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

Josh Korman, Matt Kaplinski

Joe Hazel, Ted Melis

GCMRC

Lew Coggins

Barbara Ralston

Carol Fritzinger

Funded from FY03/04 GCDAMP Experimental Flow Program

Objectives of Project

I. Estimate magnitude of incubation mortality (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. Evaluate factors that determine recruitment of juvenile rainbow trout (emergence timing, growth, habitat shifts, and mortality) and their linkage to GCD operations
   - Useful in the design flow regimes targeted at regulating trout recruitment
   - As a monitoring tool to assess impacts from GCD operations through multi- or within-year comparisons of different flow regimes

IV. Evaluate the extent of successful reproduction by rainbow trout between Lee's Ferry to the LCR confluence
   - Need to quantify the sources of reproduction (Glen mainstem vs. Marble mainstem vs. Marble tributary) if we are trying to regulate it

3 Good Reasons to Focus Effort in Glen Canyon

1. Need to understand the linkage between GCD flow and trout recruitment in Glen Canyon as it will effect fishery.

2. Logistically, Glen Canyon is a much more efficient environment to work in. Understanding from Glen can be transferred downstream.

3. If emigration of trout from Glen Canyon is supporting population in Marble Canyon, recruitment in Glen will have direct consequences on population in Marble.

Conceptual Model of Incubation Mortality

Timing of spawning

Morphology

Homing behavior

GCD flow regime

Redd Elevations

Intergravel water temperature

Air temperature

Water Temperature

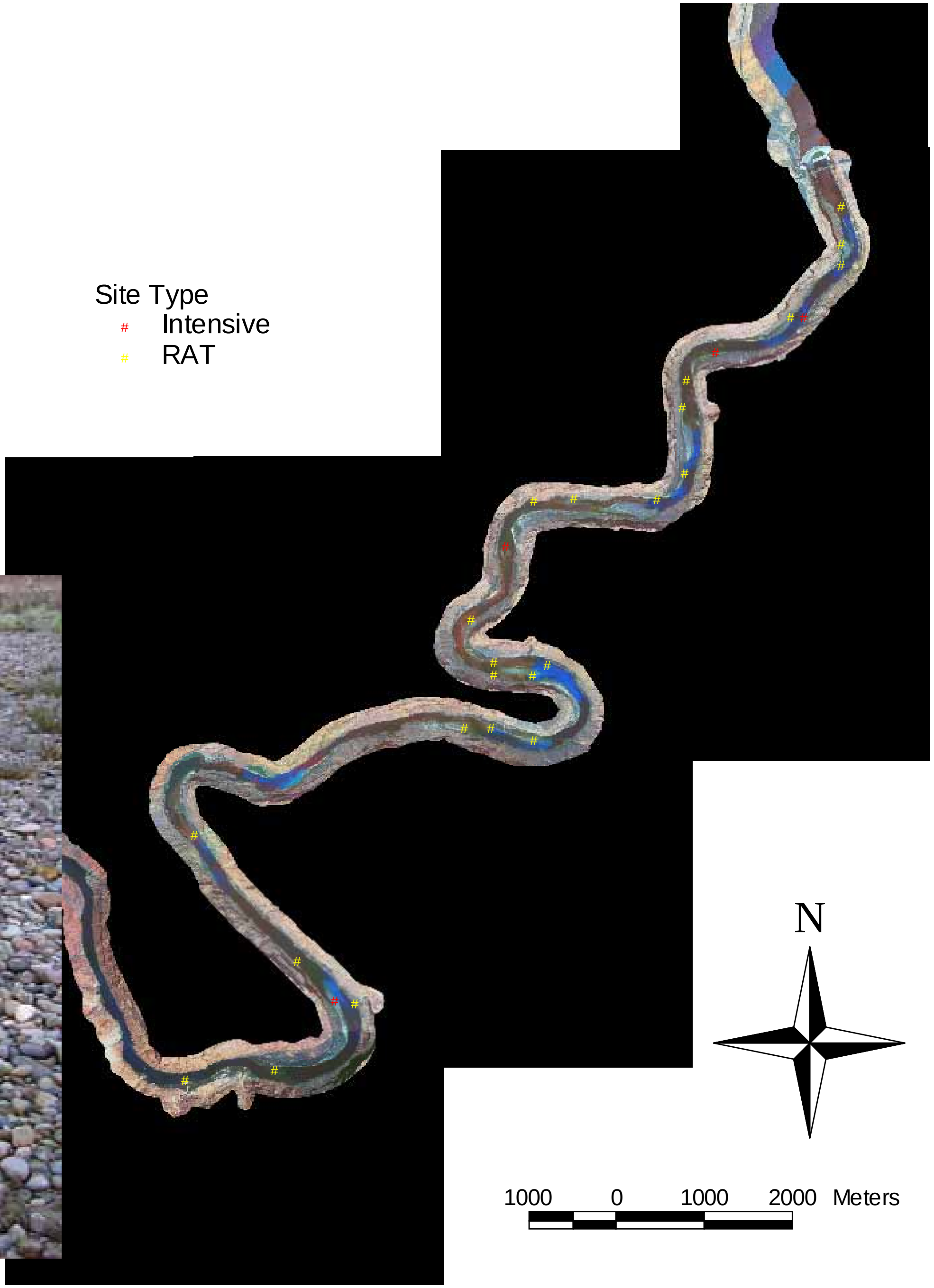
Aspect

River mile

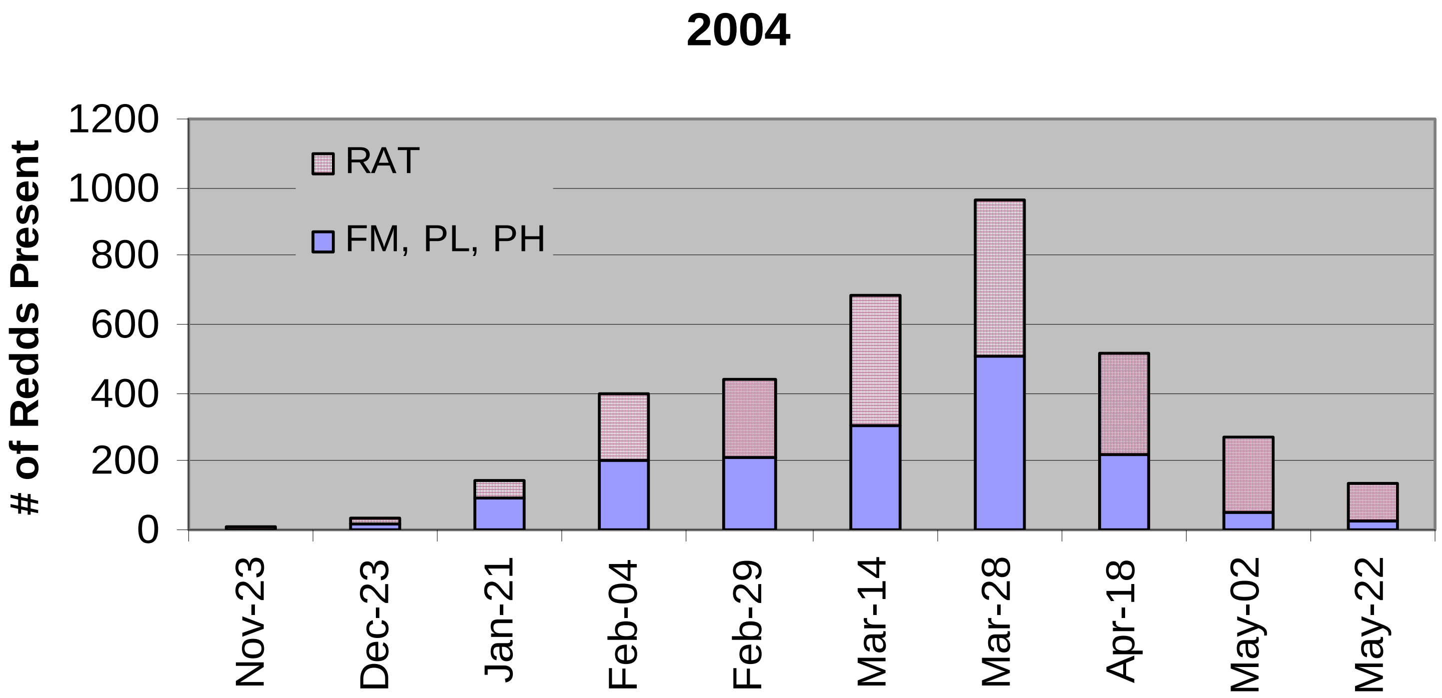
Sand content

Incubation Mortality

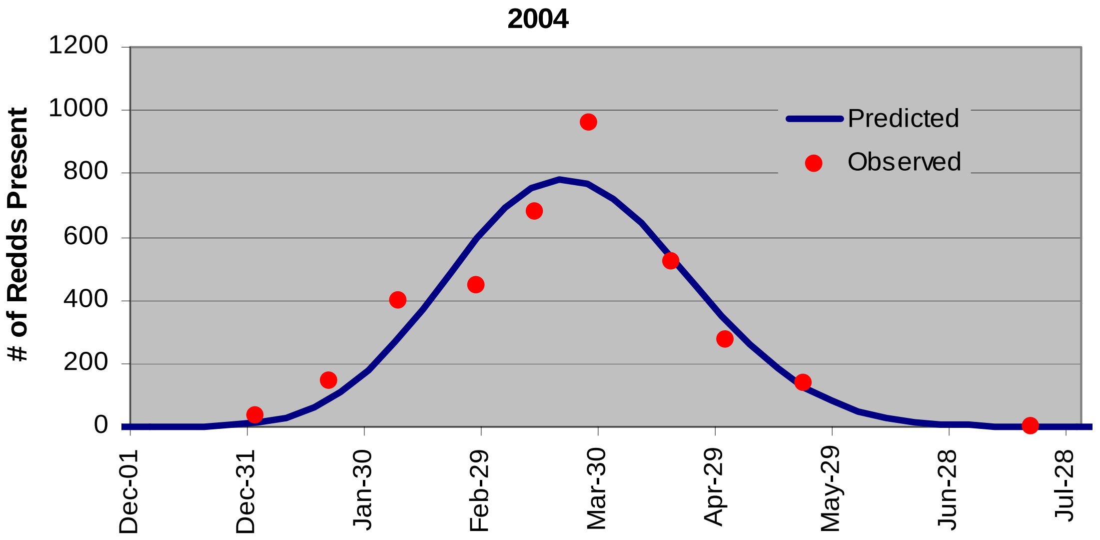
Location of Spawning Areas in Glen Canyon



