Effects of 2003/2004 GCD Enhanced Fluctuating Flows on the Early Life History Stages of Rainbow Trout in Glen Canyon

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Objectives of Project

I. Estimate extent of mortality of eggs and alevins caused by Jan.-Mar. fluctuations and to predict effects of other flow regimes.

II. Quantify spawning habitat preference (depth, velocity, substrate) to determine how discharge controls spawning elevation.

III. Estimate timing of emergence, growth, and mortality of Young-of-Year (YOY) rainbow trout in their first six months
   - as a monitoring tool to assess impacts from GCD operations through multi-year comparisons under different flow regimes
   - To improve understanding of mechanisms that control growth and survival of fish that are likely most vulnerable to dam operations. This info can in turn help design more effective flow regimes to regulate trout recruitment

IV. Determine the origin of rainbow trout between Lee’s Ferry and the LCR confluence

Part I: Factors That Determine Egg and Alevin Mortality Resulting from Fluctuating Flows

1) Timing of spawning and duration of incubation relative to change in flow regimes determine the fraction of eggs/alevins potentially effected.

2) Hypsometry (elevation of redds) determines the proportion of egg/alevins that will be exposed for different durations.

3) Intergravel temperatures, controlled by the interaction of elevation and discharge, determine the extent of mortality

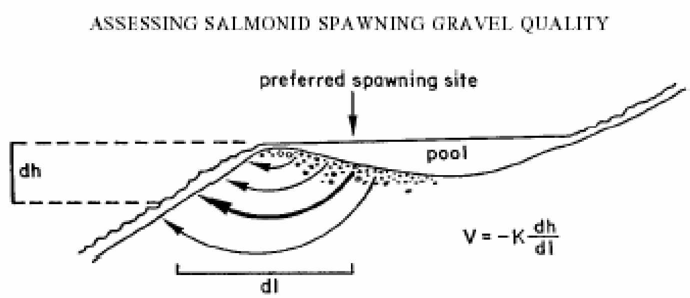
- Field data on each of these components collected in 2003 and 2004. Spreadsheet model integrates results to compute relative mortality.

Egg and Alevin Mortality: Methods

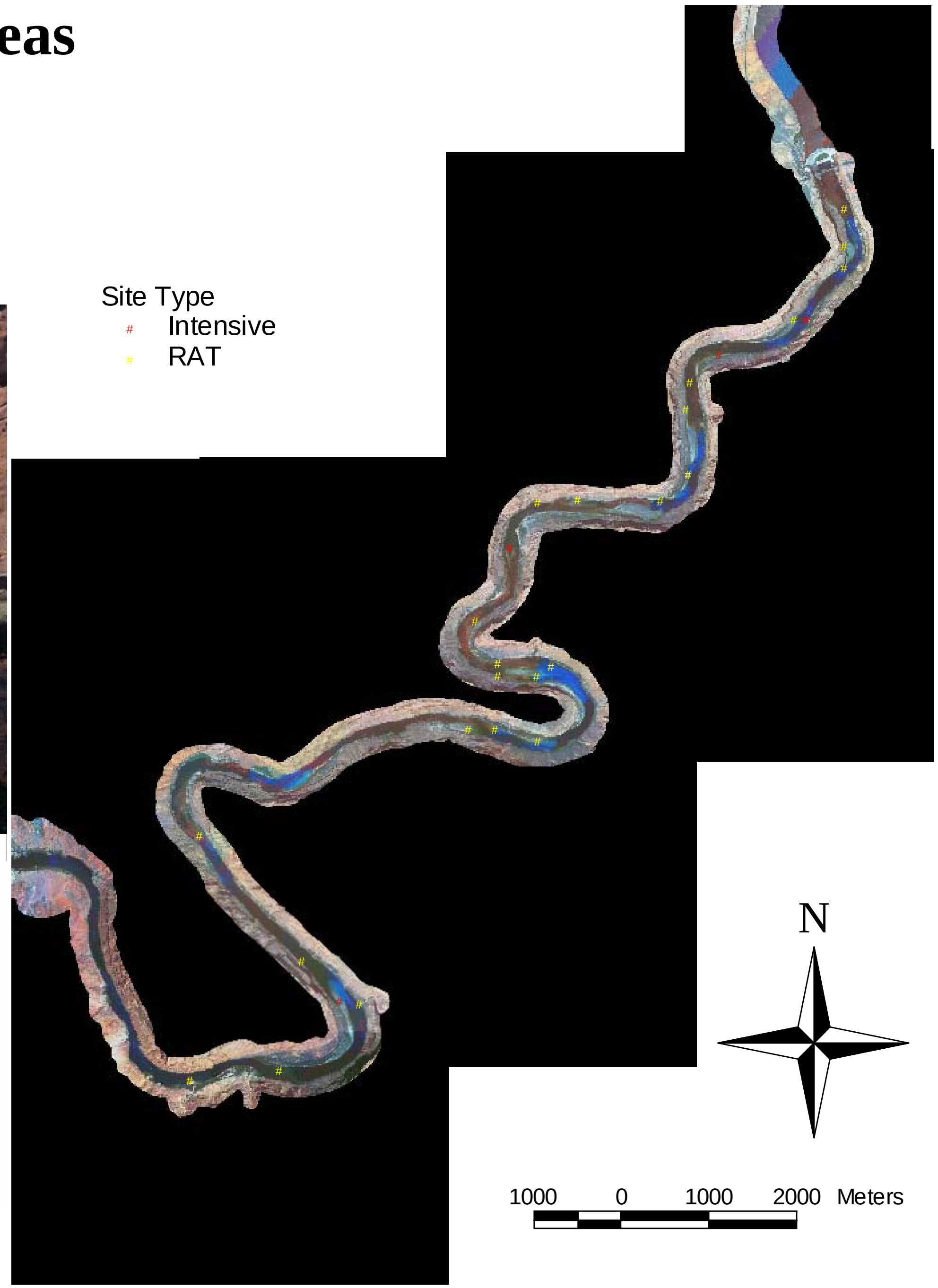
- Redd surveys conducted at intensive sites and system-wide (RAT) to determine magnitude and timing of redd deposition
  - 1 survey/month Feb.-May 2003 (n=4) + lot’s of habitat data (for obj. 2)
  - 2 surveys/month Feb-May 2004 + 1 survey/month Nov.-Jan. & Jul. (n=12)
- Counted redds and determined elevation at:
  - 3 intensive sites (Four Mile, Powerline, and Pumphouse Bars) using total station and site-specific stage-discharge curves to get elevation for each redd.
  - 24 other sites in Glen Canyon using a rod and level for clusters of redds
- Collected habitat information (depth, velocity, grain size) at intensive sites in 2003 to determine spawing habitat preference.
- Measured intergravel temperatures at 4-5 elevations from 5 – 18 kcfs at two intensive sites (Four Mile and Powerline).
- Excavated 125 redds in 2004 to directly evaluate (roughly) effects of timing and elevation on egg mortality.

Location of Spawning Areas

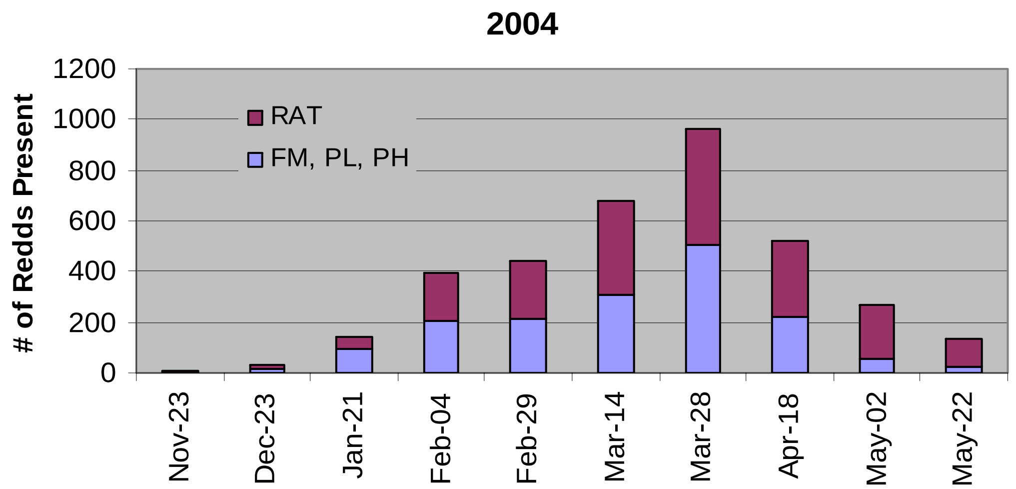
in Glen Canyon

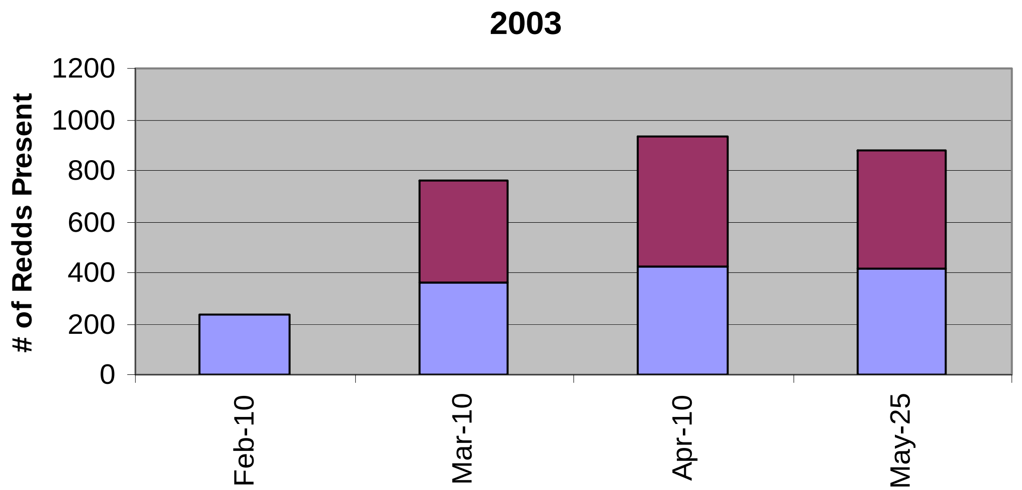


From Kondolf, 2000



Redd Counts


2004
# of Redds Present
1200
1000
800
600
400
200
0
RAT
FM, PL, PH
Nov-23
Dec-23
Jan-21
Feb-04
Feb-29
Mar-14
Mar-28
Apr-18
May-02
May-22

