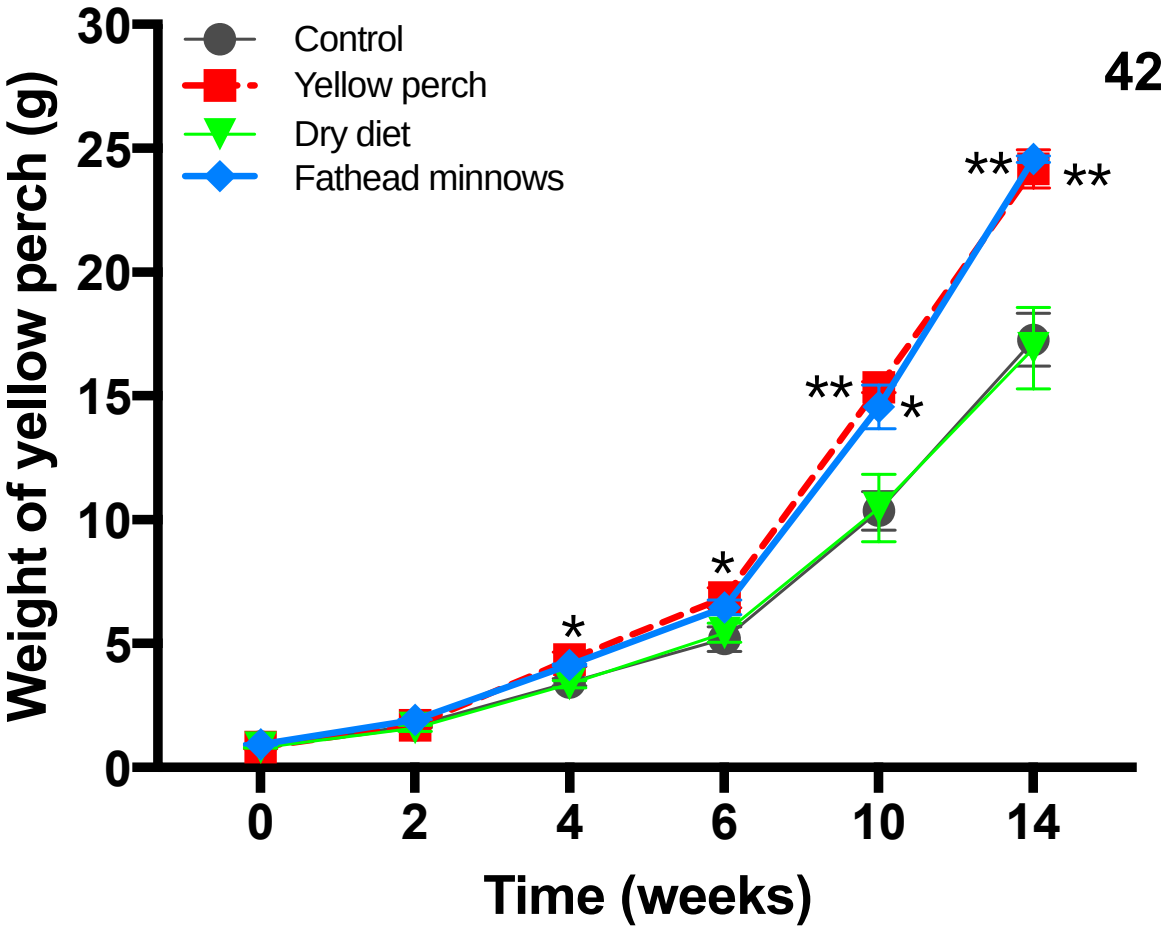
3. Dry diet



4. Fathead minnows

Experiment 2





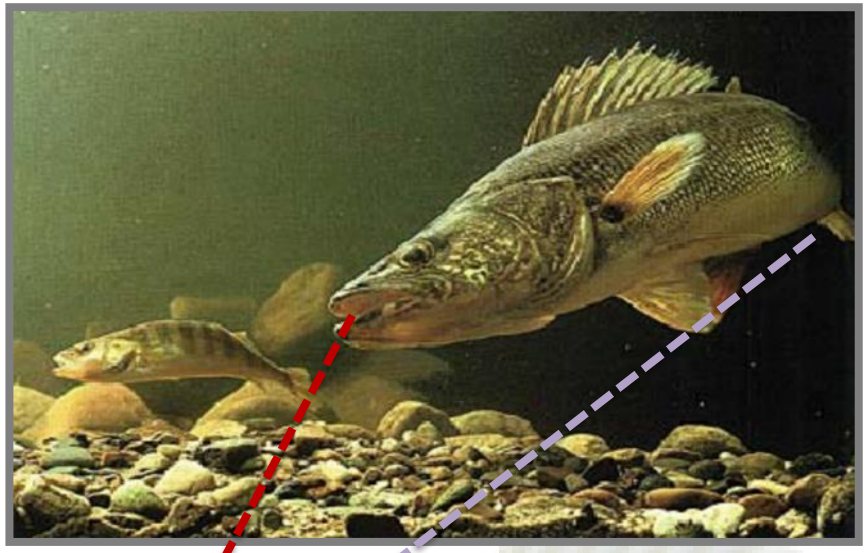
42 and 40% larger

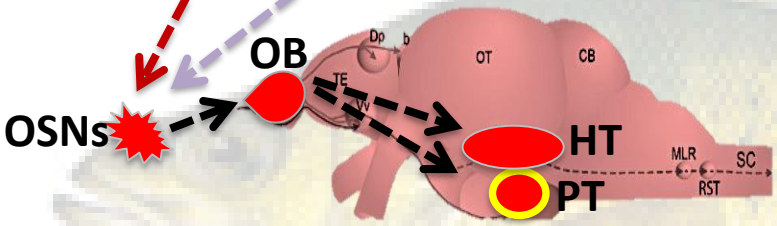
Summary

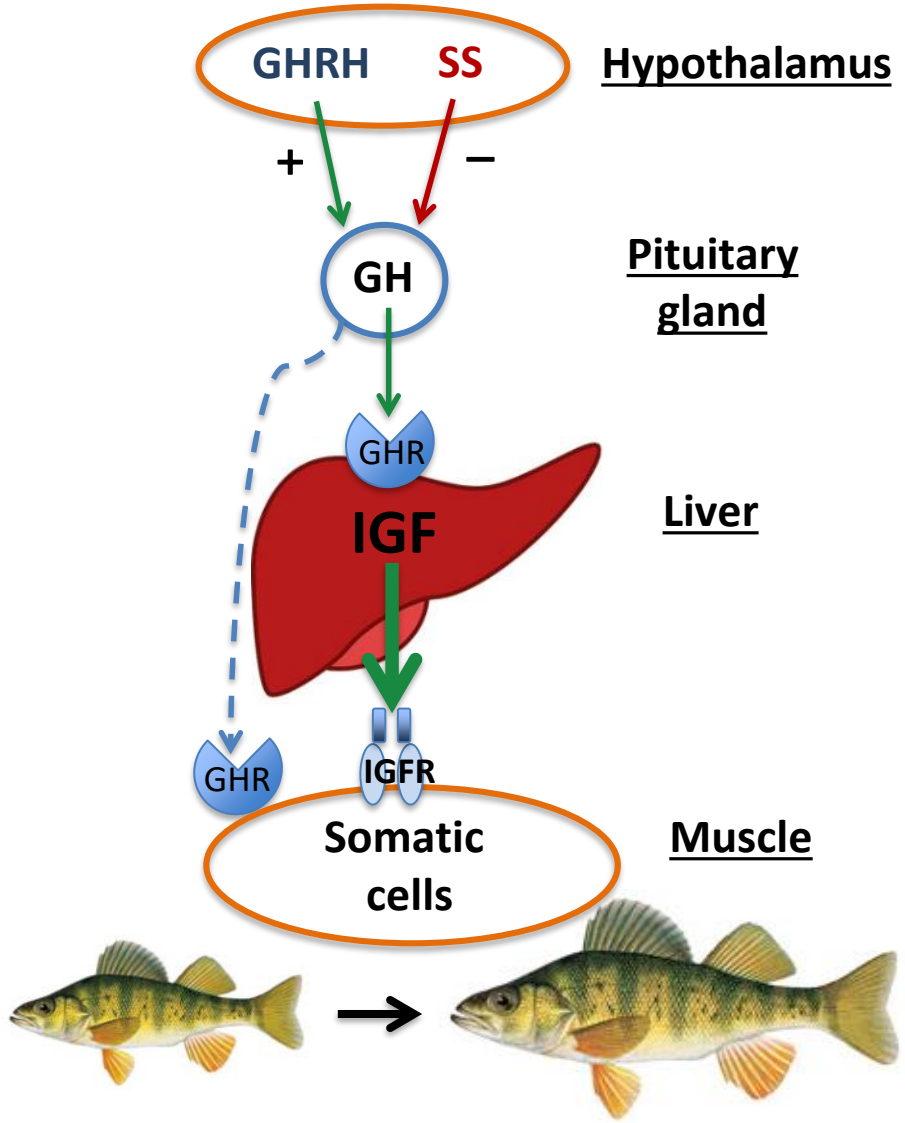
1) Factor(s) associated with walleye **predation on yellow perch or FHMs** markedly **increase growth** of yellow perch.