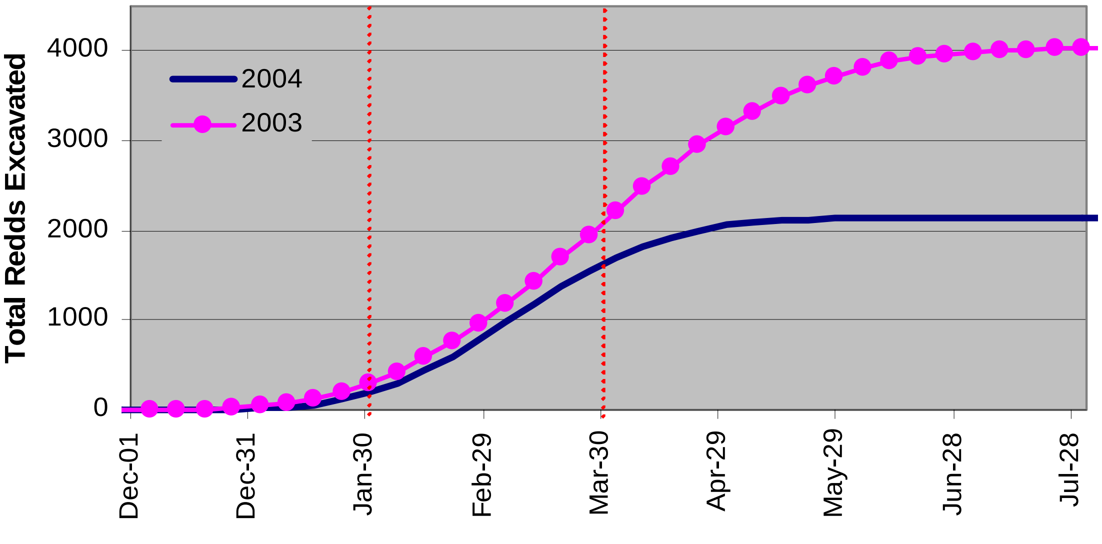
Redd Counts


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

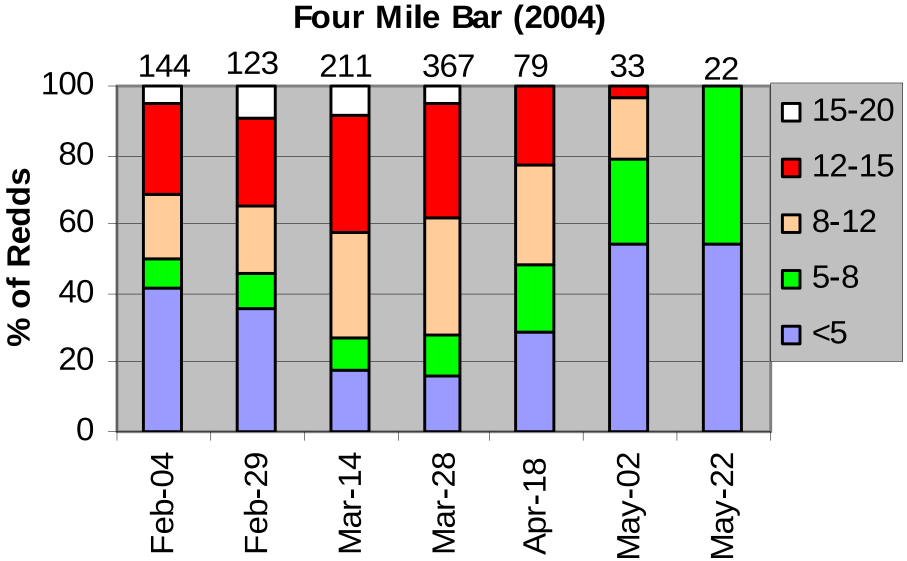
Total redds for year and timing of excavation estimated from raw counts and survey life