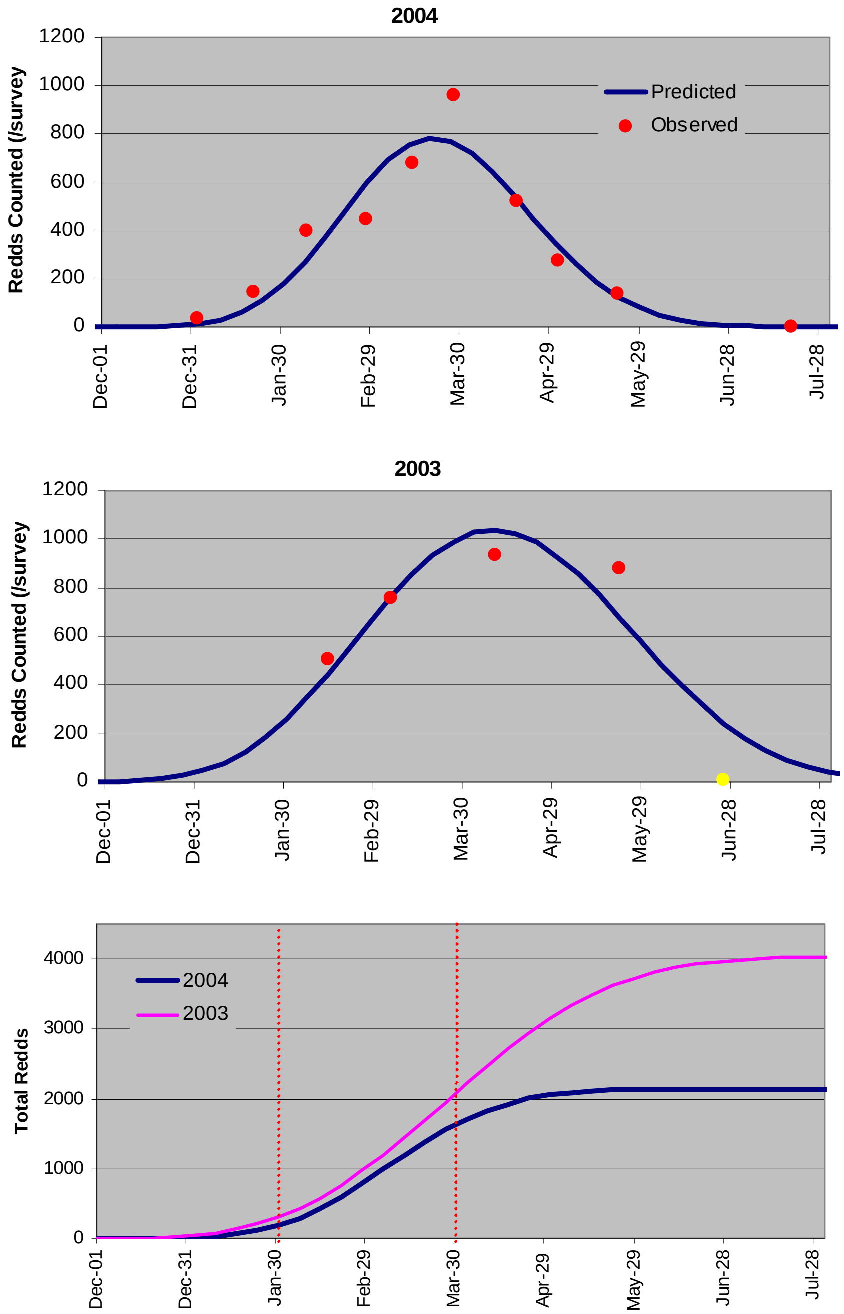

2003
# of Redds Present
1200
1000
800
600
400
200
0
Feb-10
Mar-10
Apr-10
May-25

Total redds for year and timing of excavation estimated from raw counts and survey life

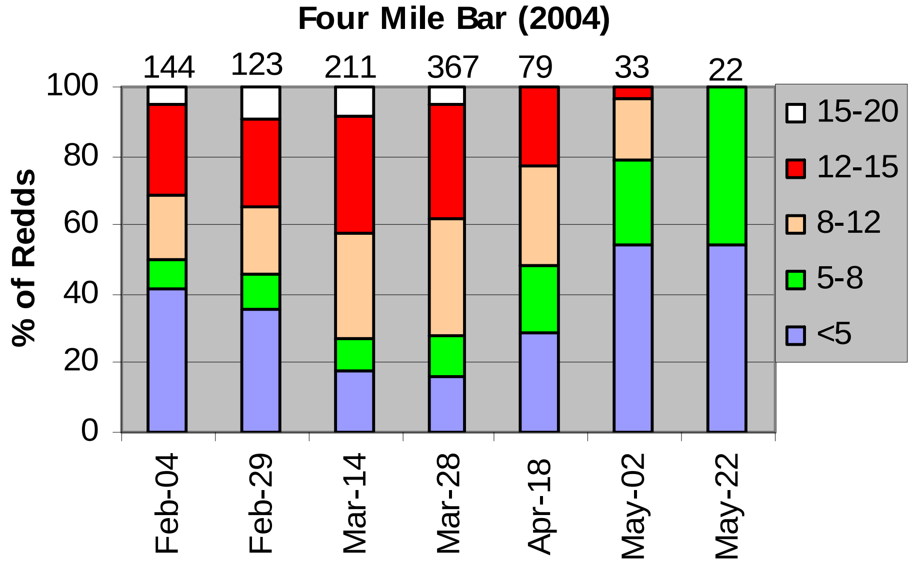
•E=AUC/SL

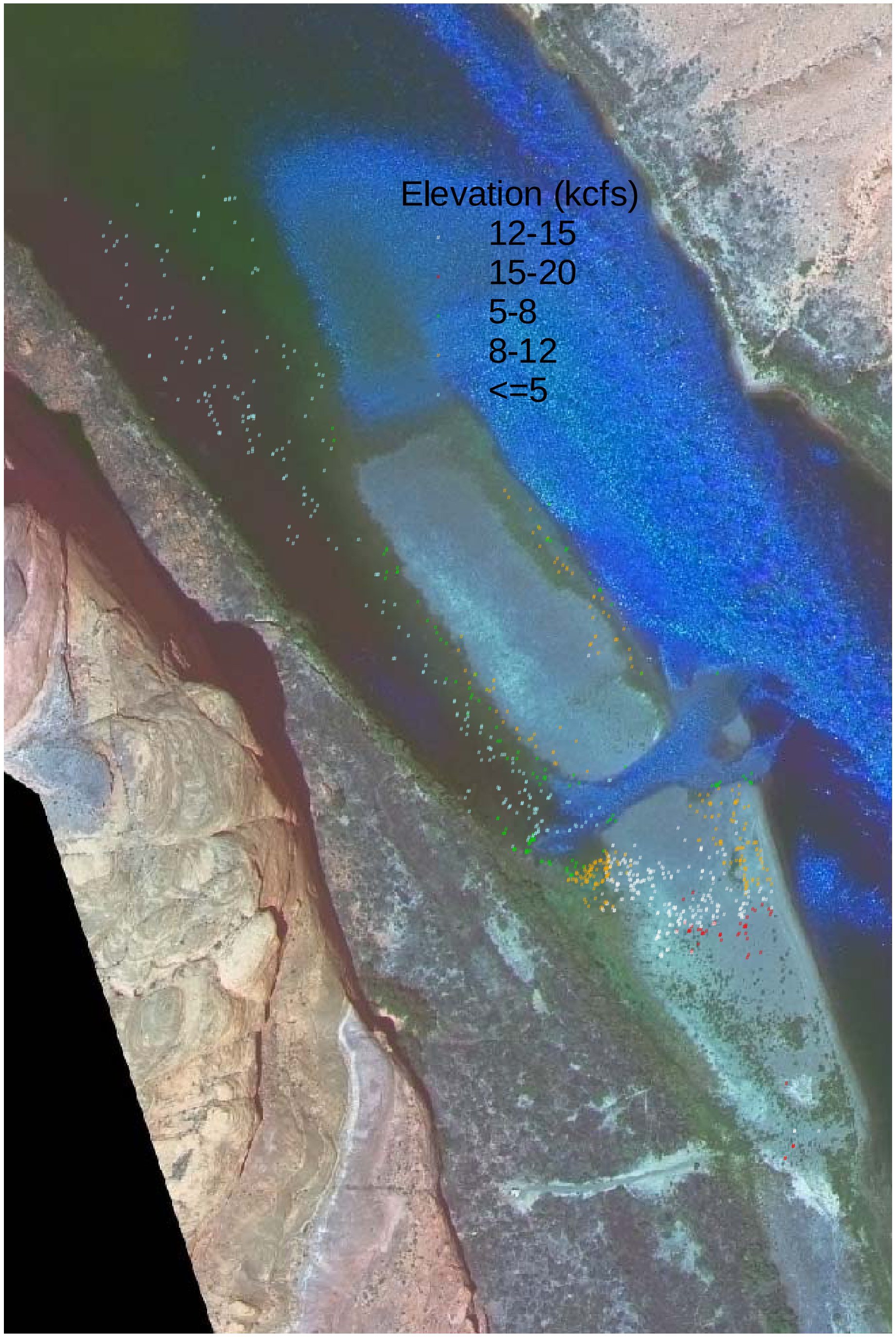
•Estimate survey life (SL) from GIS (= 3.3 – 4.2 wks) at intensive sites

