Programs of the Fish Conservation and Culture Laboratory

Joan Lindberg\textsuperscript{1}, Tien-Chieh Hung\textsuperscript{1}, Meredith Nagel\textsuperscript{1,2}

\textsuperscript{1} Fish Conservation and Culture Laboratory, UC Davis
\textsuperscript{2} Aquatic Health Program, UC Davis

Delta Smelt (\textit{Hypomesus transpacificus})

- Endemic to Bay-Delta
- Endangered species status
- Annual life-span
- Spawning season February – June
- Asynchronous batch-spawner (multiple clutches)
Main Programs of FCCL

• Delta Smelt Refuge Program
  – Develop and implement genetic breeding and rearing program

• Research Program and Collaborative studies
  – Reproductive biology, behavior studies, growth and development studies

• Aquaculture Program
  – Produce Delta Smelt and Longfin Smelt for on-site and off-site research

Selected studies

• Spawn responses to naturalistic substrates and water velocities

• Effects of light and turbidity on feeding, growth, and survival of larval Delta Smelt

• Effects of temperature and salinity on the choices of Delta Smelt

• Effects of food-limitation on the life-stages of Delta Smelt
Spawn Responses to Naturalistic Substrates and Water Velocities

Joan Lindberg¹, Brittany Kammerer¹,², Bradd Baskerville-Bridges¹

¹ Fish Conservation and Culture Laboratory, UC Davis
² Aquatic Health Program, UC Davis

Experimental Spawning Tanks

Two zones of velocity, over two years, 100 fish/tank
Deposition of Eggs

Substrate types:
- Empty trays (ET)
- Bare tank floor (B)
- Tule plant stalks (T)
- Artificial tules (AT)
- Pebble (P)
- Dead wood (W)
- Cobble (C)
- Sand (S)

Results Summary

- Most of the eggs were found on the substrates (58.5±14.6%) as opposed to the trays (4.5±4.1%).
- More eggs were deposited on the pebble and sand.
- Delta Smelt choose to spawn on substrates in the high flow velocity, each year.
Effects of Light and Turbidity on Feeding, Growth, and Survival of Larval Delta Smelt

Galen Tigan, Tien-Chieh Hung, Joan Lindberg

Fish Conservation and Culture Laboratory, UC Davis

Delta Smelt First Feeding Study

Baskerville-Bridges et al. (2000)
40-day Rearing Study

- Three levels of turbidity (2.0, 5.5, and 9.0 NTU) and light intensity (2.0, 6.75, and 9.0 µmole/m²/sec).

- Sampled on Day 10, 20, 30, and 40.

Survival and Growth

<table>
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<th>Survival (%)</th>
<th>Growth rate (mm/day)</th>
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<tr>
<td>67.8</td>
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<td>75.5</td>
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<td>53.4</td>
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[Graph showing survival and growth over time for different turbidity and light intensity conditions.]
Feeding Preference

Results Summary

• The presence of turbidity and light triggered feeding in Delta Smelt larvae.

• The survival and growth rate are higher for Delta Smelt larvae in the rearing trial with high turbidity conditions.

• The co-feeding period is shorter for Delta Smelt larvae reared under low turbidity conditions.

• Future work: different life stages and species (Longfin Smelt)
Effects of Temperature and Salinity on the Choices of Adult Delta Smelt

Tien-Chieh Hung¹⁺, Swee Teh², Saikrithika Gandhi², Joan Lindberg¹

¹ Fish Conservation and Culture Laboratory, UC Davis
² Aquatic Health Program, UC Davis

Shuttlebox System
Fish Choice at Several Temps
5 and 3 trials / treatment

Acclimated to 14°C
Acclimated to 17°C

Fish Choice at Several Salinity
Results Summary

• Temperature trials
  – 23°C for fish acclimated to 14°C
  – 25°C for fish acclimated to 17°C

• Salinity trials
  – No significant movement to a specific salinity
  – Avoiding high salinity, as the salinity increased