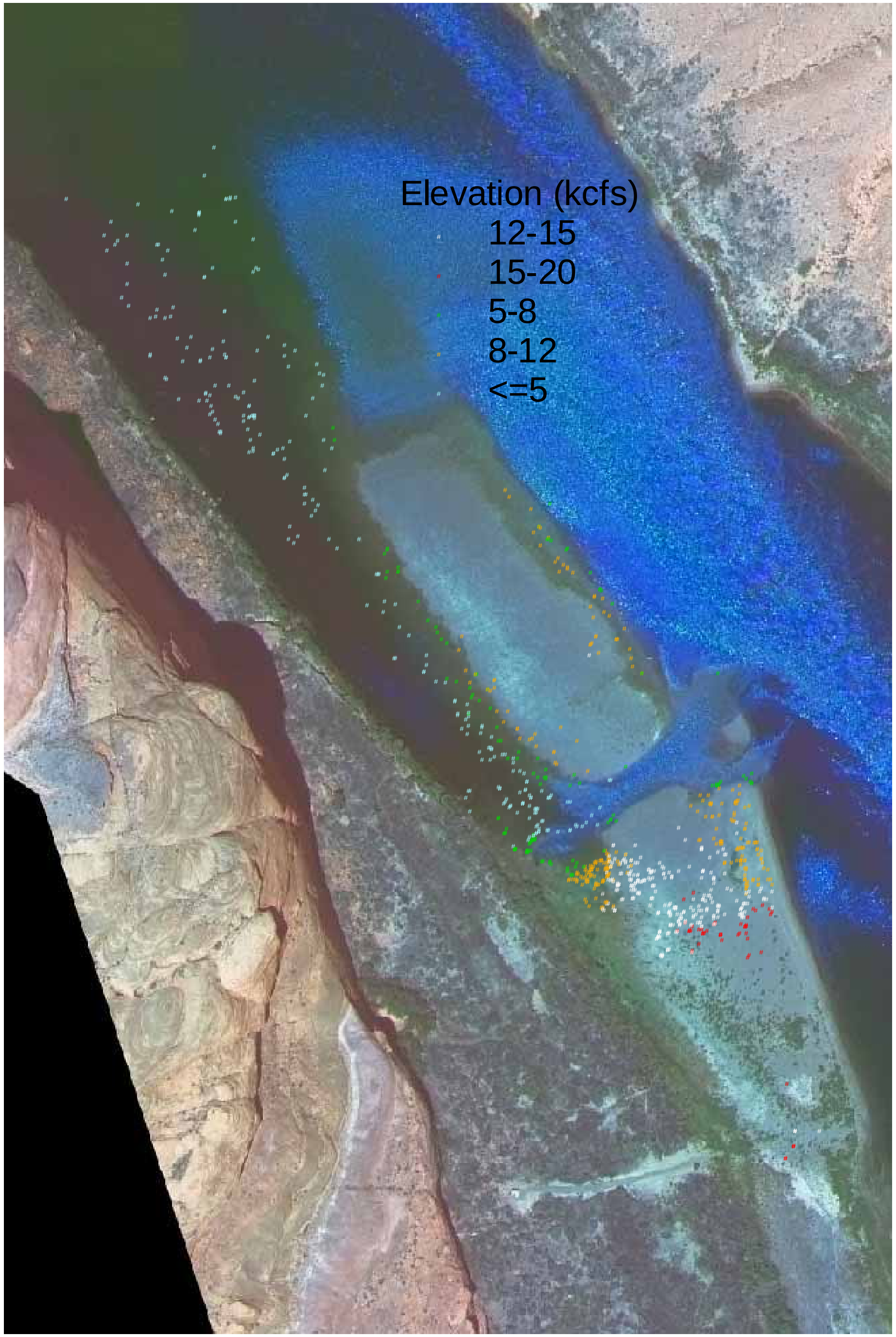


Redds = AUC/Survey Life

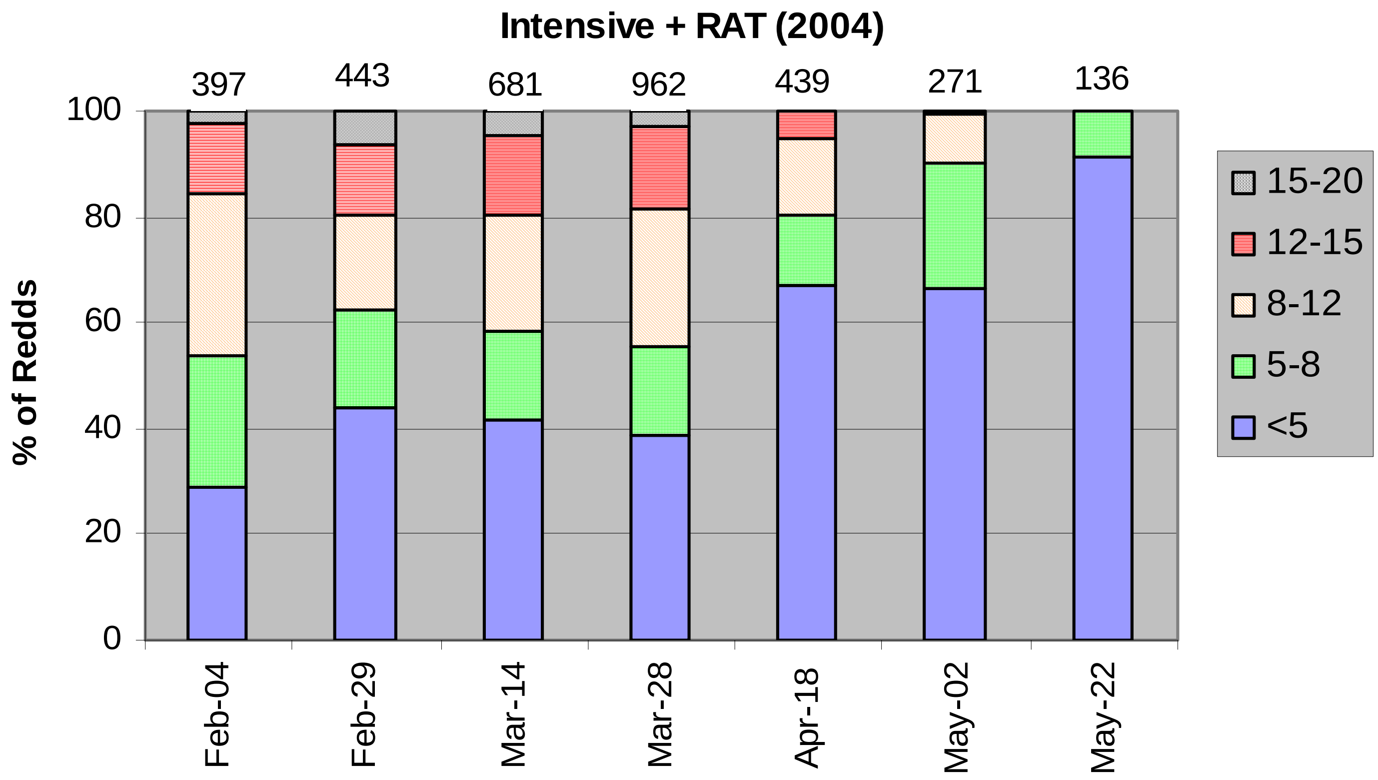


Redd Location and Elevation at Four Mile Bar, 2004

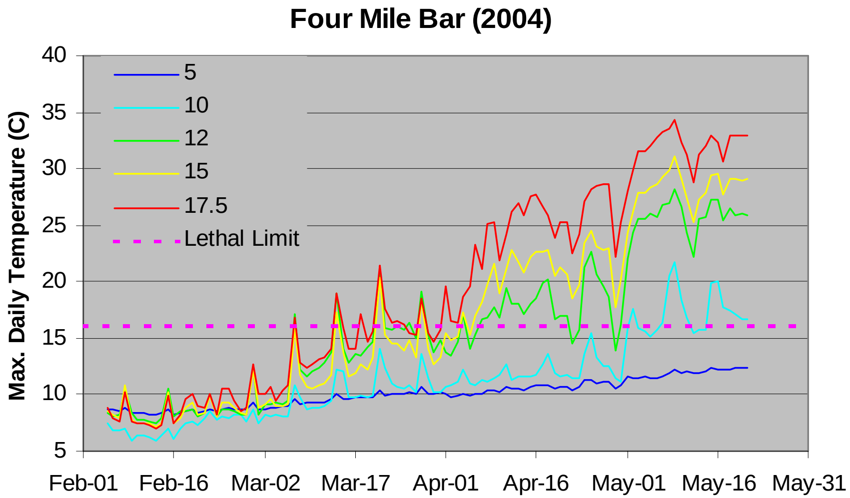


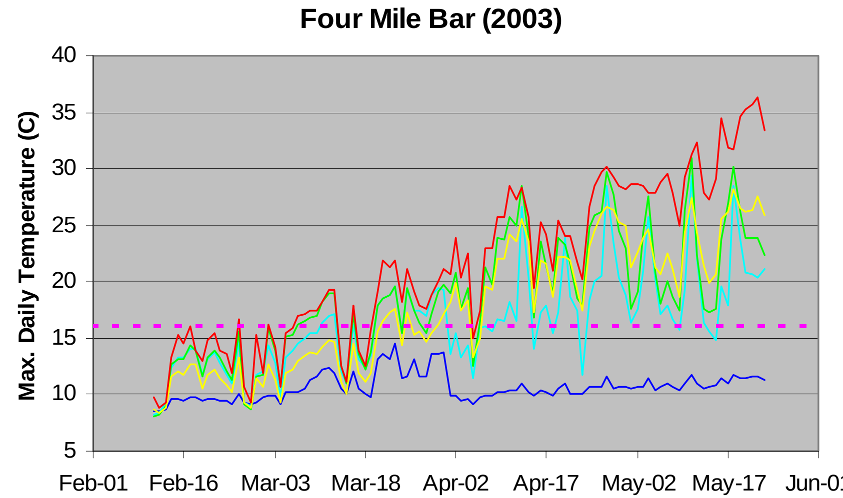


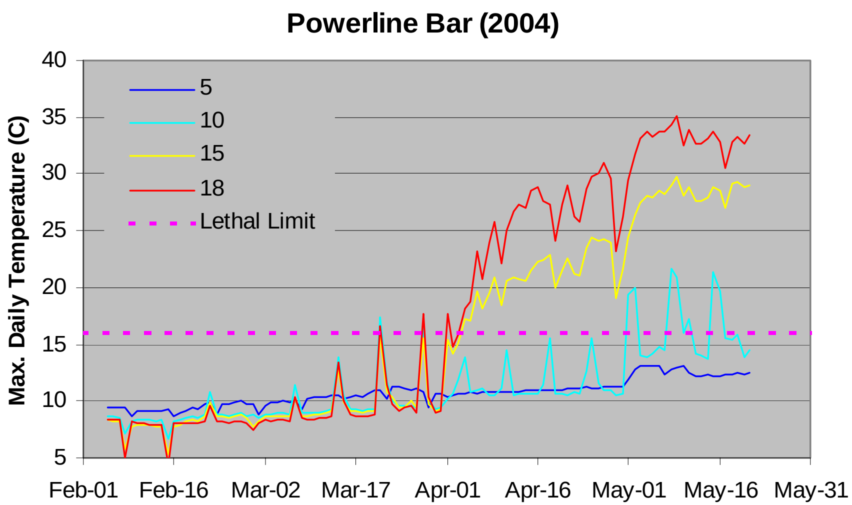
System-Wide Redd Hypsometry

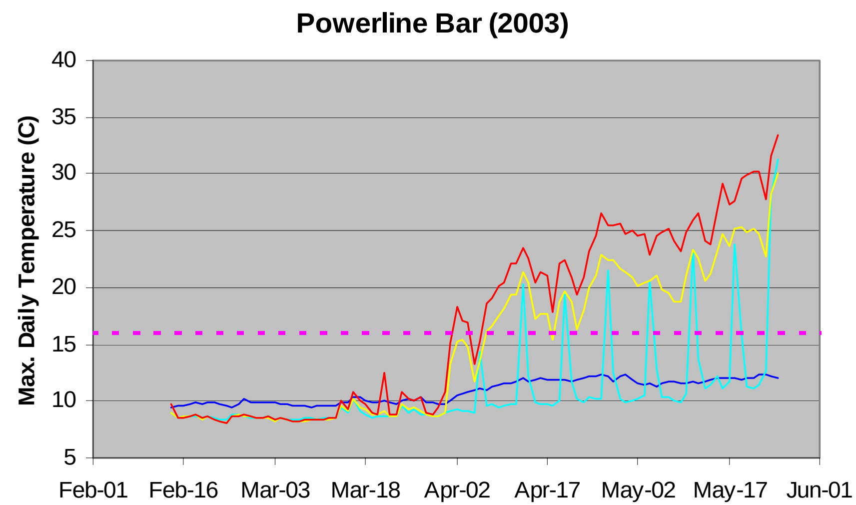


Intergravel Temperature









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	33	0	0	100	100	100
2003						
Total	4033	1811	1019	716	365	122
% Lost	23	0	0	79	68	100