•Estimate total redds (E) and timing of spawning from raw counts

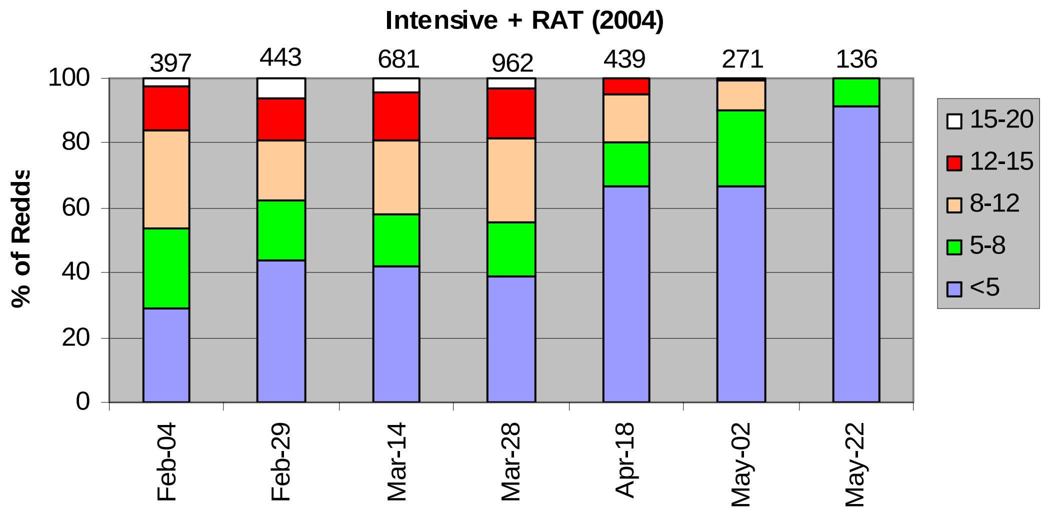


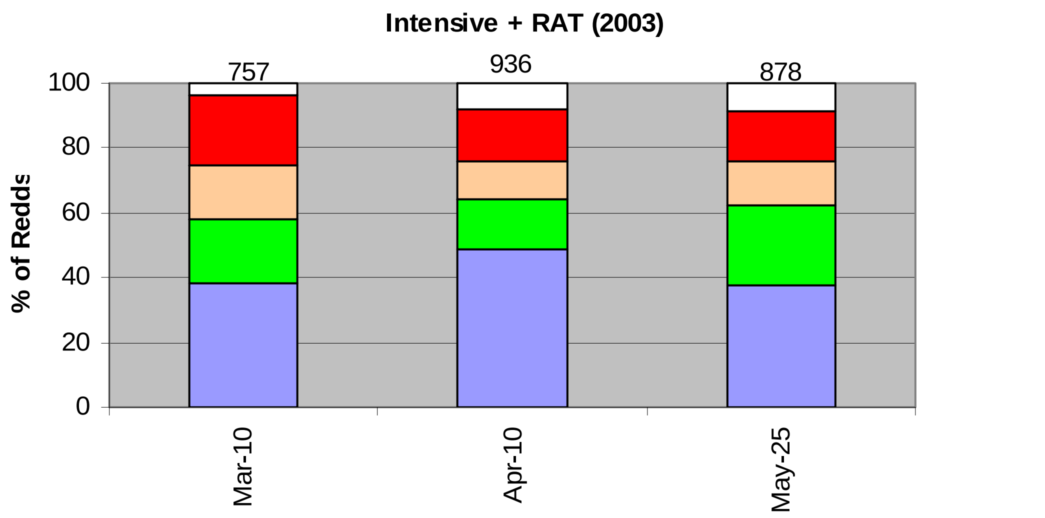
Redd Location and Elevation at Four Mile Bar, 2004