• Future work
  – Other stimuli: turbidity, toxicity, other

Investigating the Effects of Food-Limitation on the Life-Stages of Delta Smelt

Meredith Nagel1,2, Joan Lindberg1, Swee Teh2

1 Fish Conservation and Culture Laboratory, UC Davis
2 Aquatic Health Program, UC Davis
Declining Fish Abundances in the Delta

Food web interactions: **bottom-up** conceptual model of the Pelagic Organism Decline

![Diagram of food web interactions]

Quantifying the Effects of Food-Limitation

**Adult Population**
- Reproductive development
- Seasonal fecundity
- Overall fish health

**Subsequent Generation**
- Egg and larval quality
- Larval development and survival
- Maternal provisioning
Winter Food-Limitation?

- Potential low food availability in fall, coupled with warmer temperatures
- Less is known about winter food-limitation

Experimental Design

- Three replicates, control and food-limited (n=3)
- 250 fish per tank
- Each fish is uniquely tagged

Adult Delta Smelt Winter Food-Limitation Study
Experimental Design

- 10-12 fish dissected for biomarker assays
- 40 fish measured for weight and length every 2 weeks
- Constant temperature at 12°C

Experimental Design: Food-limitation

Control tanks fed 2% of body weight per day

Food-limited tanks fed 2% of body weight 4 days/week (40% reduced ration)
Eggs expressed
- Measured for weight, length, and ova weight
- Females returned to tank
- Estimate the number of eggs

Nutritional and General Health Biomarkers

- RNA/DNA – short term energy storage
- Triglycerides (TAG) – long term energy storage
- Histopathology
- Estradiol – maturation
- Fatty-Acid analysis
- Disease
Results:

Frequency Distribution Control Groups in March

Frequency Distribution Food-Limited Groups in March

Results:

Frequency Distribution of Length in Control Groups

Frequency Distribution of Length in Food-Limited Groups
Results: Spawning

• No significant difference in condition factor

Results: Spawning

- Average Weight at First Clutch
  - Control: 3.0 ± 0.2 g
  - Food-Limited: 2.8 ± 0.2 g
  - p = 0.01
  - n = 3

- Average Length at First Clutch
  - Control: 65 ± 2 mm
  - Food-Limited: 62 ± 2 mm
  - p = 0.04
  - n = 3

- Total Number of Spawning Females
  - Control: 250
  - Food-Limited: 220
  - p = 0.02
  - n = 3

- Number of Eggs
  - Control: 2000
  - Food-Limited: 1800
Results: Fecundity

Total difference of 114,440 eggs spawned

2013 Pilot Study: Fatty Acid Analysis

- Omega-3’s important in growth, neural development, and immune system functions
- Omega-3/Omega-6 ratios may have pivotal role in egg and larval quality
Results: Spawning and Clutch Interval

Number of Ripe Females for Control and Food-Limited Groups

- Smaller individuals leads to fewer offspring
- Adult food-limitation may affects larval survival by:
  - Egg and larval quantity and quality
- Impacting population abundances in subsequent year

Potential Implications for Delta Smelt

Photo by Marade Sandford
Moving Forward…. New Questions!

• How does food-limitation impact other life-stages of the delta smelt?
  
  Juveniles?

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<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
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<td>Fall food-limitation</td>
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<td>Spawning</td>
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What is Recruitment?

• The number of fish surviving to maturity to enter the adult population

**Density-Independent**
- Temperature
- Food conditions

**Density-Dependent**
- Competition
- Predation
• Changes in fish populations are primarily driven by variability in recruitment

• Eggs and larvae suffer the greatest losses – most considered natural mortality

Food-Limitation and Population Dynamics

- **Adults**: Smaller adults, fewer individuals spawning, fewer eggs

- **Juvenile**: Higher mortality, smaller fish, decreased recruitment

- **Eggs and Larvae**: Lower quality, reduced survival
Juvenile food-limitation: Impacts on recruitment and population dynamics?

- Small alterations to juvenile growth and survival can have massive repercussions on recruitment and the adult population

Objectives:
Evaluate food-limitation on the old and young cohort of a season in terms of:

1.) Growth
2.) Survival
3.) Subsequent impacts on adult fecundity
4.) Temperature