2) Factor(s) are **chemical cues in the water**, not the smell or presence (sight) of the walleye.

Pheromone Source & Mechanism of Action?



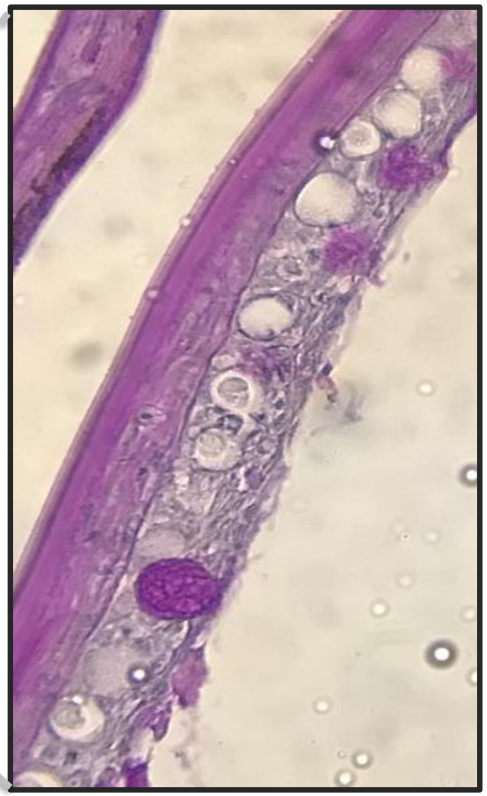




Pheromone Source

Club cells "Alarm substance cells"

- Damaged skin causes release of chemicals that elicit behavior response on conspecifics
- Club cells contain cytokines, cytochrome P-450, tissue repair substances (GAGs), proteins CC10-CC16, uteroglobin/blastokinin