Comparison of 2004 Redd Mortality with Other Scenarios

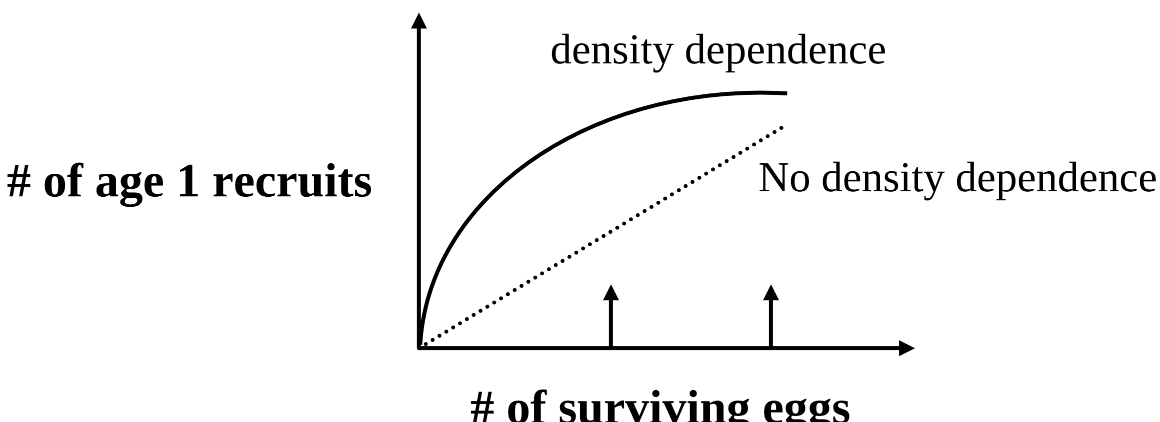
Scenario	% Redds Lost
2004	33
2004 with ROD Flows Jan: 12-20 with Sunday 12 Feb-Mar: 8/15 with Sunday 8	ca. 30 14 33
2004 + Extend Flux. Through Apr.	40
2004 + Sunday Steady Flow of 5 kcfs	49
Extended Flux and Sunday Steady 5 kcfs	56
Pre-ROD	ca. > 75

Conclusions from Redd Mortality Study

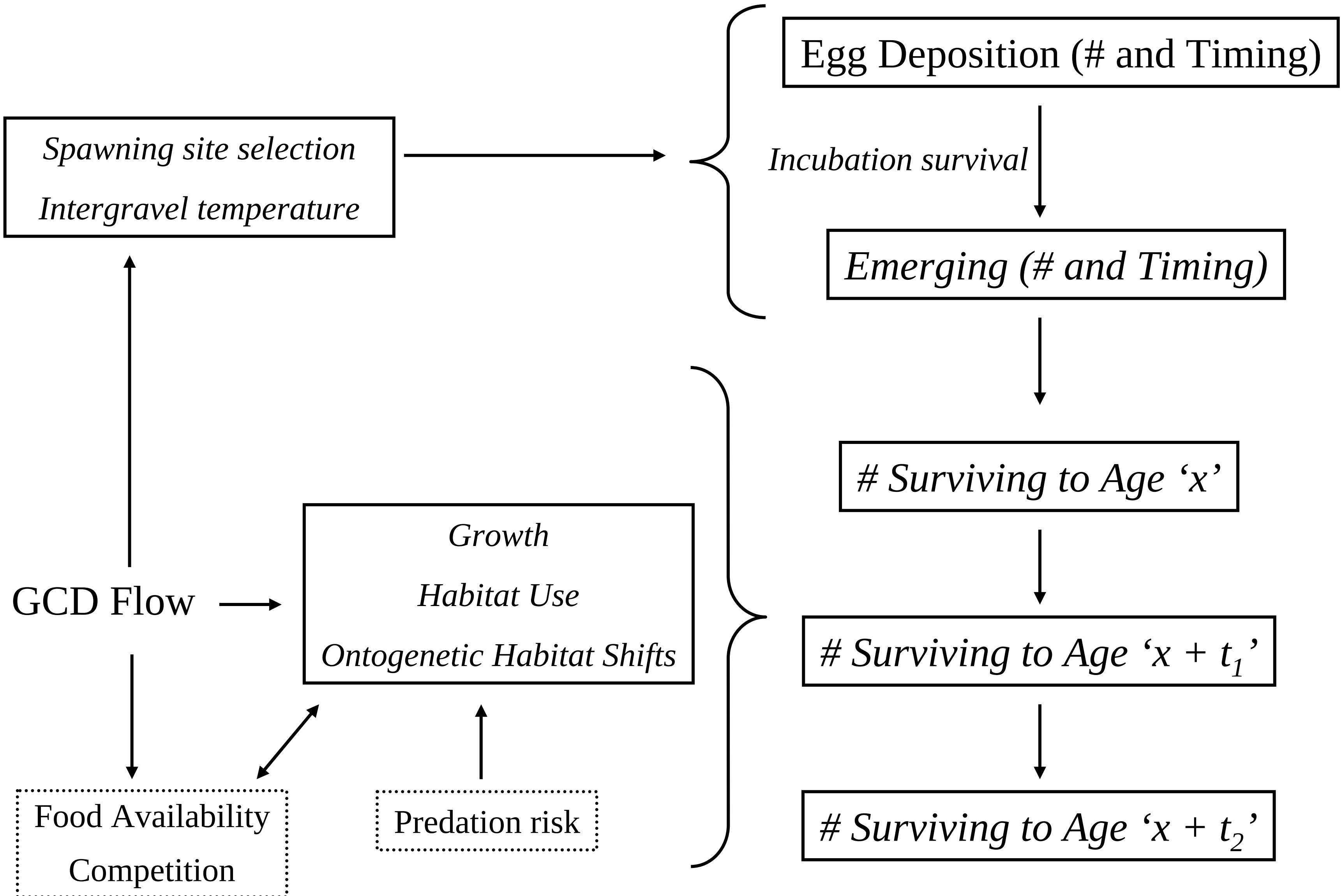
Very unlikely to see any effect of 2003/2004 Jan.-Mar. flows on recruitment to age 1 rainbow in Glen Canyon:

1. Little difference in redd mortality relative to normal ROD flows

2. Additional redd mortality likely compensated by reduced density-dependent mortality at later life stages



Estimation of Incubation Survival and Growth, Habitat Use, and Survival of Young-of-Year (YoY) Trout



Habitat Types

Low angle habitat

20-60 mm YoY

Debris fans, cobble and sand bars

50% of shoreline length Glen Canyon

20 sites/trip sampled by backpack electrofishing

600 m/trip sampled, or 2% of shoreline length of this type

Steep angle habitat

> 60 mm YoY

Talus slopes

40% of shoreline length in Glen Canyon

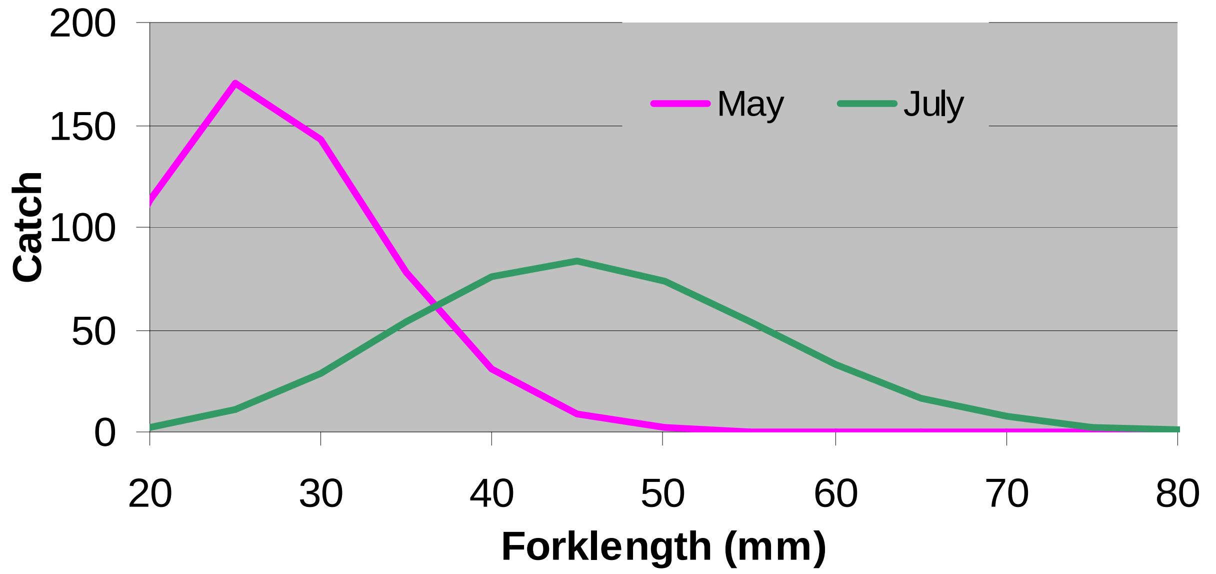
20 sites/month sampled by boat electrofishing

1000 m/trip sampled, or 5% of shoreline length of this type

Statistical Catch-at-Age Model

- Obtain length-frequency data for multiple sample periods
- Use simple population and observation models to predict length-frequency for these same periods based on following parameters:
  - # of fish hatching per week
  - Survival of fish each week
  - Growth rate (otolith data)
  - Vulnerability
- Estimate parameters (and uncertainty) by comparing model predictions to the length-frequency observations

Statistical Catch-At-Age Analysis (SCA)



	Traditional SCA (Adult / catch from fishery)	**Hyper SCA** (Juvenile / catch from scientific surveys
Size-at-age	Imprecise	Precise
Catchability	Variable	Consistent
Habitat use	Minor	Significant

Model Structure

Population Dynamics

Recruitment (# hatching/wk)

$$N_{0,\ t} = R\int_{t-1}^{t} \theta_t^{(\alpha-1)}\left(1-\theta_t\right)^{(\beta-1)}dt$$

Movement

$$MOV_a = \frac{l^{MovSl}}{MovHalf^{MovSl} + l^{MovSl}}$$

Alive (/age and wk)

$N_{L,a,t} = N_{L,a-1,t-1} * (1 - MOV_a) * S_L$

Lorenzen
Size-survival

$N_{S,a,t} = (N_{S,a-1,t-1} + N_{L,a-1,t-1} * MOV_a) * S_S$

Observation Dynamics

Growth (age-length)

$$L_a = \frac{L_\infty}{1 + e^{-K(a-t_0)}} + \nu_a$$

Vulnerability - Length

$$V_{h,l} = \frac{l^{VulSl_j}}{VulHalf_h^{VulSl_h} + l^{VulSl_h}}$$

Caught (/length category per trip)