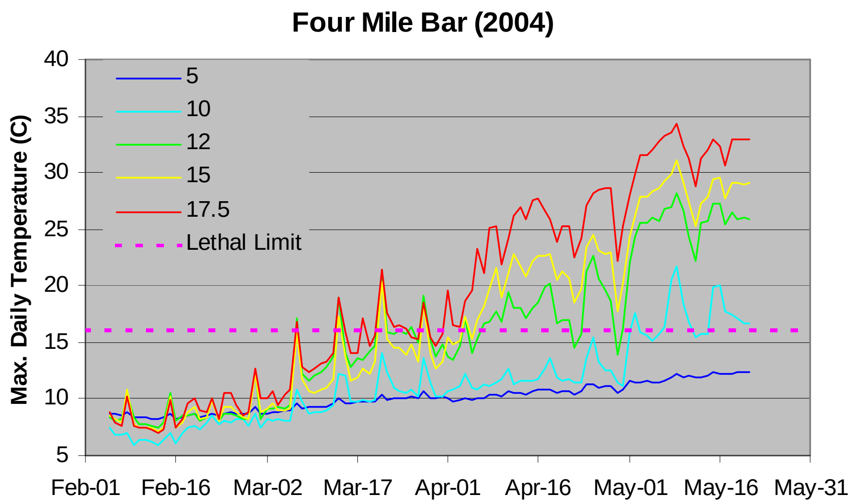


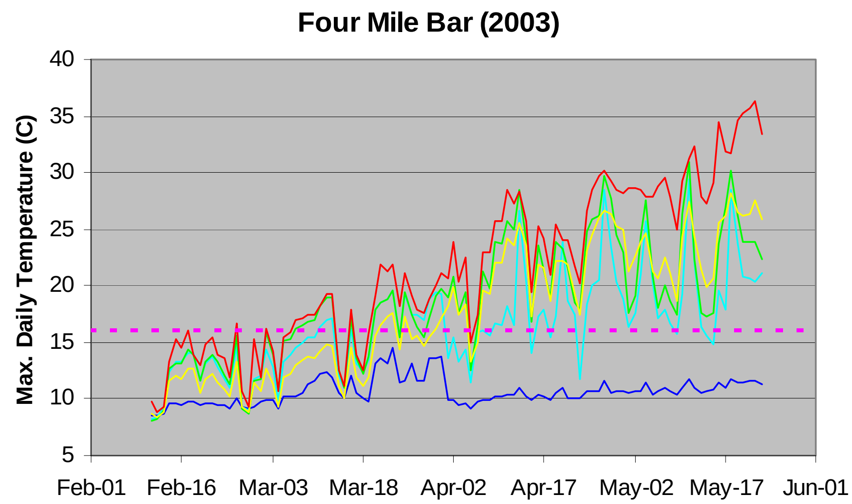
System-Wide Redd Hypsometry

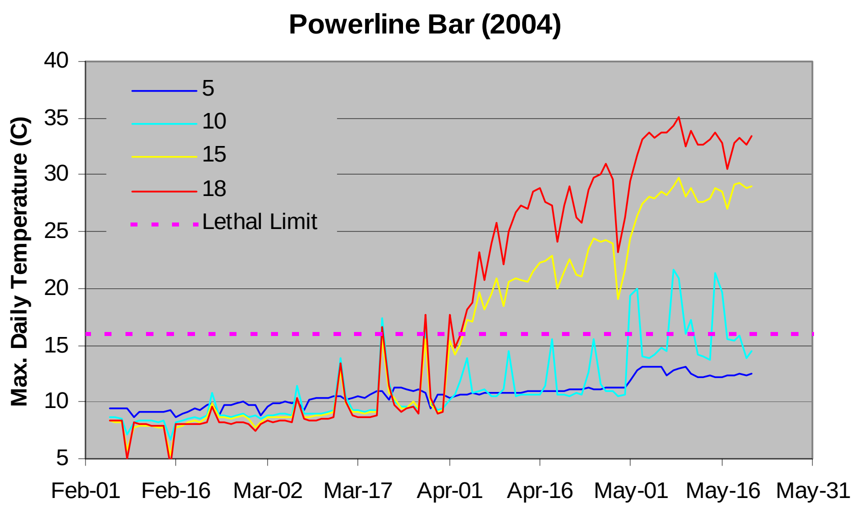


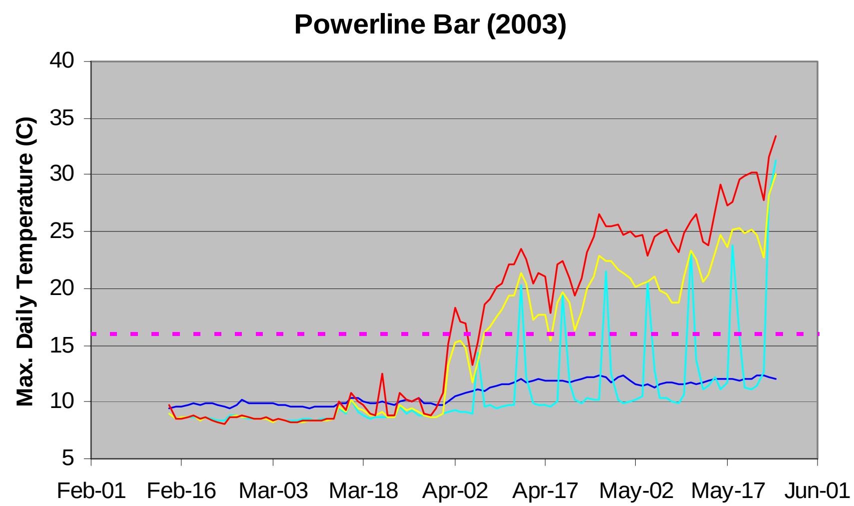


Intergravel Temperature

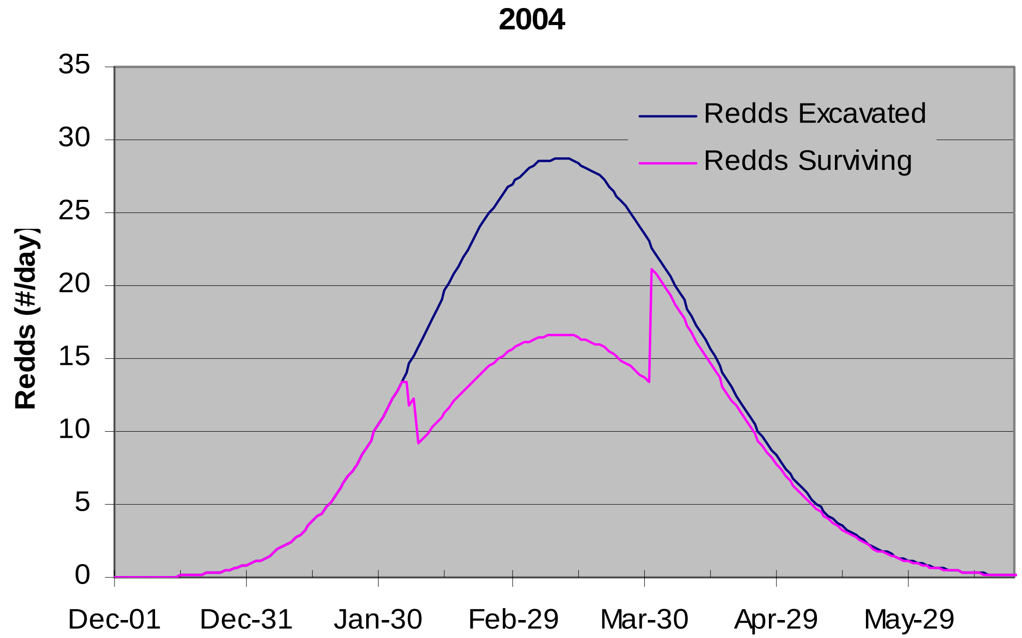


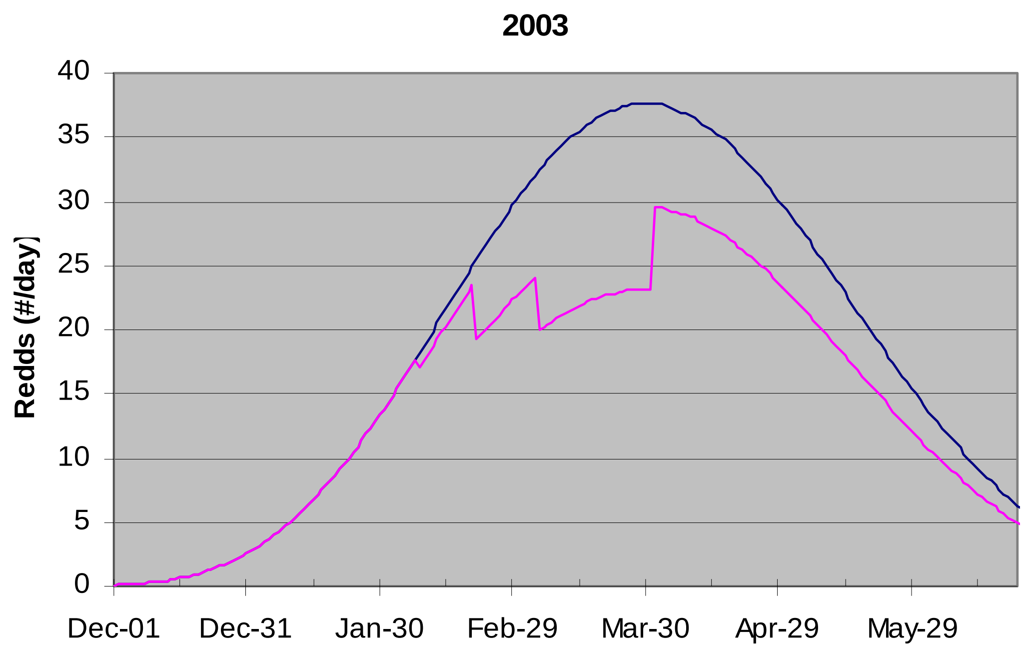






Temporal Dynamics of Mortality





Summary of Egg/Alevin Mortality

	All Stages	< 5 kcfs	5-8 kcfs	8-12 kcfs	12-15 kcfs	15-20 kcfs
2004						
Total	2142	1069	374	401	234	65
% Lost	28	0	0	85	86	87
2003						
Total	4033	1811	1019	716	365	122
% Lost	23	0	0	79	68	82

Direct Estimates of Egg Mortality

	Feb-Mar	Apr-May	Total
Redds Examined			
<8	27	8	35
8-12	46	12	58
12-20	32	0	32
Total	105	20	125
Redds with Eggs (Live or Dead)			
<8	15	5	20
8-12	33	4	37
12-20	23		23
Total	71	9	80
% Redds with Dead Eggs			
<8	13	60	25
8-12	24	100	32
12-20	30		30
Total	24	78	30

Conclusions from Egg/Alevin Mortality Study

- Increased fluctuations during Jan. likely do not cause much mortality as emergence occurs before the onset of lethal temperatures.

- Extending the range of fluctuations through April or May through the spawning period would substantially increase mortality.

- Decreasing the minimum daytime flow to 5 kcfs would substantially increase mortality by eliminating production from the 5-8 kcfs range.

- Ultimate test of model will be to compare seasonal pattern in surviving redd numbers with those inferred from back-calculated hatch dates derived from fry sampling. Ideally this comparison would be done in both ROD- and enhanced fluctuation-years.

Part III: YoY Emergence Timing, Habitat Use, Growth, and Survival

- Knowing emergence timing defines the window for flows targeted at reducing YoY survival. In conjunction with redd counts can be used to evaluate effects of flows on egg/alevin survival.

- Understanding ontogenetic habitat shifts from low angle shorelines to steeper habitats also useful for defining window of vulnerability.

- The effect of temperature and GCD operations on YoY growth may be an important component that determines year-class strength.

- Documenting changes in the survival rate of YoY in first six months, when they are likely most sensitive to habitat changes would be a high-resolution monitoring tool to assess impacts of GCD operations.

Methods for YoY Study

- Monthly catch-per-effort sampling by backpack and boat electrofishing in fry habitat at daily minimum flow (23:00 – 7:00).
  - 2003 (Jun-Oct): 20 low angle backpack sites (LF only)
  - 2004 (Apr-Oct): 20 low angle backpack sites (LF)
    20 steep talus shoreline boat sites (LF)
    80 sites from LF to LCR in Apr., Jun., and Aug.

- Age a subset of fish from otoliths to develop length-age key and accurately estimate time of hatch and emergence. (n = 237 in 2003, 2004 pending)

- Translate length-frequency of catch (by month) into age-frequency.

- Use model to compute in-season estimates of apparent mortality and recruitment.

- Examine relationships between operations and mortality and growth patterns.

Habitat Types


Talus – Steep

40% of Glen Canyon

30% of Marble Canyon

Sample by boat


Debris Fans, Cobble and Sand Bars – Low

50% of Glen Canyon

50% of Marble Canyon

Sample by backpack in Glen

And boat/backpack in Marble

2004 Length Frequency

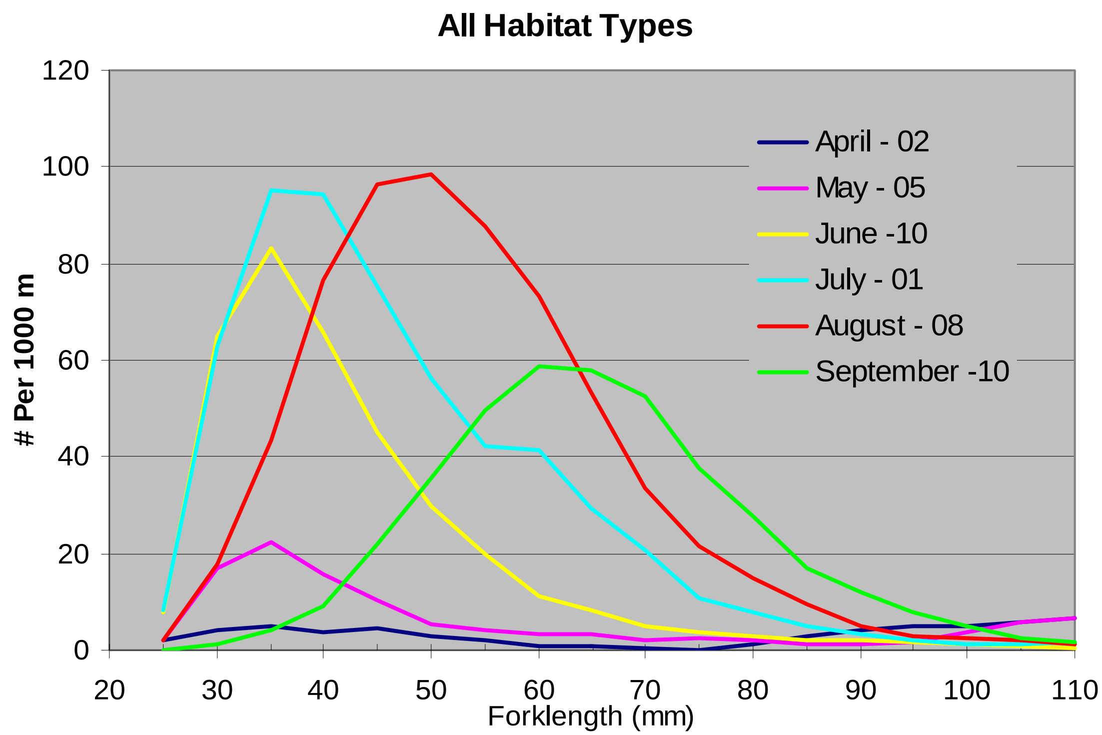
Factors Determining Changes in Length-Frequency Over Time

Recruitment (emergence)

Size-dependent Vulnerability

Survival

Growth



N = 4,300

2004 Length-Frequency in Glen Canyon

Factors Determining Changes in Length-Frequency Over Time

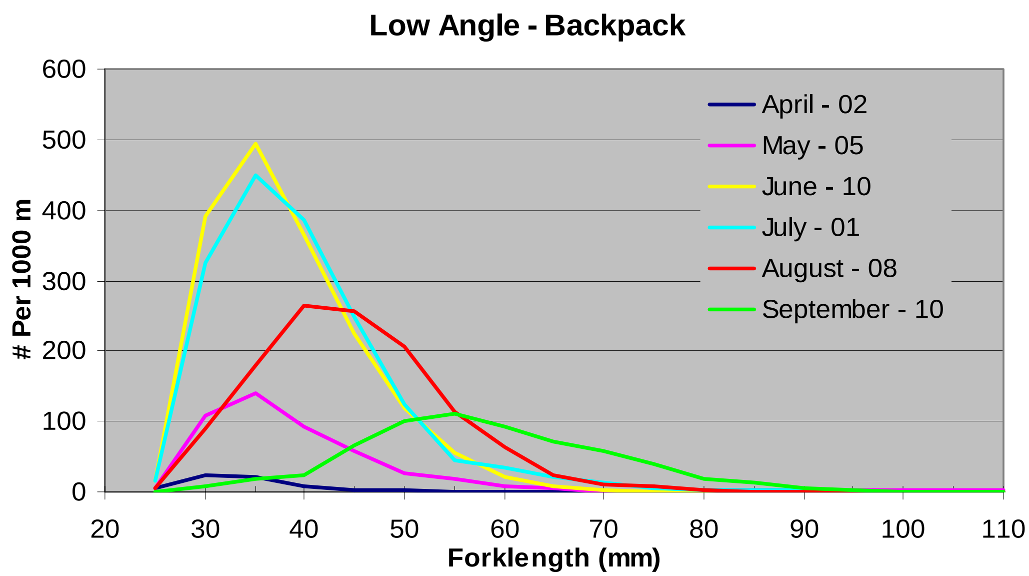
Recruitment (emergence)