Pheromone Source

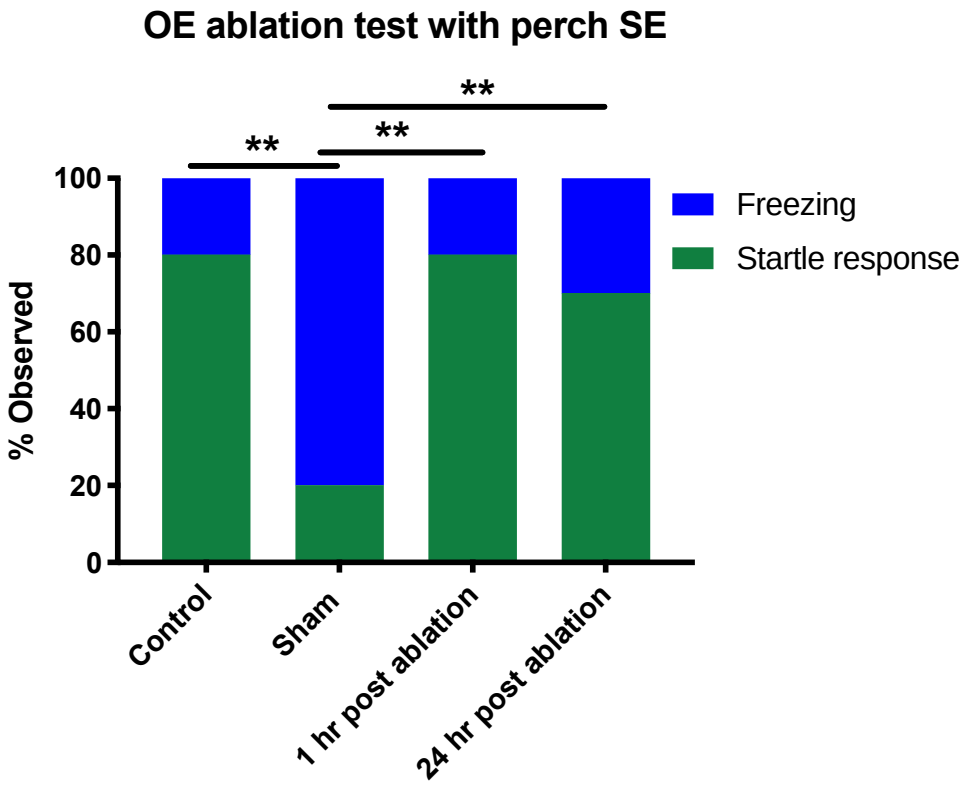
Behavior Assay

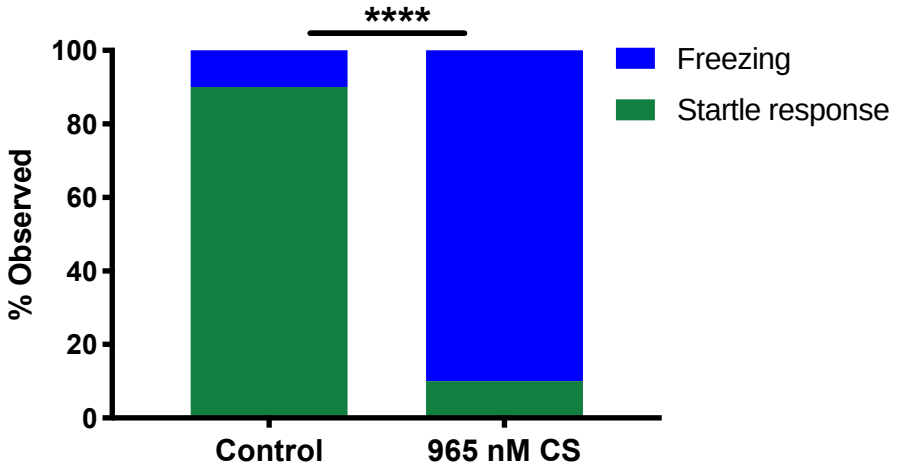
- Possible link between behavior response to alarm substance(s) and growth promoting pheromone?

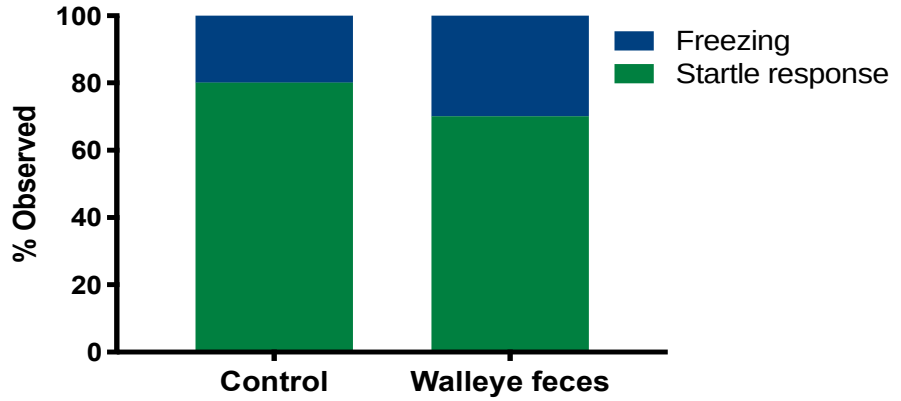
Pheromone Source

Behavior Assay

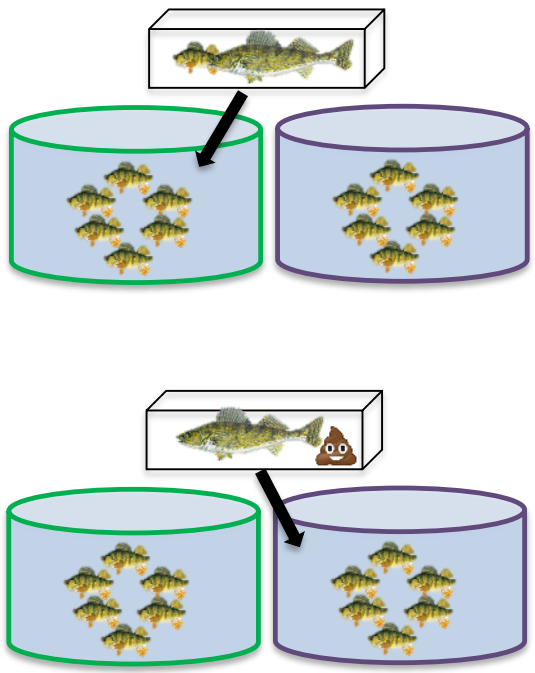
- Possible link between behavior response to alarm substance(s) and GPP?