$C_{h,l,t} = N_{h,l,t} * q_h * V_{h,l}$

Catchability (conditional)

$q = Cobs_h / Cpred_h$

Fit Parameters by maximizing likelihood assuming error is Poisson-distributed

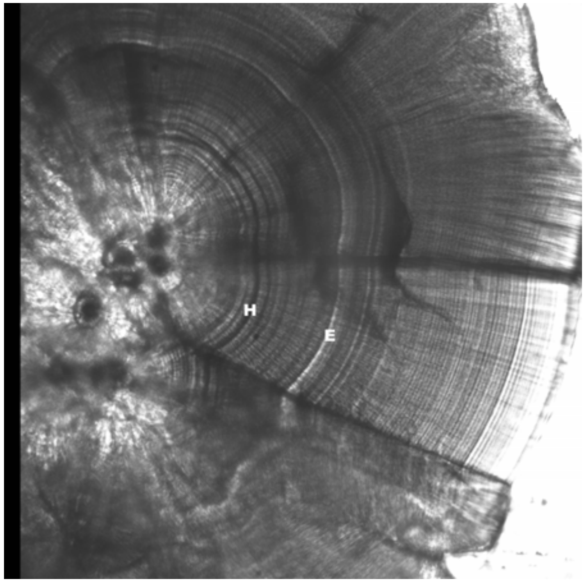
$$\boldsymbol{L}(k_{h,l,t} \mid S_h, \alpha, \beta, VulHalf_h, VulSl_h, MovHalf, MovSl) = \frac{e^{-p_{h,l,t}C_{h,t}}(p_{h,l,t}C_{h,t})^{k_{h,l,t}}}{k_{h,l,t}!}$$

r_t

$S_{h,\,(t,t+i)}$

Sum likelihood across habitat types (h), length categories (l),
And sampling trips (t)

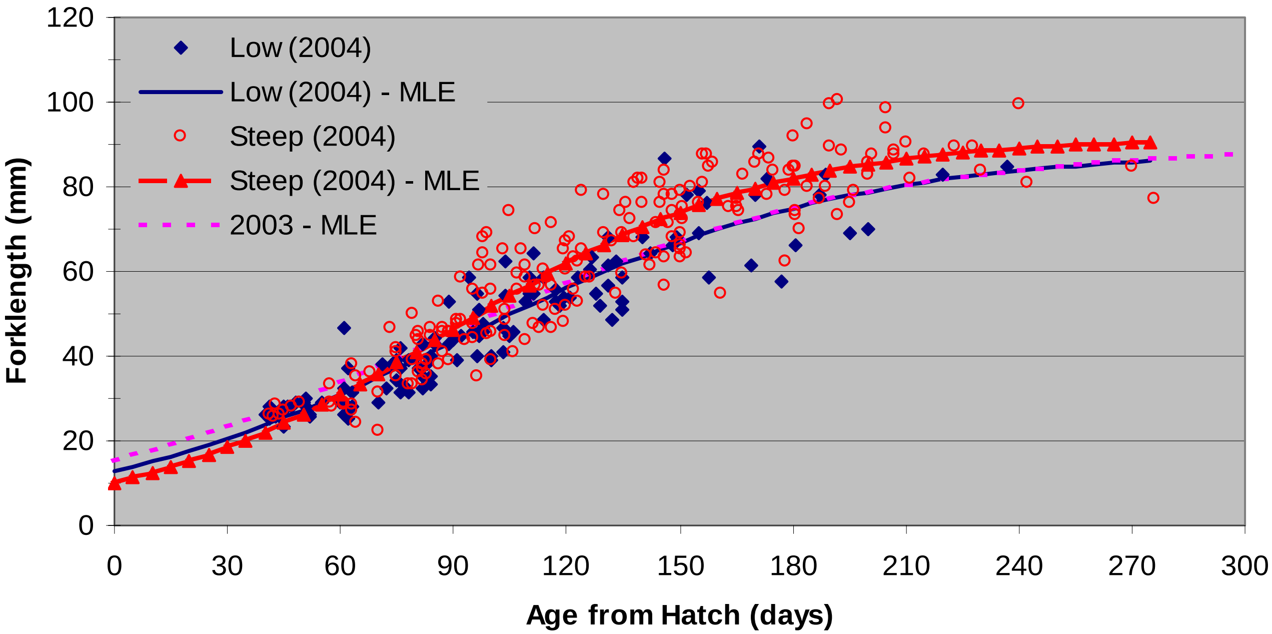
Maximize likelihood using iterative search procedure