Size-dependent Vulnerability

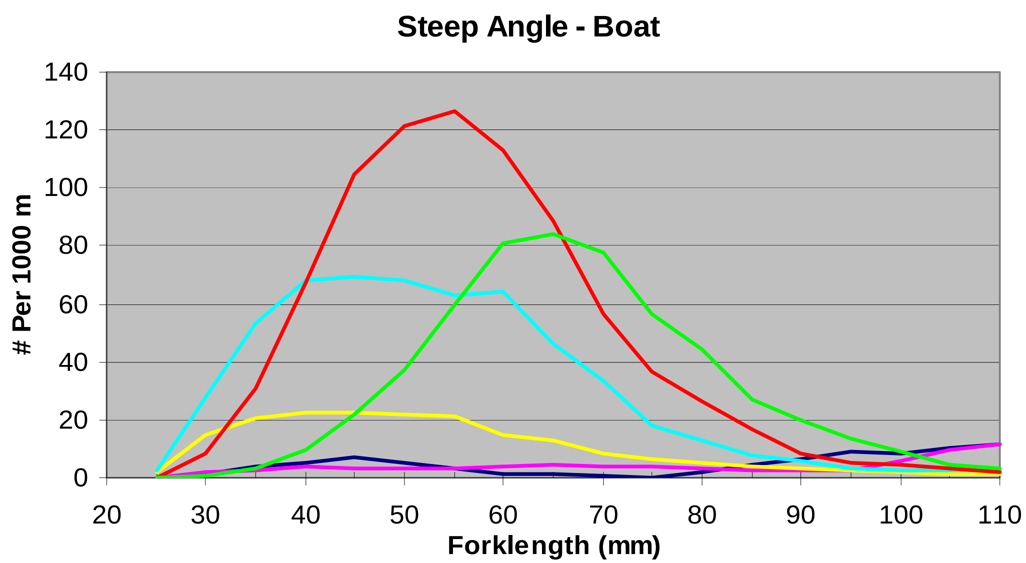
Survival

Growth

Migration

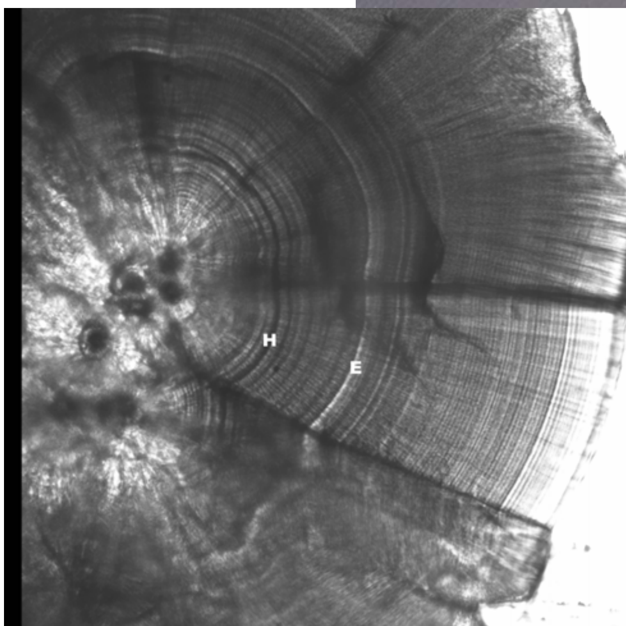


N = 1,476

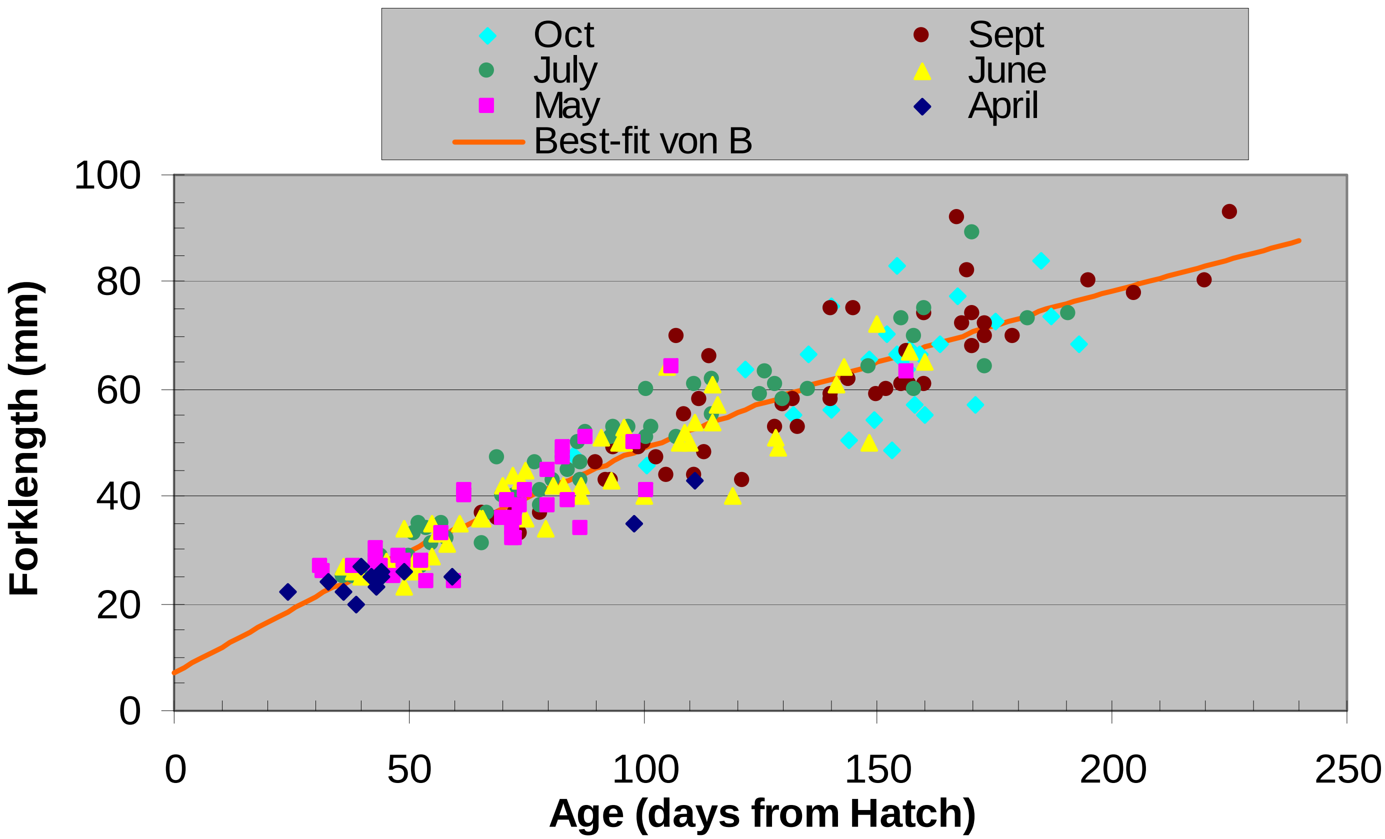


N = 2,845

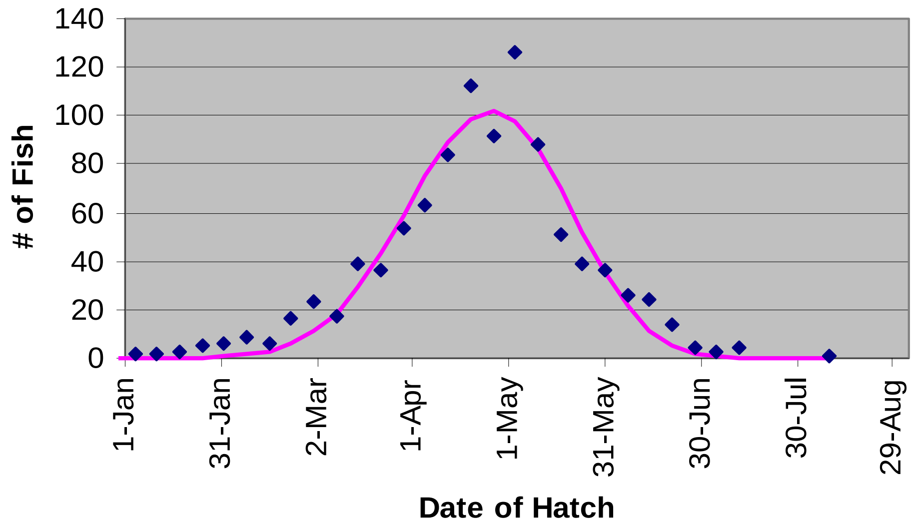
Otolith Microstructure

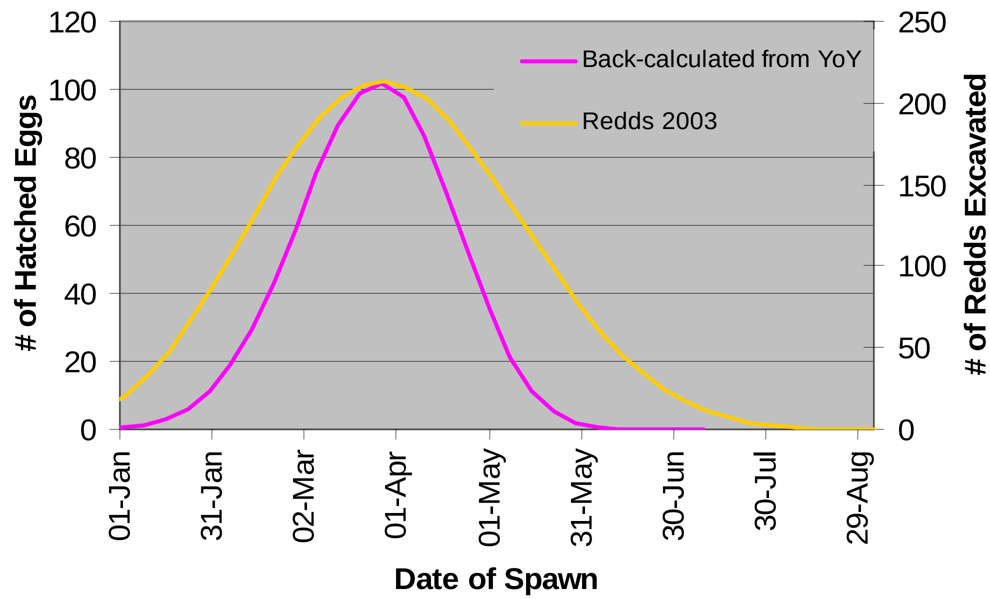


Size-at-Age for YoY's in Glen Canyon 2003