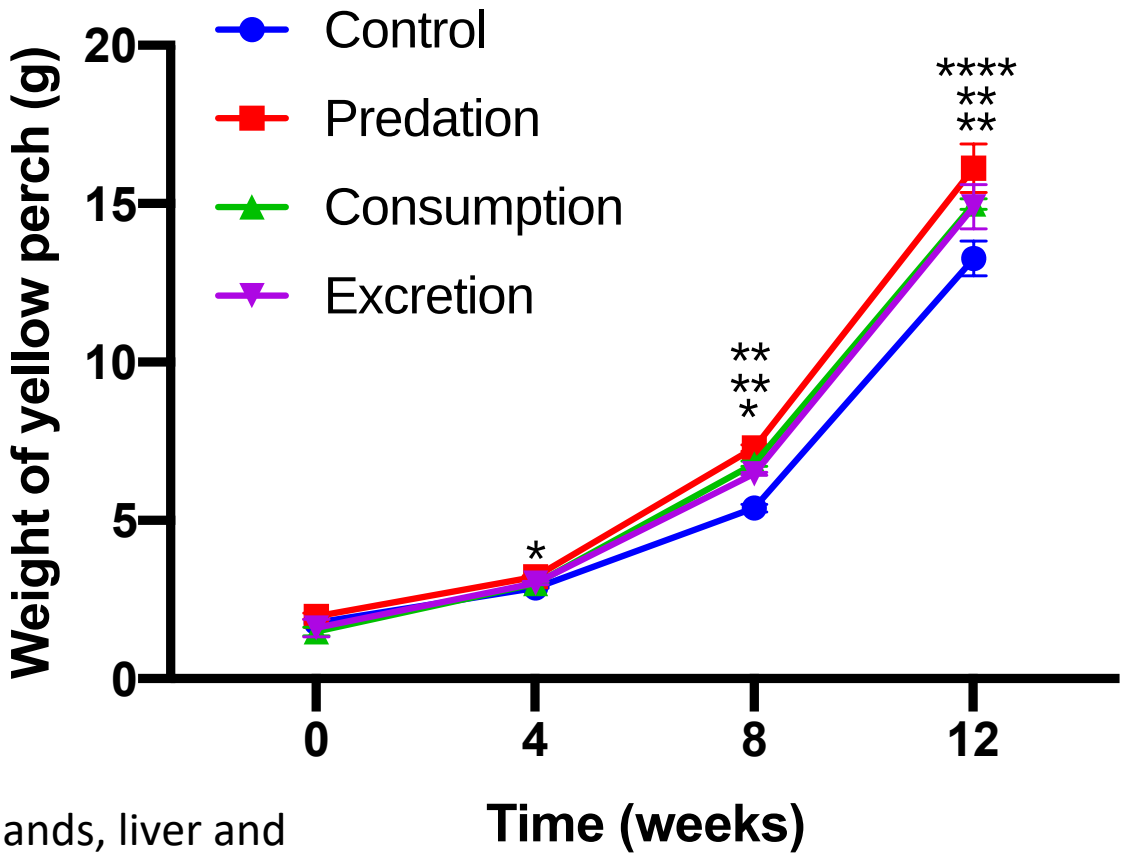






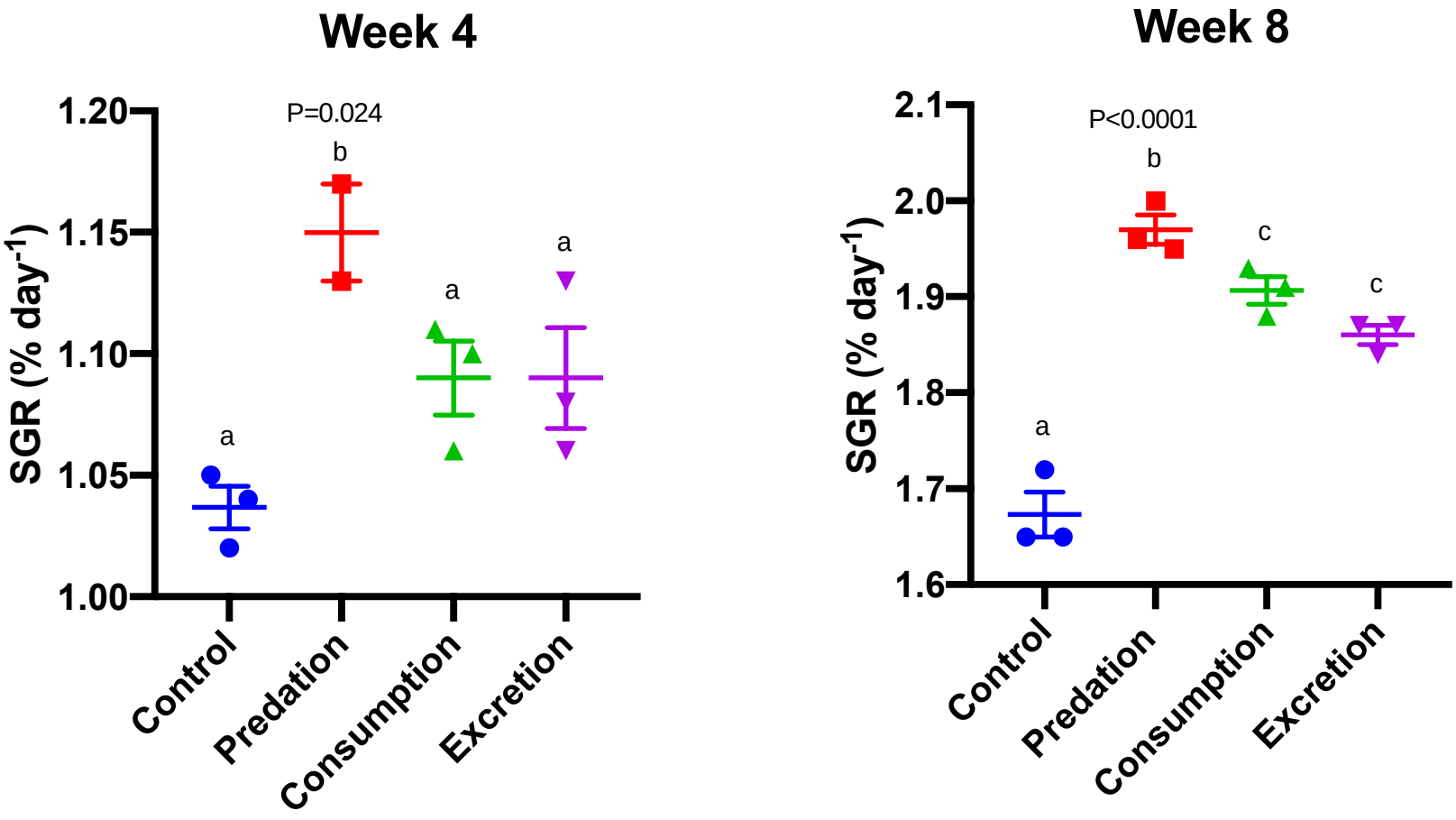
Source of Putative GPP & MOA



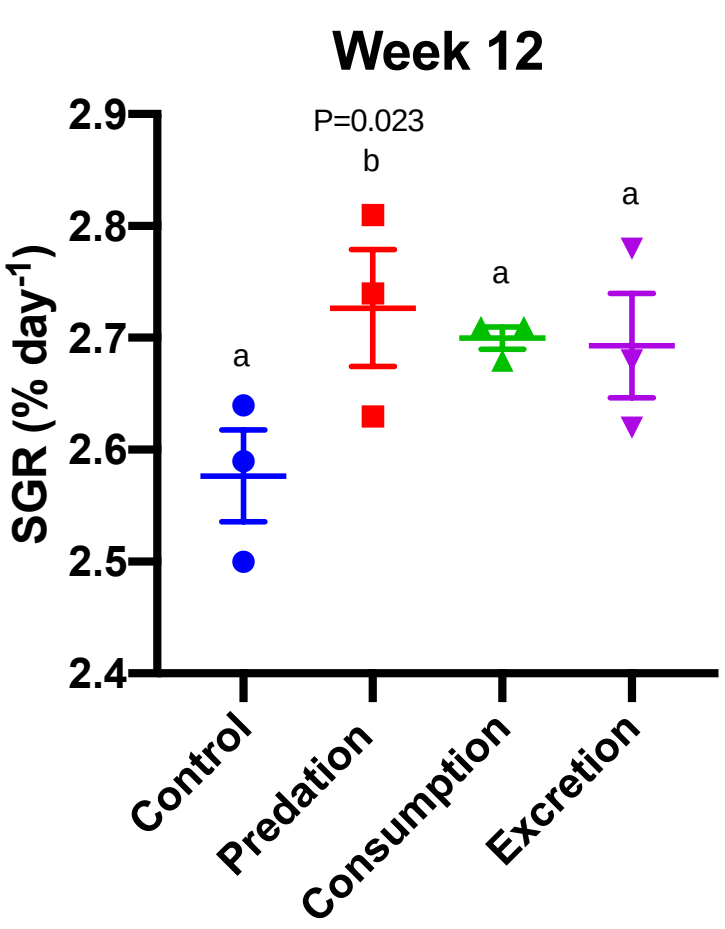