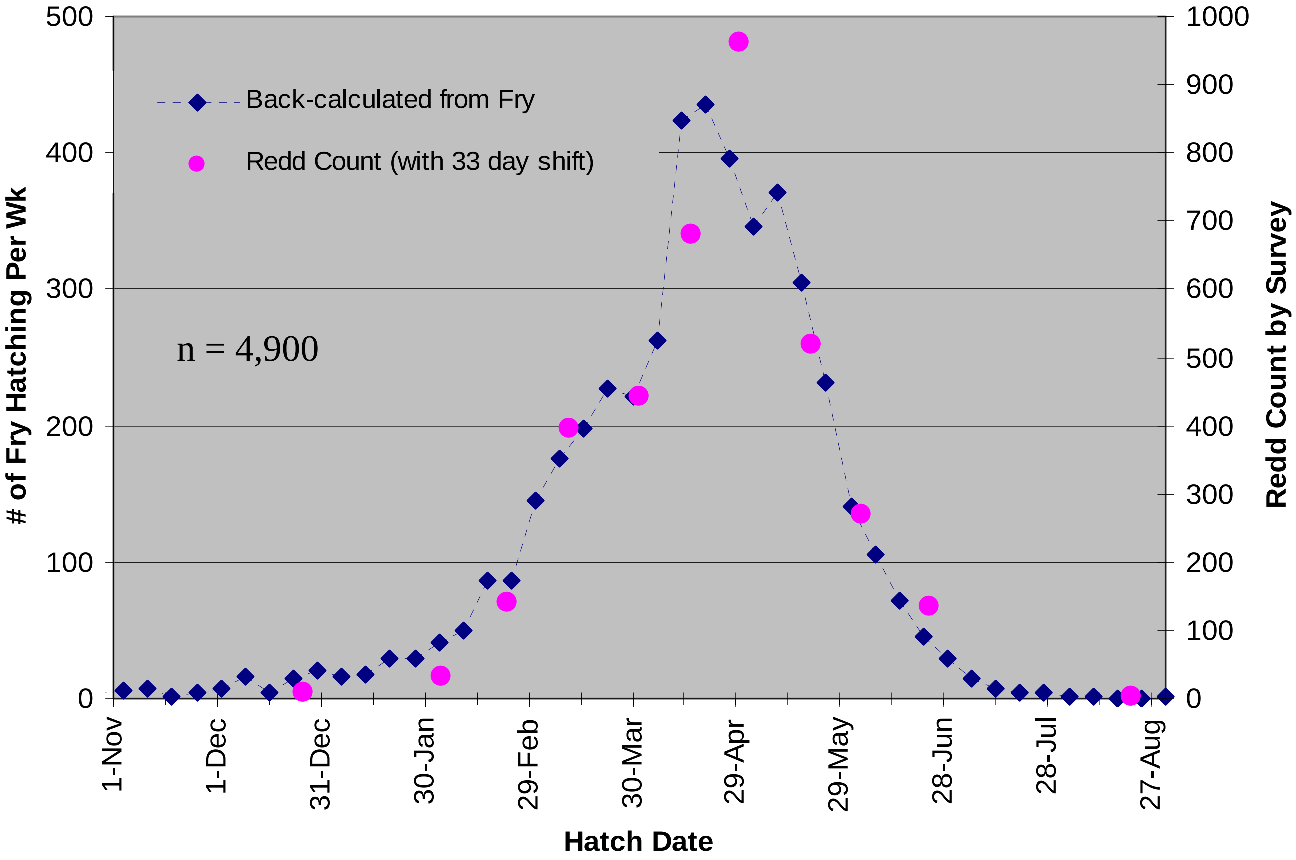
Length-at-Age from Otoliths

Otolith measurements from Dr. Steven Campana

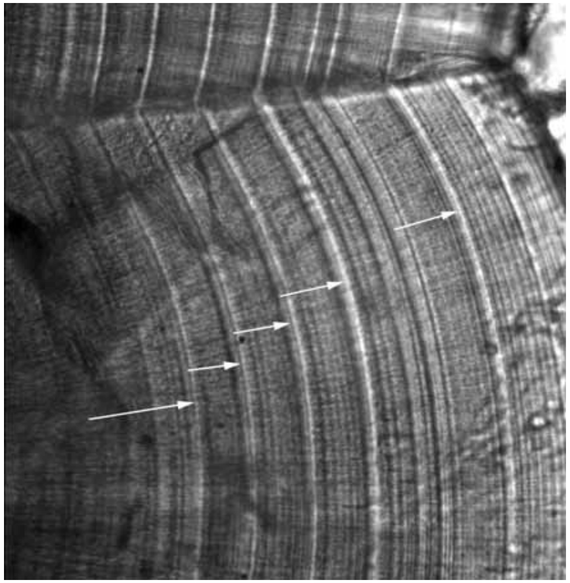
Fisheries and Oceans Canada

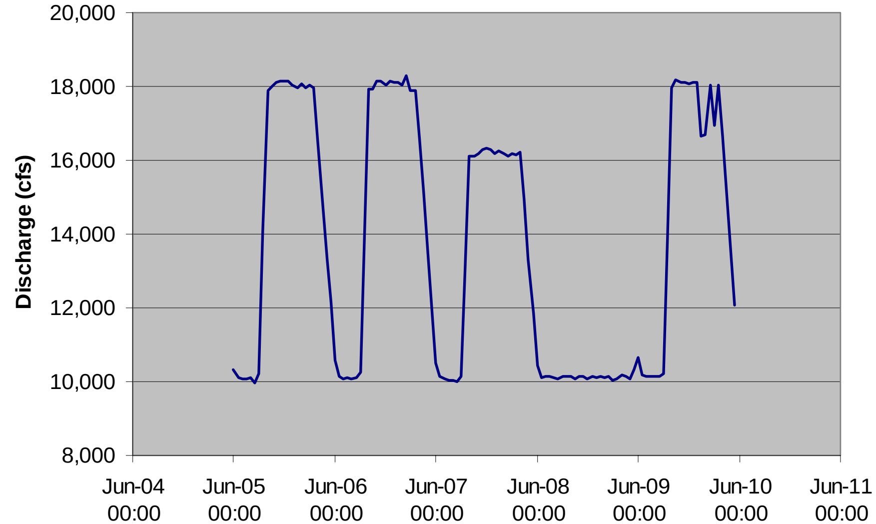


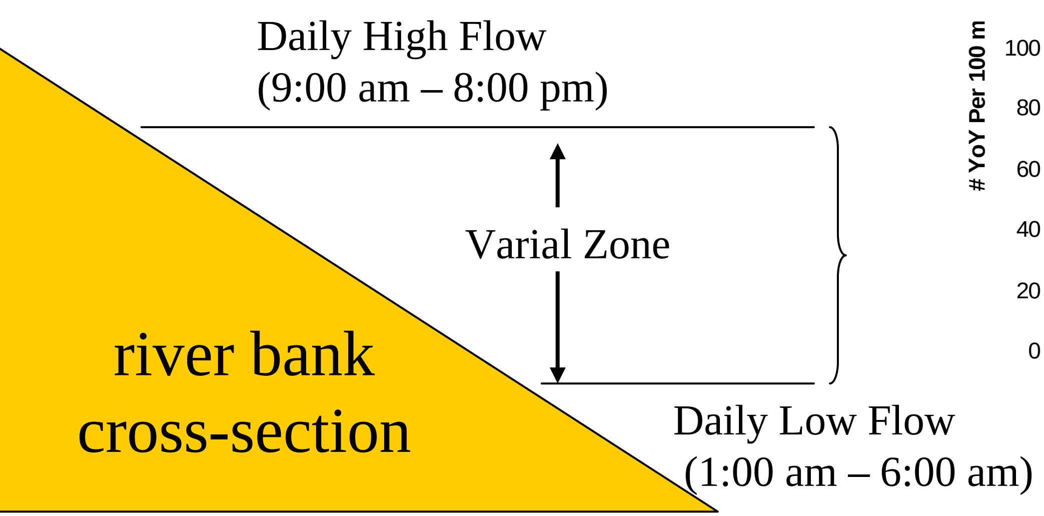
Hatch (Recruitment) Timing

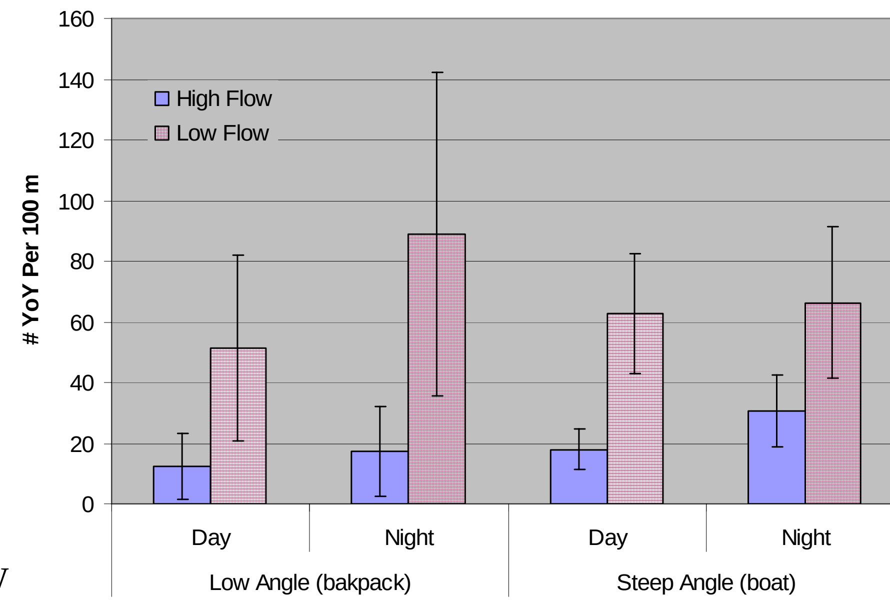


And on Sunday Let them Grow

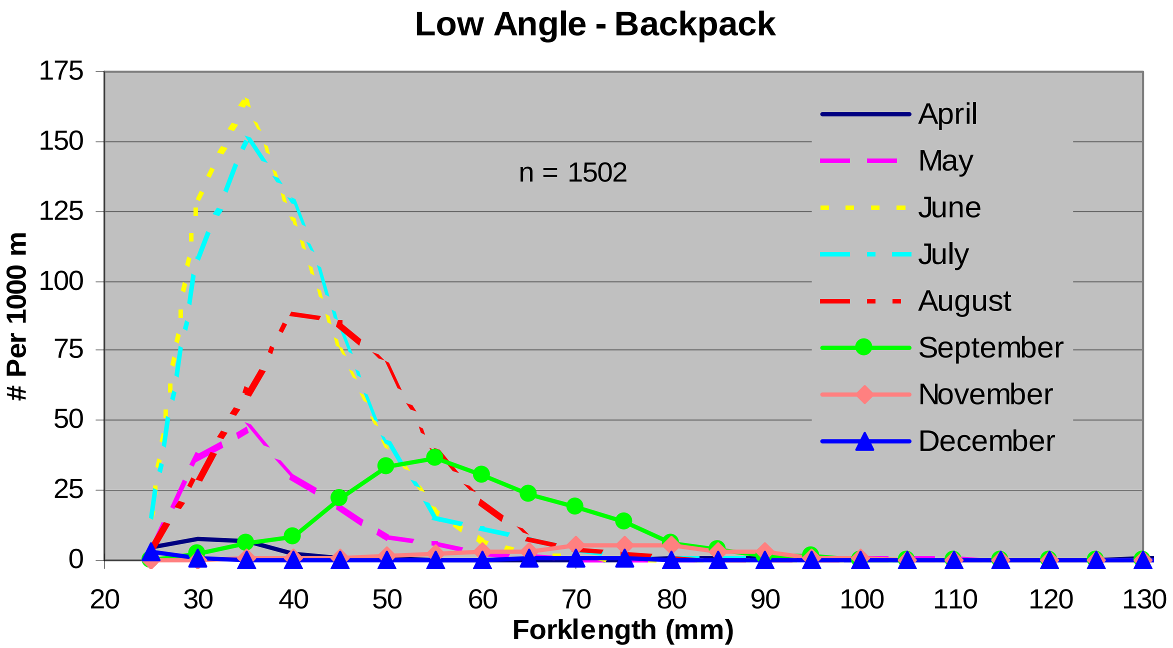


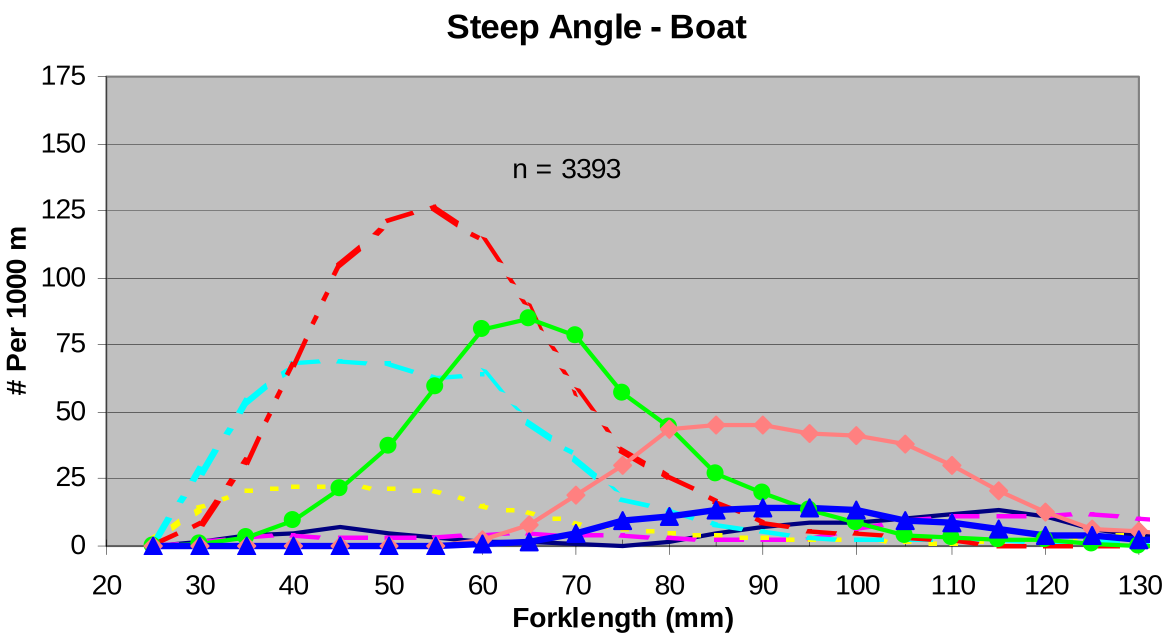


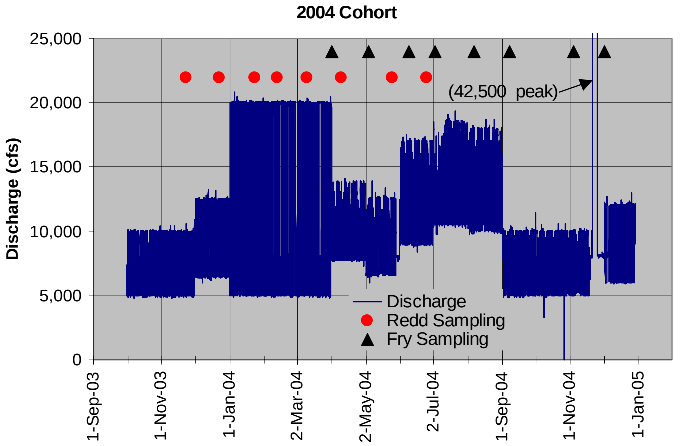


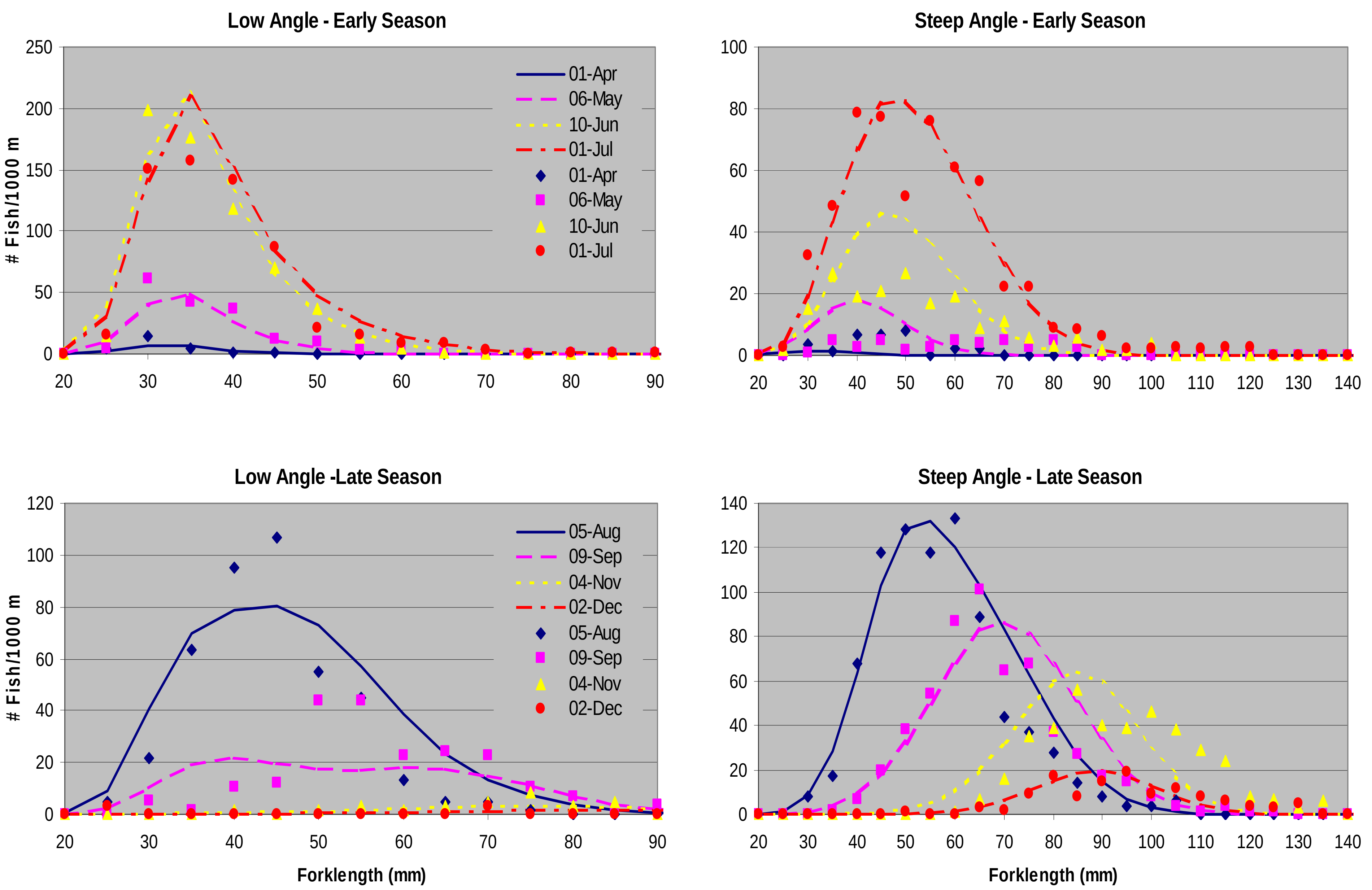


Observed Length-Frequencies



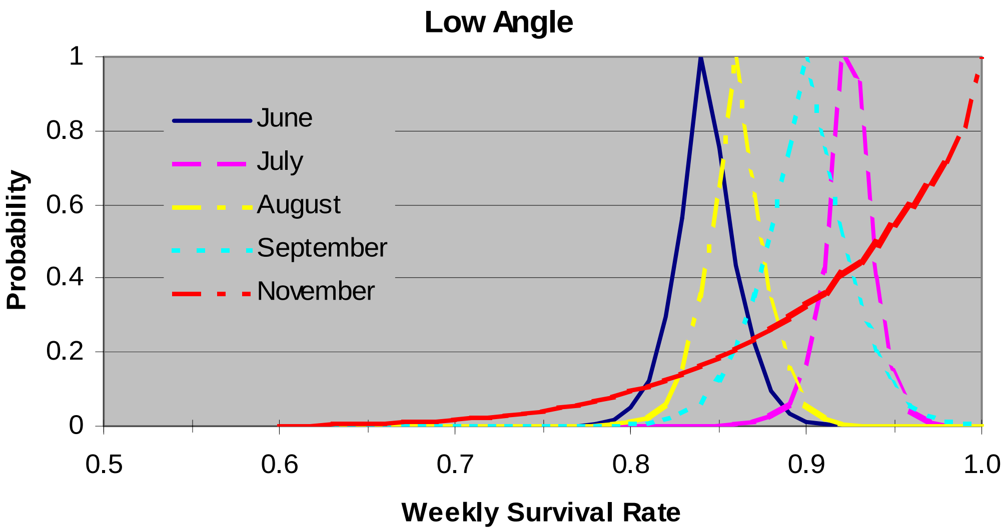