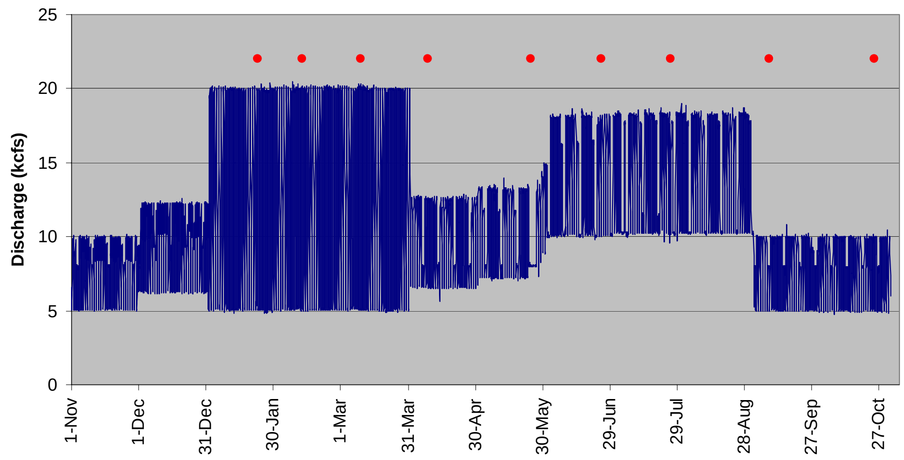
Back-calculated Timing of Hatch 2003



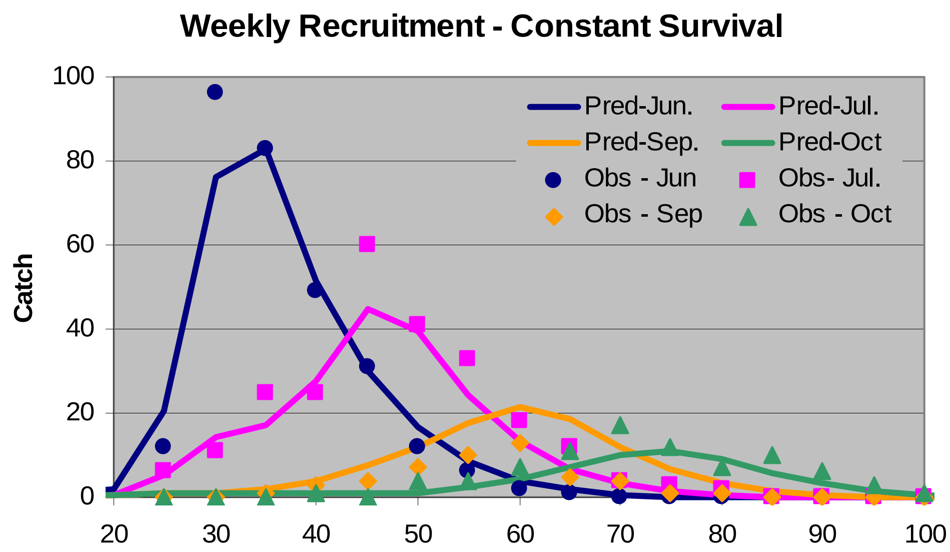


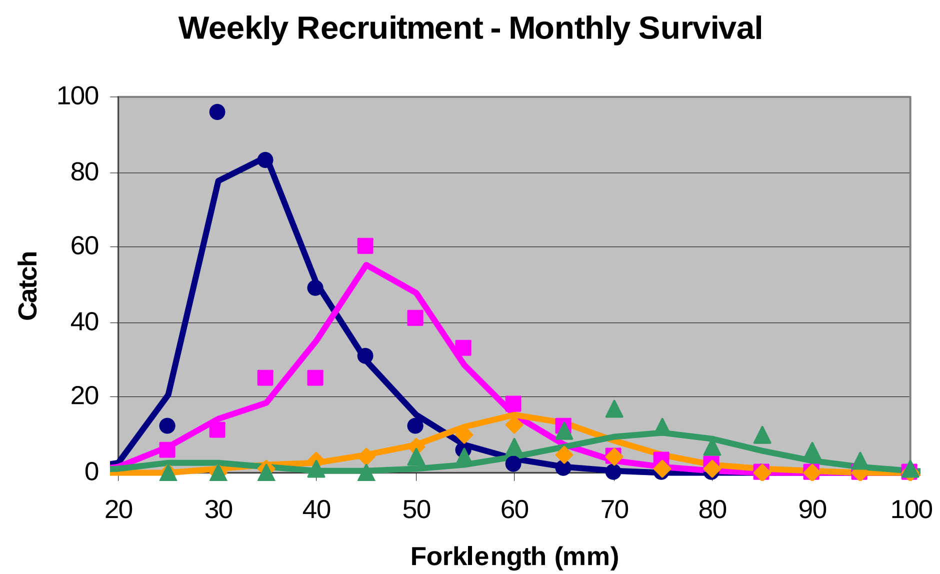
What Happened to YoY in Early September?

Flow-change induced movement
out of low angle habitats

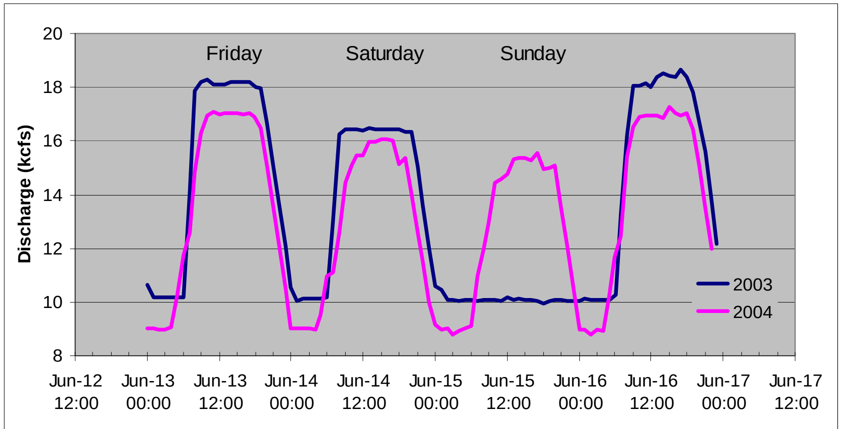


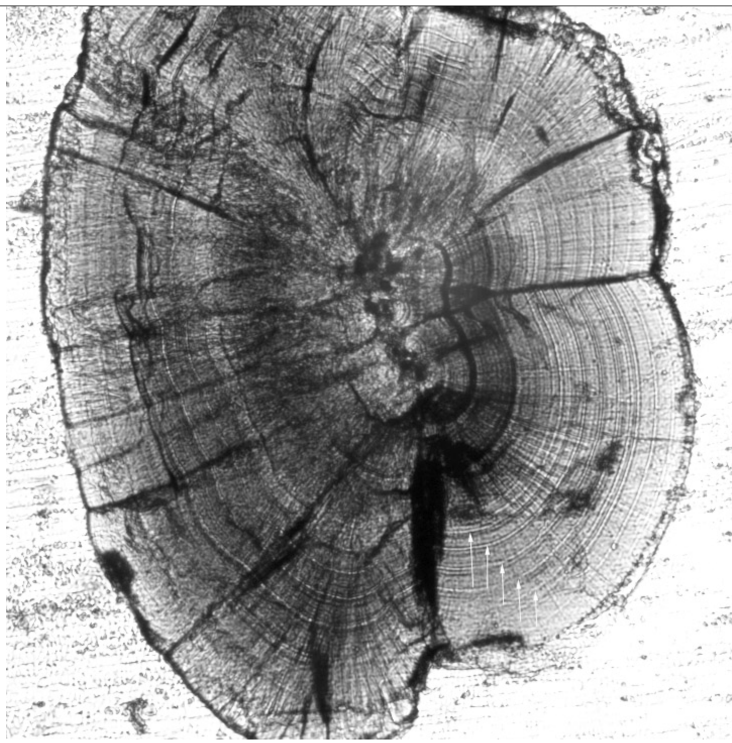
Flow-change induced mortality
in low angle habitats