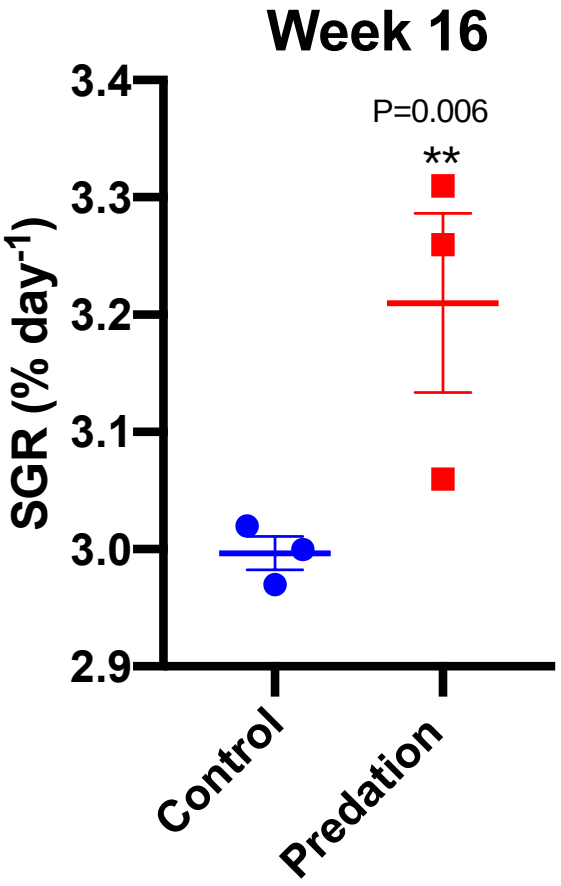
*Collect plasma, pituitary glands, liver and muscle tissues to measure circulating IGF-1 and gene expression of growth factors