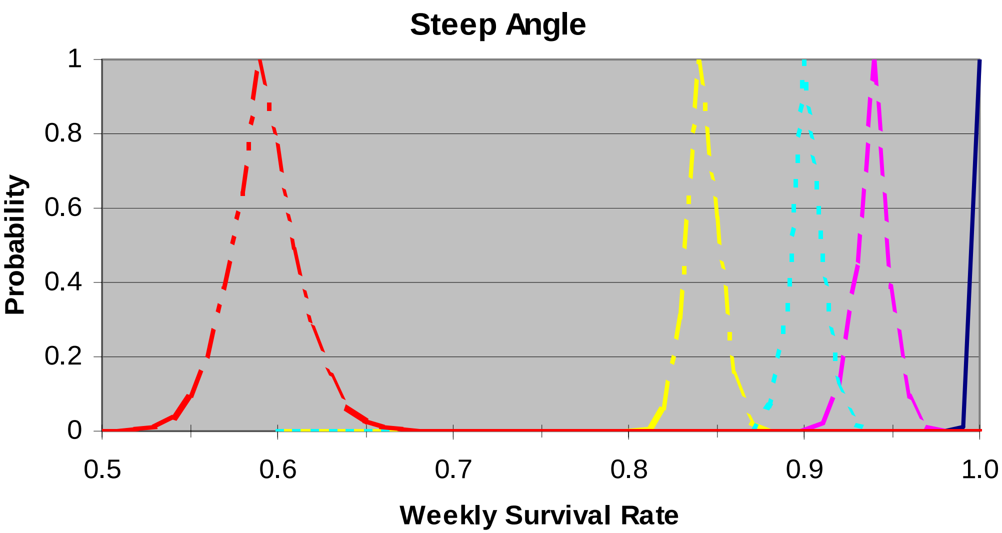


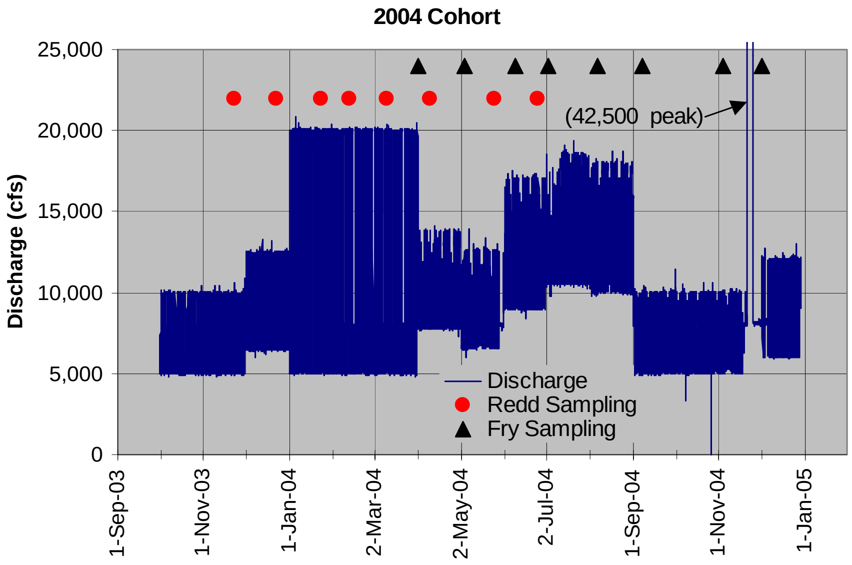


Low Angle - Early Season
Steep Angle - Early Season
Low Angle -Late Season
Steep Angle - Late Season
Fish/1000 m
Forklength (mm)
01-Apr
06-May
10-Jun
01-Jul
05-Aug
09-Sep
04-Nov
02-Dec

Uncertainty in Monthly Estimates of Survival Rate







Conclusions

- Daily fluctuations are reducing YoY growth rates
  - Increased growth on Sundays seen in otoliths when flows are near minimum elevation where YoY's are holding
  - 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 laterally (Shirvell 1994).
    - Foraging area theory (Walters and Jaunes).