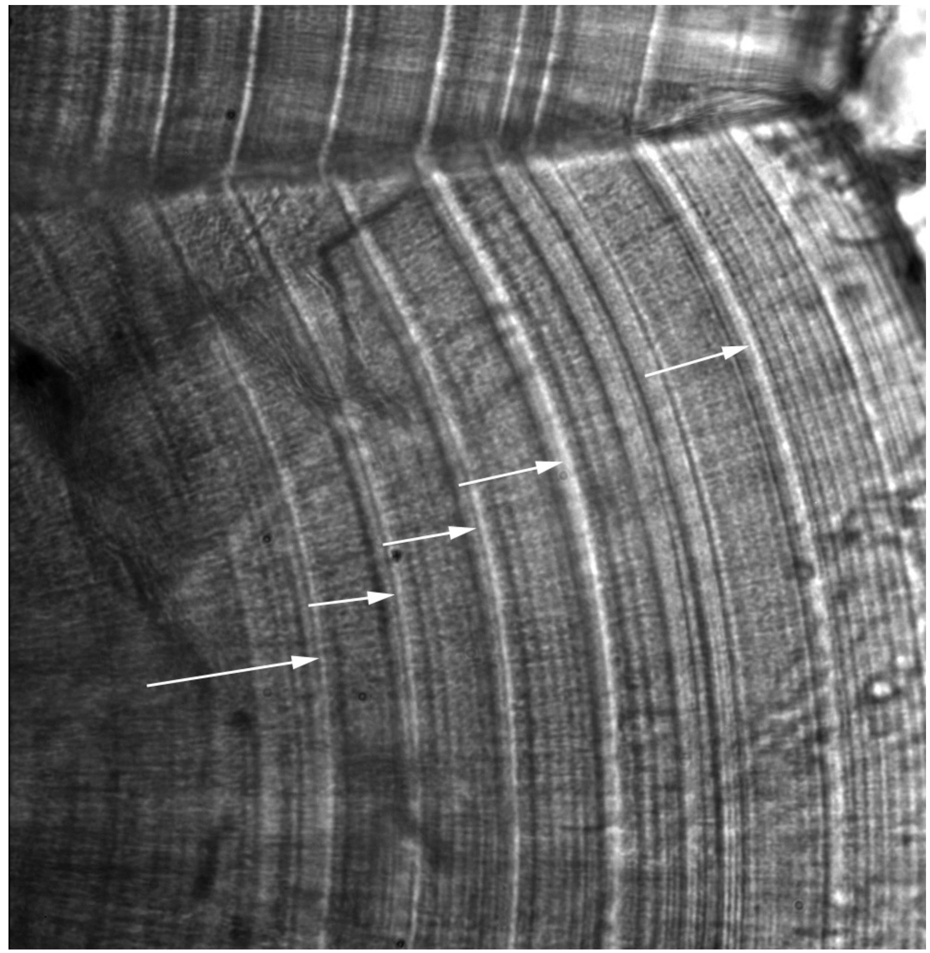




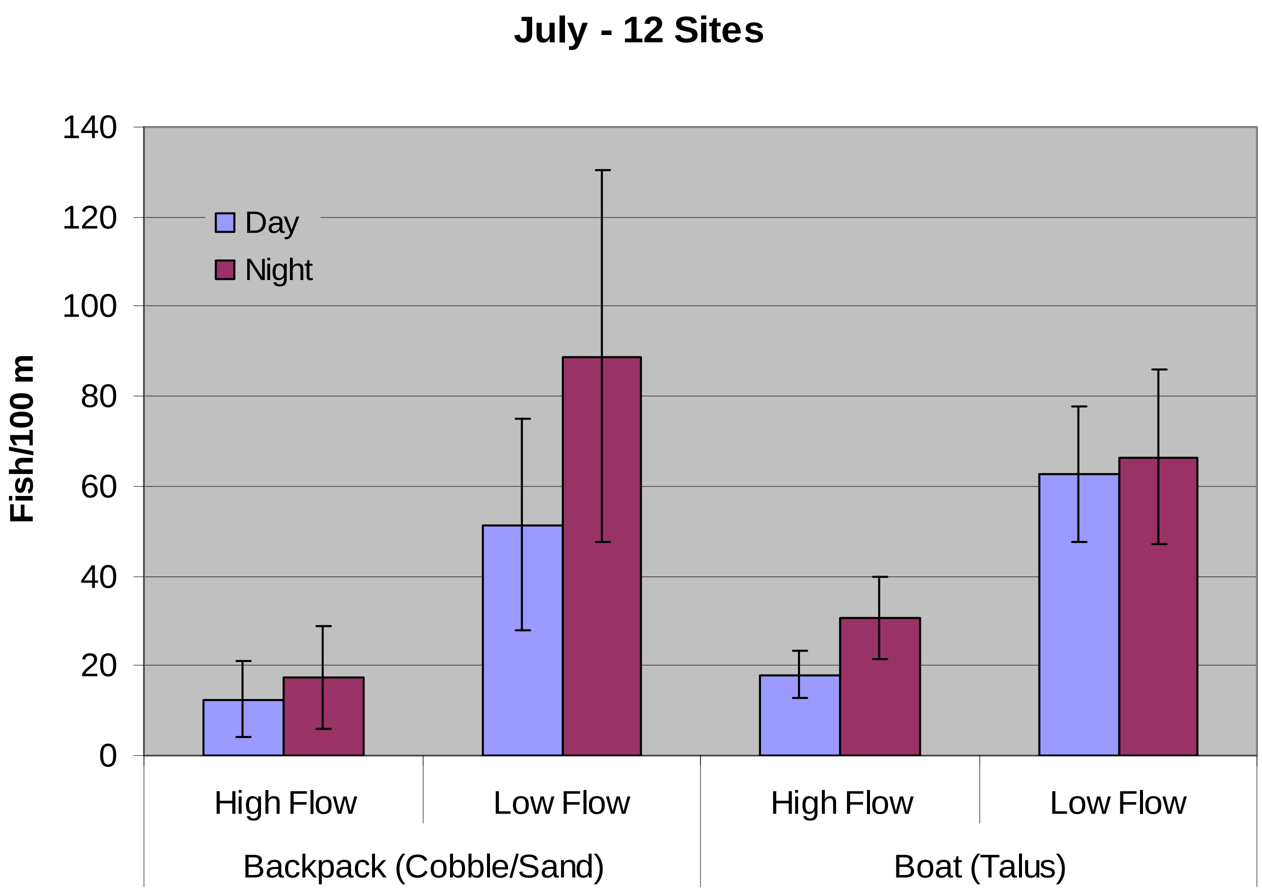
And ~~the Lord~~ Clayton Said:
“Let them Grow on $unday”







Evidence that YoY do not follow the waters edge with flow increases during the day



Evidence That Suggests ‘Stranding’ Flows Could be Used to Regulated YoY Recruitment in Glen Canyon

- Much literature on stranding:
  - Stranding rates highest for very young/small fish and in low angle complex habitats (Halleraker et al. 2003).
  - Stranding rates highest following a long habituation period to one flow regime (Halleraker et al. 2003).
  - Stranding difficult to observe directly in field (Slatveit et al. 2003).

- Daily fluctuations are likely reducing YoY growth but not daily stranding events.
  - Observed large decrease in catch rates during and after memorial day weekend.
  - 4-fold higher densities at low flow than at high flow (2004 study).
  - Literature
    - Juvenile trout do not fully compensate for increased water flow by changing microposition (Vehenan et al. 2003).
    - After initial velocity increases fish move closer to the streambed, and then, if necessary by moving latteraly (Shirvell 1994).
  - Increased growth on Sundays seen in otoliths when flows are near minimum elevation where YoY’s are holding (however this could be a temperature effect)

- Decreased density of fish in low angle habitats following Sept. change in minimum flow
  - Could have been a stranding-induced mortality or a temporary movement from low angle to steep habitats

Advantages of Stranding Flows

- High steady flow for 2 days followed by sudden decrease in flow to 5 kcfs for 1 day. Before and after monitoring to measure effect.

- One or two events in June and/or July when small YoY are most abundant.

- Six Reasons to Try It Experimentally
  1) Reduce recruitment while minimizing impacts of food base, thereby supporting adult growth and improving fishery.
  2) If rainbow in Marble Canyon are coming from Glen Canyon, making Glen as attractive as possible (low density with lots of food) may minimize emigration.
  3) Smaller fluctuations will reduce downstream sand transport. We may be mining a precious resource when we don’t have to.
  4) Potential impacts of fluctuating flows on native fish are reduced.
  5) Stranding flow would be very easy and reasonably inexpensive to evaluate.

- Conclusions depend in part on results from catch-at-age analysis on 2004 YoY data to determine the extent of mortality from Sept. event.

Part IV: Origin of Rainbow Trout below Lee's Ferry

1) Is there suitable spawning habitat in the mainstem?

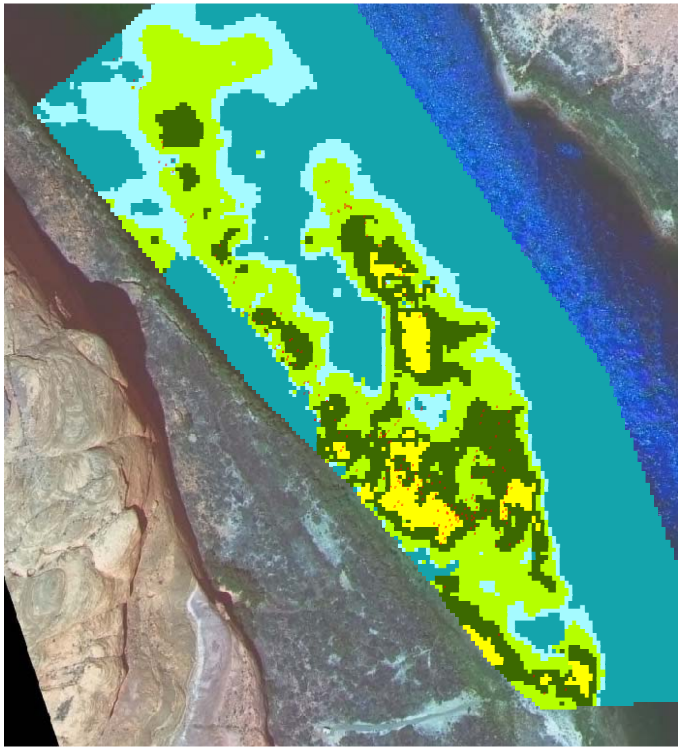
2) Is there direct evidence of spawning in the mainstem?

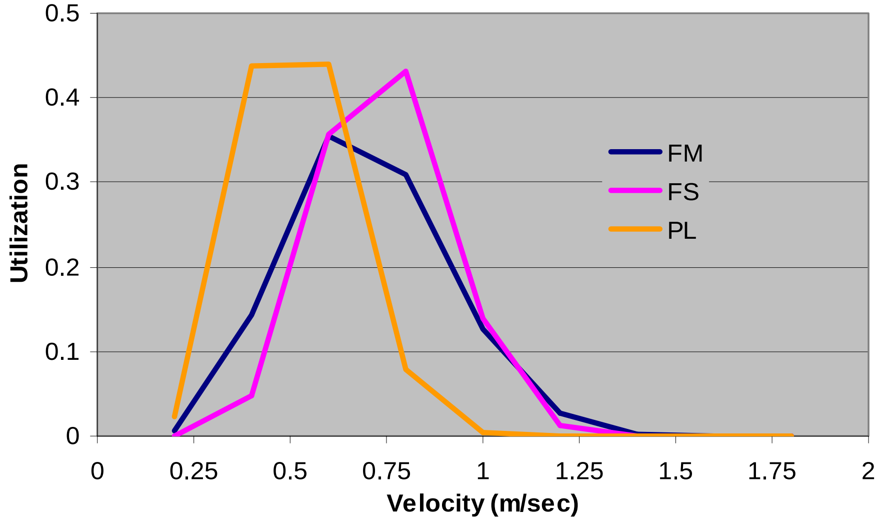
3) Are there Young-of-Year downstream of Lee's Ferry?