Specific Growth Rates



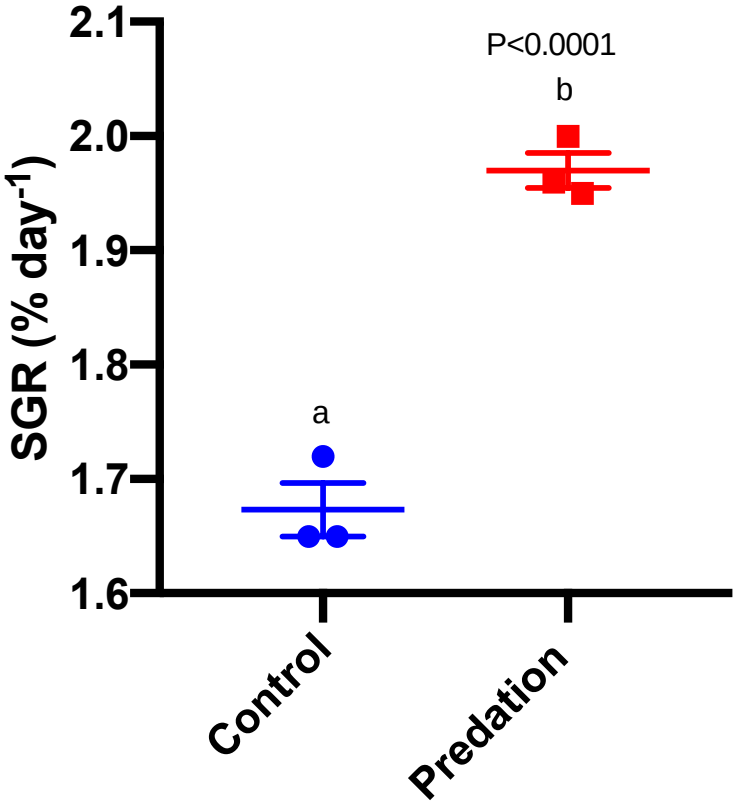
Specific Growth Rates

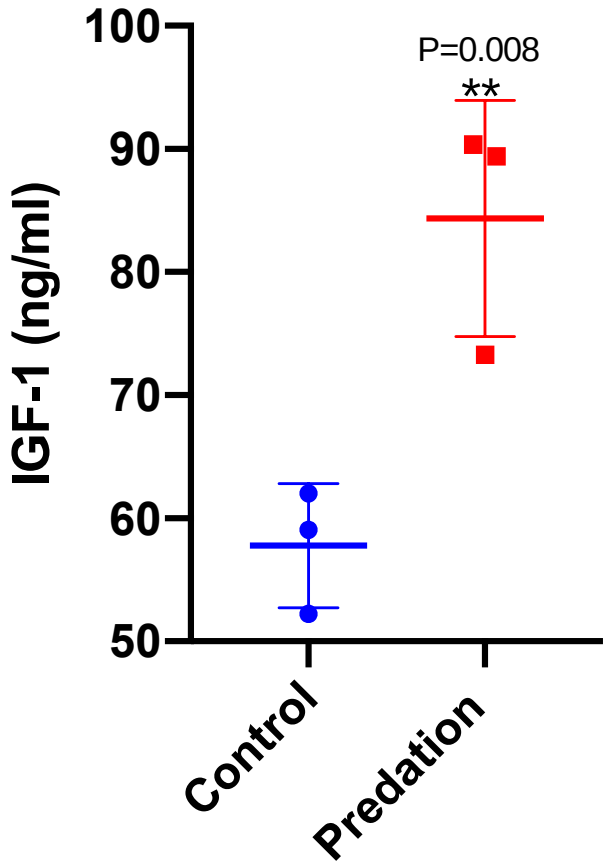




MOA-HPS axis

Week 8



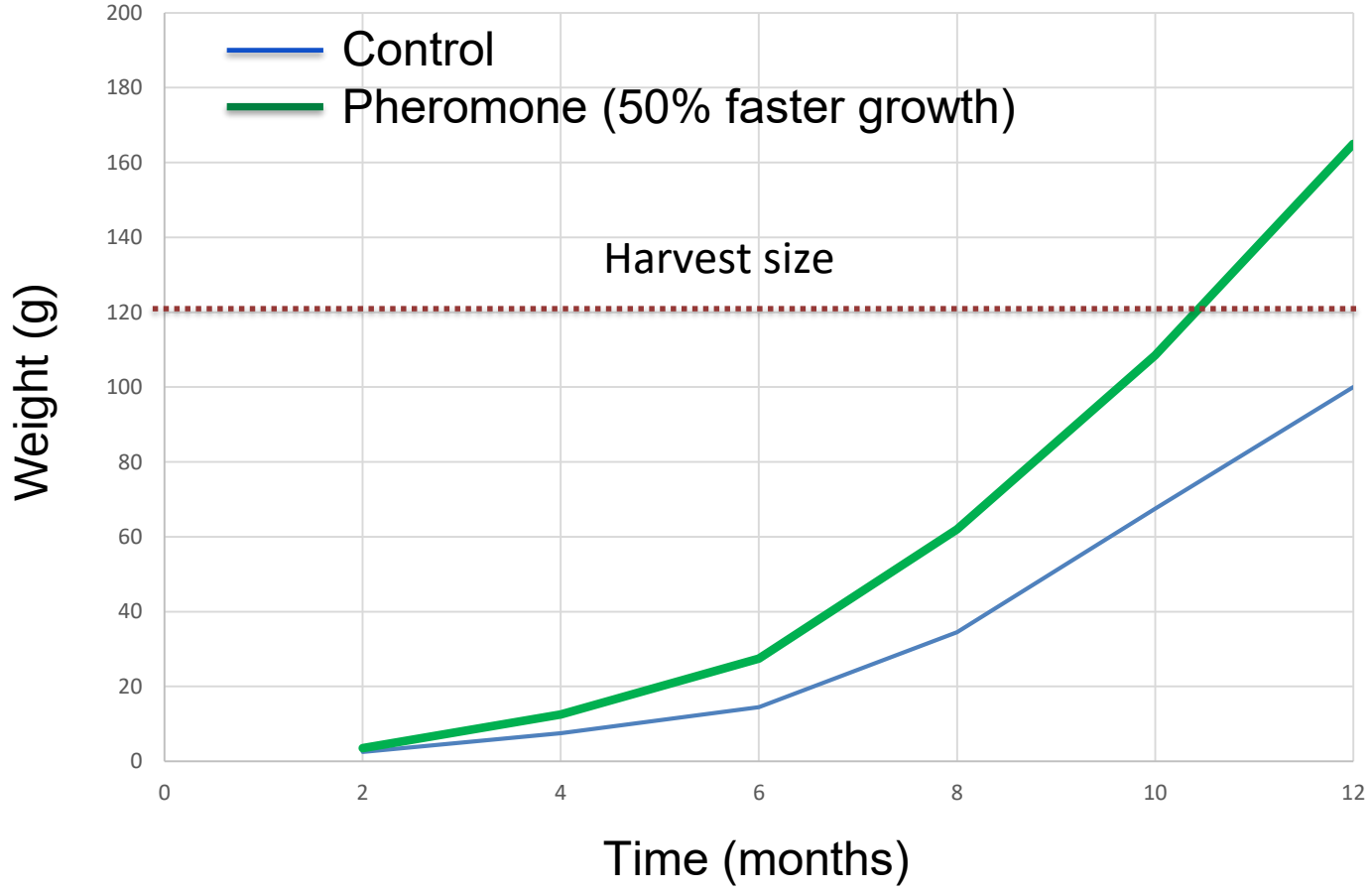


Future Directions

- Determine if accelerated growth continues with exposure to predation odors.
- Use biomarker(s) of accelerated growth to determine source of putative growth promoting pheromone.
- Conduct feed trials to determine if yellow perch exposed to odors are consuming more.

