How does temperature affect fish?

- Egg maturation/hatching
- Growth
- Swimming ability
- Predation vulnerability
Mainstem Colorado River Temperature

N. Voichick, USGS
Egg/larval survival

5 °C - 0 % survival of humpback chub embryos (Marsh 1985)

10 °C - 0 % survival of humpback chub embryos (Marsh 1985)

12 °C - 12 % hatching success and 15% larval survival (Hamman 1982)

16 °C - 62 % hatch success and 91% larval survival (Hamman 1982)

19 °C - 84 % hatch success and 95% larval survival (Hamman 1982)
<table>
<thead>
<tr>
<th>Temperature °C</th>
<th>June 20, 2010</th>
<th>December 2, 2010</th>
<th>Average Growth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Length (mm)</td>
<td>Total Length (mm)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean   Range</td>
<td>Mean   Range</td>
<td></td>
</tr>
<tr>
<td>12.5</td>
<td>50.5   (40 - 65)</td>
<td>52.8   (40 - 68)</td>
<td>2.3</td>
</tr>
<tr>
<td>20</td>
<td>50.5   (40 - 67)</td>
<td>72.3   (55 - 103)</td>
<td>21.8</td>
</tr>
</tbody>
</table>

166 days  
0.4 mm/month in Cold Water  
3.9 mm/month in warm water

D. Ward, Unpublished Provisional Data
Figure 1. Changes in length (TL) over time for early life stages of big river fishes reared at three temperatures. Points represent mean responses of each species; ages are days post hatch at initiation of experiment. Circles denote 10 C, Squares 14 C and Triangles 20 C.

Clarkson and Childs 2000, *Copeia*
Juvenile growth

Figure 1. Humpback chub length with standard error bars
Figure 9. Temperatures in recirculating systems

- **12°C**
- **18°C**
- **24°C**

Gorman and Vanhoosen, 2000
Swimming Ability

Ward et al. 2002, Transactions of the American Fisheries Society
Average decrease in swimming ability at reduced temperatures

Predation Vulnerability

Two control trials (20ºC) and two experimental trials (10ºC)
Comparison of number of attacks versus number of prey consumed

Ward and Bonar 2003, *Southwestern Naturalist*
Table 1. Ability of flannelmouth sucker to escape predation by rainbow trout following an abrupt 10°C temperature change as measured by the number of attacks and number of prey consumed during 10-min predation tests.

<table>
<thead>
<tr>
<th>Temperature ºC</th>
<th>Number of attacks</th>
<th>Number consumed</th>
<th>% Successful attacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>52</td>
<td>3</td>
<td>5.8</td>
</tr>
<tr>
<td>10</td>
<td>23</td>
<td>9</td>
<td>39.1</td>
</tr>
</tbody>
</table>

Ward and Bonar 2003, *Southwestern Naturalist*
Rainbow Trout

Brown Trout

Number of HBC Alive

D. Ward, unpublished provisional data
Increased water temperature

- Growth
- Swimming Ability

Predation vulnerability

How much increase in temperature is enough?