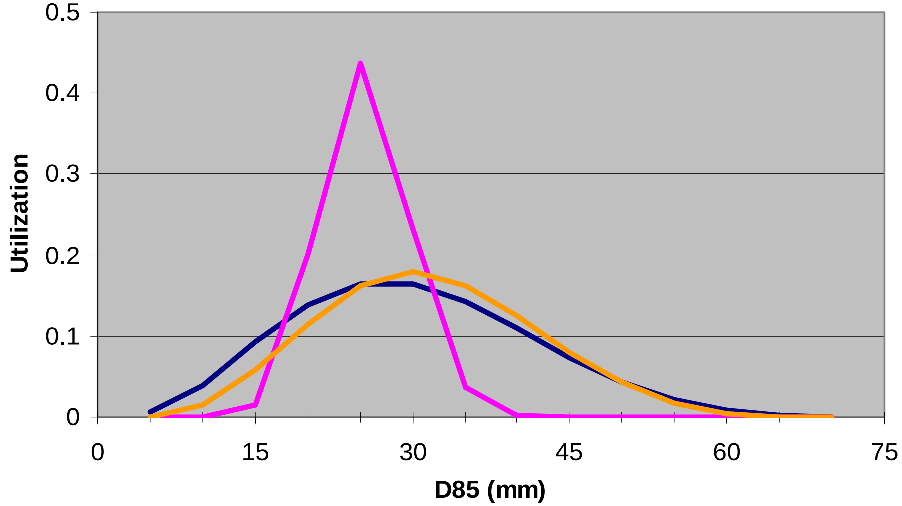
4) Is there suitable spawning habitat or direct evidence of spawning in tributaries downstream of Lee's Ferry?

1) Is there suitable spawning habitat in the mainstem?

Site	Area ('000 m2)	Grain Size	D/V
FM	28	196	460
FS	17	136	177
PL	11	64	257
PH	<1	22	66



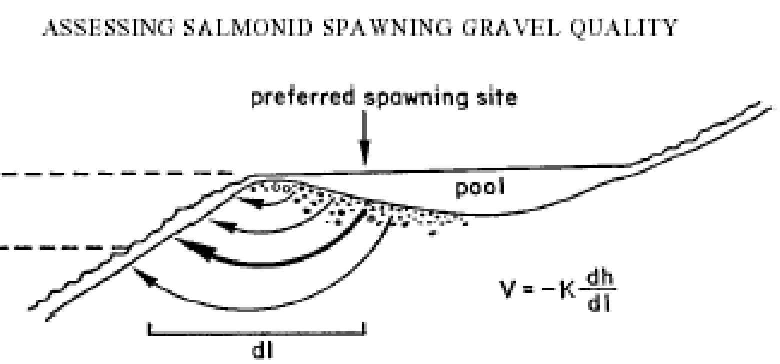





N 36 51.121
W111 36.417
Hdg: 235.3
Speed: 0.0
18:46:36
06-11-04

1) Is there suitable habitat in the mainstem (con't)

- Very small pockets of suitable gravel above 8 kcfs.
- Small amounts of suitable spawning substrate below 8 kcfs except at:
  - 1.6*, 5.5, 37.6, 49.1, Little Nankoweep Ck., 53.1 (lower Nankoweep Camp), 54.0*, 55.3*
- A good proportion of the suitable gravel we did find was 3-10 meters deep and often below riffle/rapid where energy was high enough to scour sand, but not too high to scour gravel.



2) Is there direct evidence of RBT spawning in the mainstem?

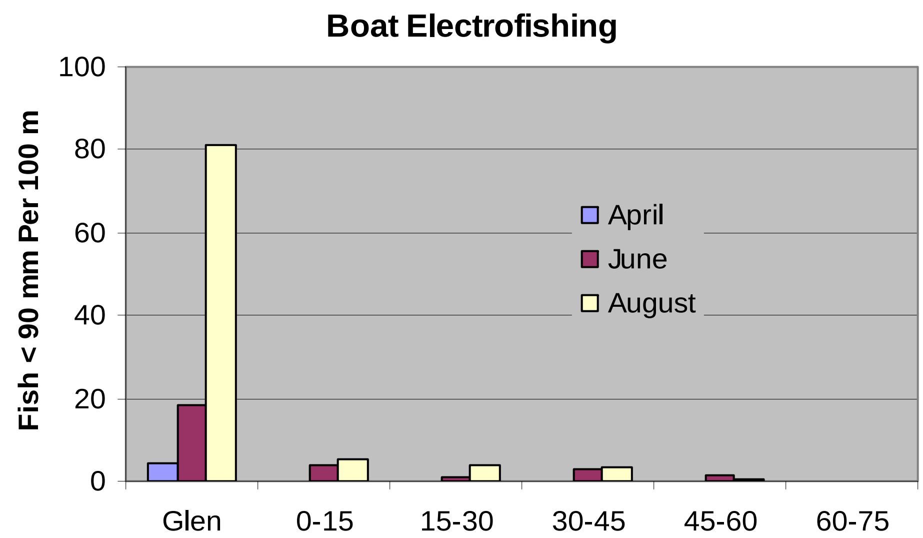
- Coggins et al. found ripe fish during MR in winter but Coggins and Kaplinski saw no redds above minimum flow elevations (5 kcfs) based on limited survey in spring.
  - They did not survey below minimum flow elevation

- April ’04 trip found no redds above the minimum flow elevation (8 kcfs).
  - Turbidity was too high to look for redds below minimum flow.

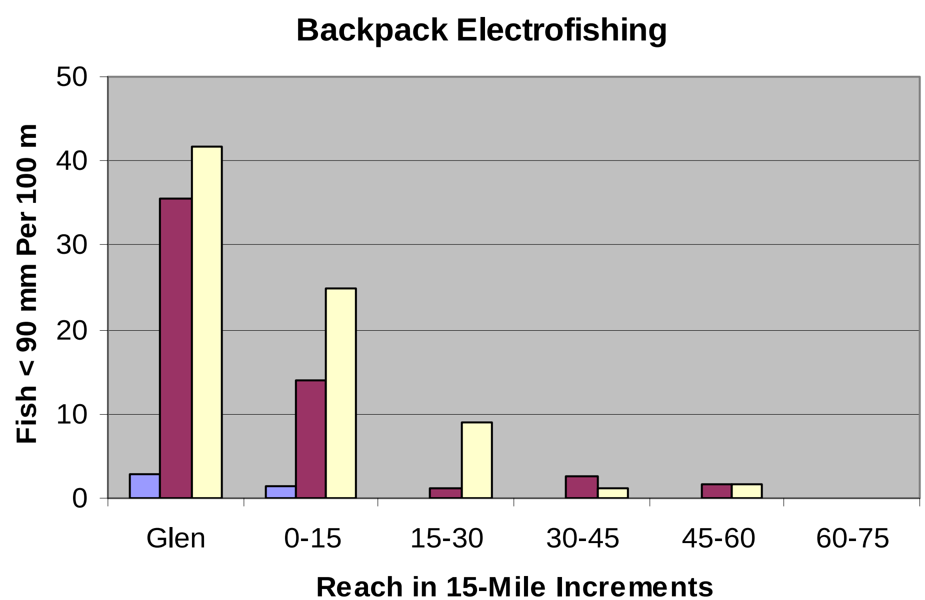
- June ’04 trip had good water clarity but no redds observed.
  - Could have been too late in season.

- Surveys were conducted following 9 mechanical removal trips in 1.5 yrs. It is possible that the majority of spawners were removed below Kwagunt Rapid.
  - However, removal would not have effected fish densities in the vicinity of Nankoweep Ck. where suitable spawning habitat is present.

3) Did we find Young-of-Year downstream of Lee's Ferry?



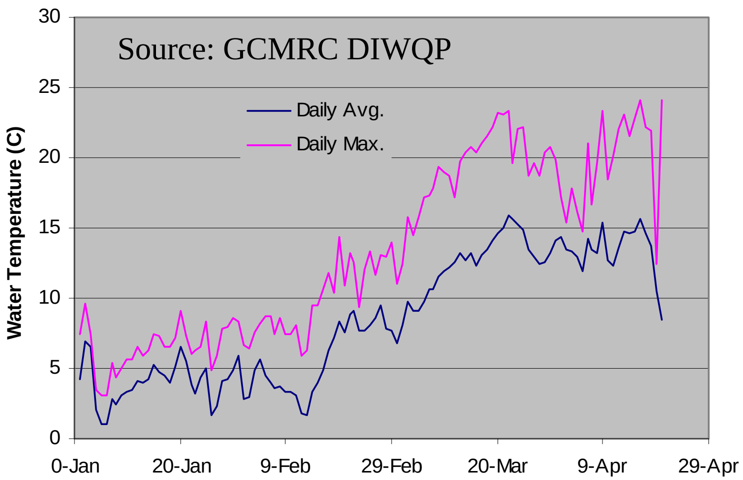
Yes, but very few.



Spatial and seasonal patterns in YoY abundance suggest that the majority of them probably came from Glen Canyon.

4) Is there suitable spawning habitat or direct evidence of spawning in <u>tributaries</u> downstream of Lee's Ferry?

- In it's April '04 condition, Nankoweep Ck. could support a few thousand spawners.
  - Gravel quality is excellent and temperature is suitable in winter.
  - Emergence would need to occur by mid-March, thus spawning throughout most of January would likely be successful.
- Saw a few pairs of fish spawning, but temperatures by April were already too high.
- No YoY captured but they might have entered mainstem shortly after emergence in March (but almost no mainstem YoY were found).



Conclusions on Origin of Rainbow Trout below Lee's Ferry

All evidence suggests that there was very little rainbow trout reproduction below Lee's Ferry in 2004. Why?

1) Mechanical removal removed all the spawners. Unlikely, many adult fish above and within control reach.

2) Spawning habitat in mainstem and tributaries to ephemeral. Nankoweep is suitable as are small areas in mainstem, but they may not have been consistently available across years, which may be a requirement for spawners to key-in on those locations.

3) Current condition of fish in Grand Canyon is too poor to support maturation due to lower food supply relative to Glen Canyon. When densities were lower growth in Grand Canyon may have been sufficient.

Monitoring Options

A. Consistent and relatively long-duration treatments coupled with monitoring adult abundance, size, and condition.

- Measuring what you care about
- Time delays between treatment and response
- Linkage to dam operations may be weak (depends on expt. Design)

B. Enhance A) with monitoring of growth and mortality for life stages that are most sensitive to dam operations.

- Short response time
- Strong linkage to dam operations
- Does not require as rigorous an experimental design