Practical Implications

Developing yellow perch aquaculture and improved stocking



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Journal of FISH BIOLOGY

Questions?

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Chemicals released by predation increase the growth rate of yellow perch, *Perca flavescens*

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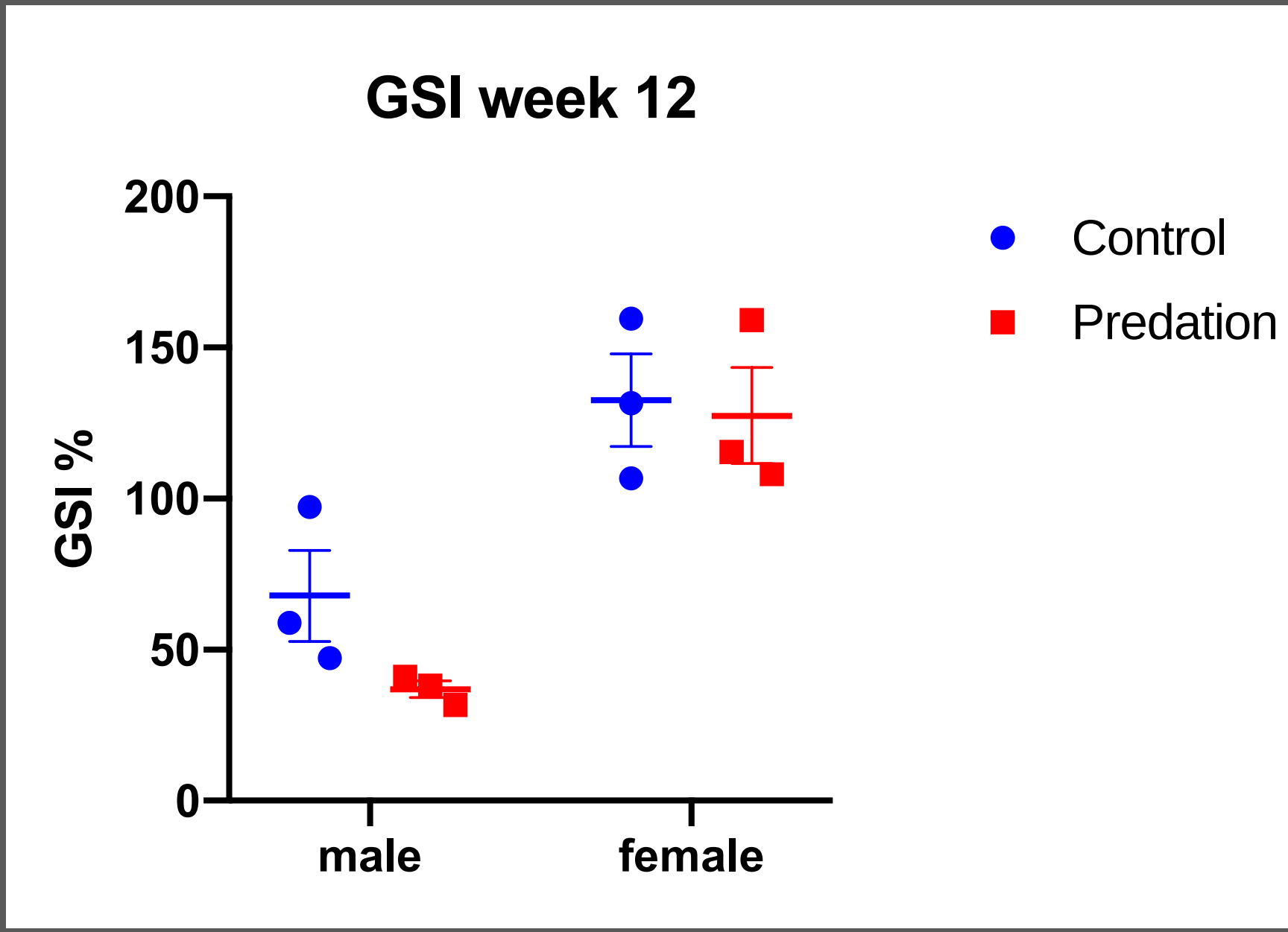