- Sudden changes in flow (Aug-Sept) increase YoY Mortality Rate through stranding and or displacement
  - Reduced survival will be compensated by increased survival rates during winter due to lower densities.
  - Ultimately need to compare survival predictions with long-term recruitment index (age 1 or adult CPE from AGF).

- Catch-at-age model potentially valuable monitoring tool to assess across- and within-year effects of GCD operations.
  - Requires assumption that size-dependent catchability is constant over sampling period

Is There a Better Way to Regulate Trout Recruitment in Glen Canyon than Higher Fluctuations

- ‘***Juvenile Stranding Flow’***: High steady flow for 2 days followed by sudden decrease in flow to 5 kcfs for 24 hrs.

- One or two events in June and/or July when small YoY are most abundant and present in low angle shorelines where effects of flow change will be most pronounced.

- Will it Work?
  - Aug.-Sep. survival rate was anomalously low.

  - Hydro operations can strand fish (much literature and regulation):
    - Stranding rates highest for very young/small fish and in low angle complex habitats (Halleraker et al. 2003) such as cobble and vegetated sand bars in Glen Canyon.
    - Stranding rates highest following a long habituation period to one flow regime (Halleraker et al. 2003) like 10-18 kcfs summer flows.
    - Juvenile stranding difficult to observe directly in field (Slatveit et al. 2003) but there is anecdotal evidence from fishing guides in Glen Canyon.

  - Will it have a significant effect on recruitment? Need to monitor it!

Stranding Flow (con't)

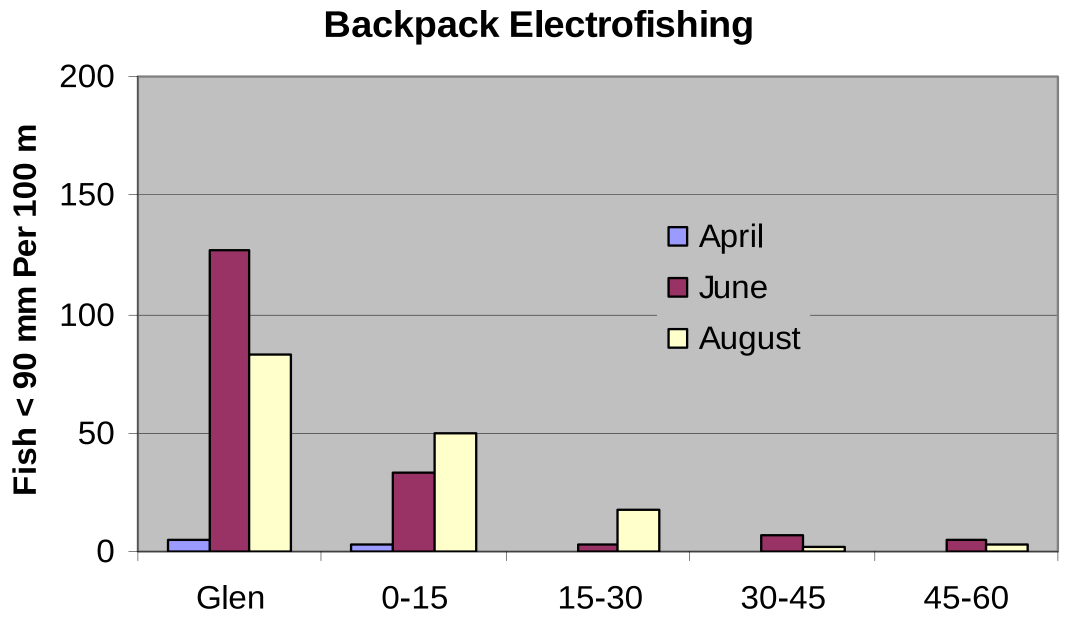
Reasons to Try It (assuming you want to reduce recruitment!)

1) Reduce recruitment while minimizing impacts of food base, thereby supporting adult growth and improving fishery.
2) If rainbow population in Marble Canyon is supported by population in Glen Canyon, making Glen Canyon as attractive as possible (low density with lots of food) may minimize emigration.
3) Less harmful than high fluctuations on sand storage and bar stability.
4) Stranding flow would be very easy and reasonably inexpensive to evaluate.

Reasons Not To:

1) Potential impact on native fish
2) Not a moneymaker
3) Need to maximize recruitment in Glen to meet management target

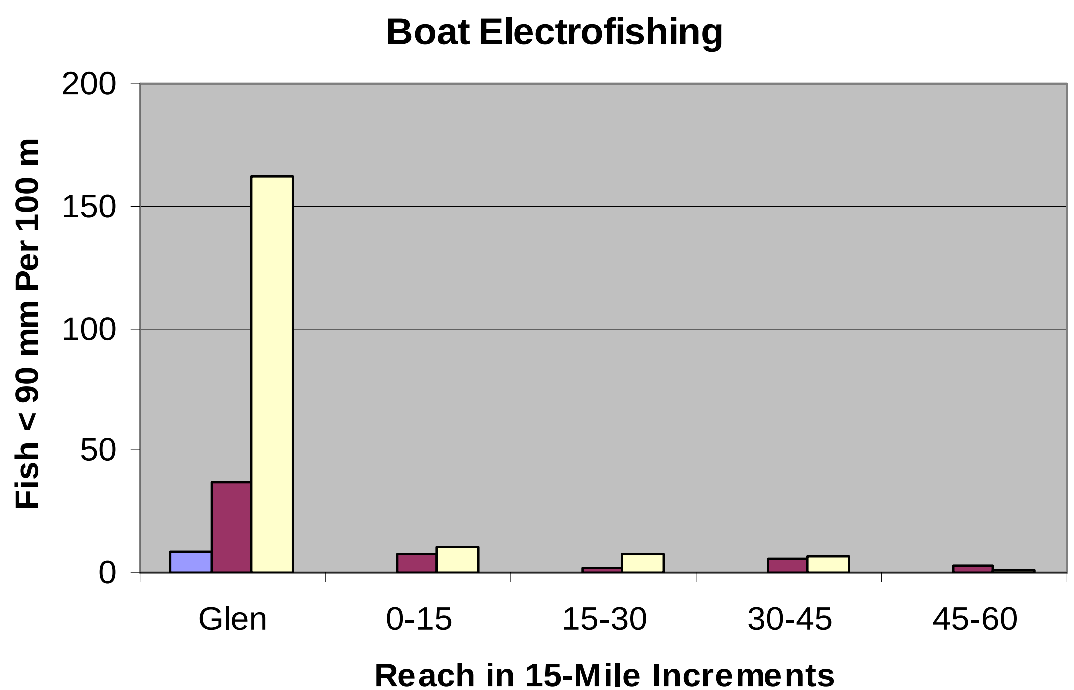
3) Did we find Young-of-Year downstream of Lee's Ferry?



Yes, but very few.

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

Growth rate and emergence timing for YoY in Marble Canyon identical to that from Glen Canyon.



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

1) Is there substantial suitable spawning habitat in the mainstem?

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

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

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

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.

Why VERY little Reproduction of Rainbow Trout in Marble Canyon in 2004?

1) Mechanical removal removed all the spawners. Unlikely, many adult fish above and within control reach. No reason spawners should be concentrated in removal reach (mostly below LCR).

2) Spawning habitat in mainstem and tributaries too ephemeral. Nankoweep is suitable as are small areas in mainstem, but they would not be consistently available across years. Consistent availability may be a requirement for substantive use if spawning site fidelity is strong.

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 adequate.

Measuring Recruitment Factors using a Statistical Catch-at-Age Modelling Approach

- Define spawn-timing and magnitude through redd surveys
- Measure change in length-frequencies from monthly Catch-Per-Effort sampling in 2 habitat types
- Length-stratified sub-sample of catch to measure size-at-age from daily otolith increments
- Fit survival rate, hatch-timing, movement, and vulnerability parameters of statistical catch-at-age model using maximum likelihood

Conflict Between 2004 Observation of No Reproduction with results from Tagging Studies (80's/early 90's) Documenting Limited Downstream Dispersal

- Increased densities in Glen through 90's due to ROD flows could have increased rate of downstream dispersal.

- Resulting high densities of trout in Marble Canyon led to reduced growth which could have reduced reproduction.