GSI week 12
GSI %
200
150
100
50
0
male
female
Control
Predation

Discussion

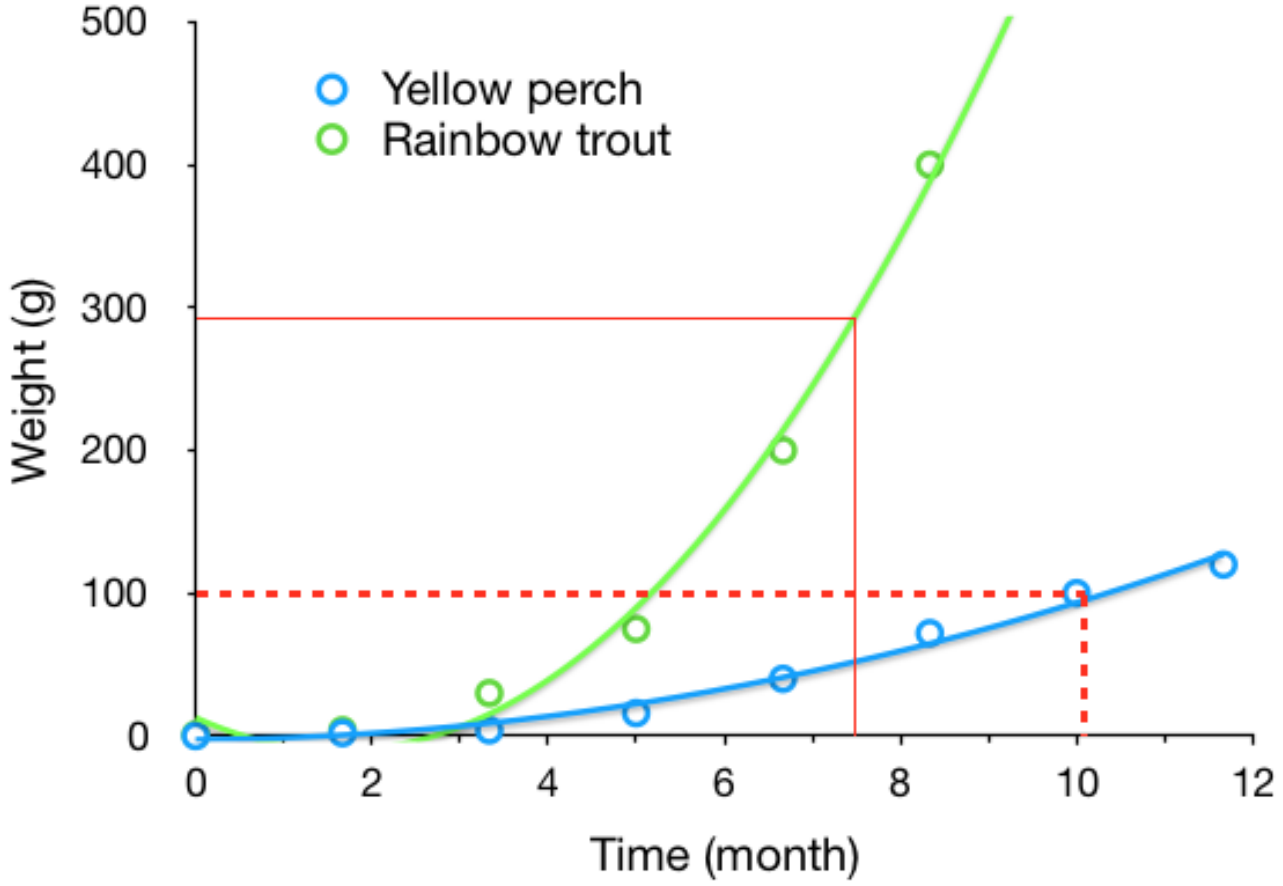
Phenotypic plasticity – morphological defense

- Phenotypic plasticity shown in crucian carp in response to predators (Brönmark & Miner, 1992; Brönmark & Petterson, 1994; Stabell & Lwin 1997; Domenici et al. 2008)
- Grow larger than gape of predators mouth
- Inducible, chemically-mediated growth mechanism evolved to avoid predation

Domenici et al. 2008

Discussion

Implications – Developing yellow perch aquaculture



Odorants Sensed by Fish

The fish olfactory system can detect a wide range of water soluble compounds which elicit, or contribute to, behaviors crucial for survival such as feeding, reproduction, social interaction, and avoiding predation. Amino acids and nucleotides indicate the presence of food. Nucleotides, such as adenosine-5′-triphosphate (ATP), indicate food freshness in carp (Hara and Zielinski, 2007). Amino acids induce appetitive swimming behavior characterized by increased number of turns and swimming speed in zebrafish (Lindsay and Vogt, 2004). Steroids and prostaglandin F2α, which are hormones produced in the gonads and released in urine, were shown to trigger species and sex specific reproductive behaviors in a variety of teleosts (Hurk and Lambert, 1983; Stacey and Kyle, 1983). Bile acids are steroids secreted by the liver and released in urine, which have been implicated in migration to spawning sites in lampreys (Sorensen et al., 2005). While bile acids are agreed upon as one of the main classes of odorant in fish, their putative role as social pheromones, indicating the presence of other fish, is not yet conclusively proven in teleosts (Doving et al., 1980). Compounds released from the skin of injured fish have long been known to elicit a vigorous, stereotyped alarm response from many species of fish (von Frisch, 1941). This alarm response is characterized by darting followed by slow swimming or freezing (Speedie and Gerlai, 2008; Doving and Lastein, 2009).

↑× □□↓□□□□□oMathoMathParactrlPrrtmcsmca first time, an onto- genetic shift by yellow perch in their response to conspecific chemical alarm cues. YOY perch (individuals < 60mmSL) significantly increased anti- predator behaviour in response to the cues of both YOY and adult perch. Adult perch (individuals > 110mm SL), however, increased their foraging behaviour in response to the same cues. These results support our model of a threat-sensitive trade-off between anti- predator and foraging benefits in response to conspe- cific and/or heterospecific chemical alarm cues (Brown et al. 2002, Golub & Brown 2003). Previously,

↑× □□↓□□□□□oMathoMathParactrlPrrtmcsmca promote growth md may play a role in mediating sexually related dimorphic growth in yellow perch. The fact that E2 stimulated growth and an androgen had either negligible (at low doses) or negative (at high doses) effects in this species contrasts with the findings on most other teleosts (Donaldson et al. 1979), and demonstrates that sgecies-related differences in the effect of steroids on growth occur in teleosts, just as in mammals (Heitzman 1978).