Physiological Changes in Migrating Juvenile Spring/Summer and Fall Chinook Salmon and Effects on Performance and Survival

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Energy Reserve Depletion Hypothesis (1/4)

Snake River salmonids are adapted to natural (pre-development) migration conditions.

Under natural river conditions, Snake River s/s Chinook salmon migrated from rearing areas to the ocean in two to five weeks. Under natural and present conditions, the migration is continuous, with limited foraging (*unlike fall Chinook salmon*), and without the "option" of residualization (*unlike fall Chinook salmon* and steelhead).

It is a "make or break" strategy.

Energy Depletion Hypothesis (2/4)

Migrating smolts are in a catabolic state.

Migrating s/s Chinook smolts are in a life-stage-specific metabolic state that involves the progressive mobilization of body carbohydrate, lipid, and (potentially) protein reserves.

This catabolic state is maintained throughout the period of downstream migration.

Energy Depletion Hypothesis (3/4)

Migration through the hydrosystem is extended for 3 to 5 weeks longer than under “natural” conditions, with possible adverse consequences.

If the migration is sufficiently protracted, lipid reserves will be depleted, and body protein (including muscle protein and rate-controlling enzymes) will be used as a source of energy.

Consequently, performance capabilities (e.g., swimming, osmoregulation) may be reduced.

Energy Depletion Hypothesis (4/4)

Food availability will affect the energy balance of migrating fish, and could be a mitigating factor.

The rate of depletion of energy reserves will depend in part upon food availability. Food availability may trend upward during the migration season. As a result, depletion of energy reserves might be mitigated in later-migrating S/S Chinook salmon and in summer-migrating fall CS.

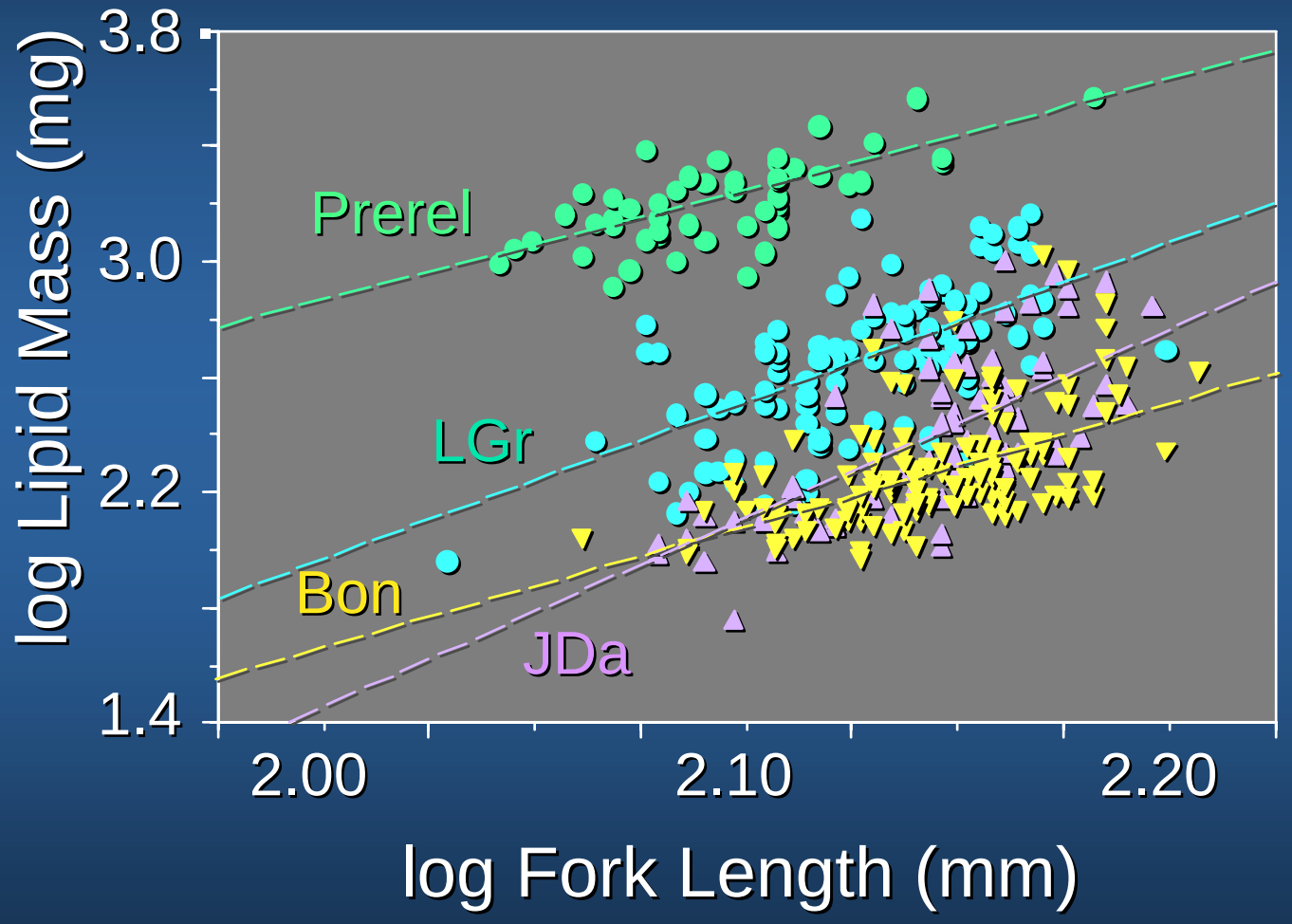
Methodology

- We sampled S/S Chinook salmon that had been PIT-tagged at three Idaho hatcheries—Dworshak, Rapid River, and McCall—for the Comparative Survival Study. We sampled Fall Chinook salmon that had been PIT-tagged and released above LGR for NMFS and Nez Perce studies.
- Computer-operated diversion systems at Lower Granite and Bonneville dams were programmed to divert fish from each hatchery ("diversion-by-code") at 6- to 7-d intervals throughout the migration.
- Energy reserves (lipid and protein), blood chemistry, and other physiological indices were determined for migrating fish.
- Laboratory experiments were done with migrating S/S CS captured at LGR to determine if some blood-chemistry indices are useful indicators of nutritional status.

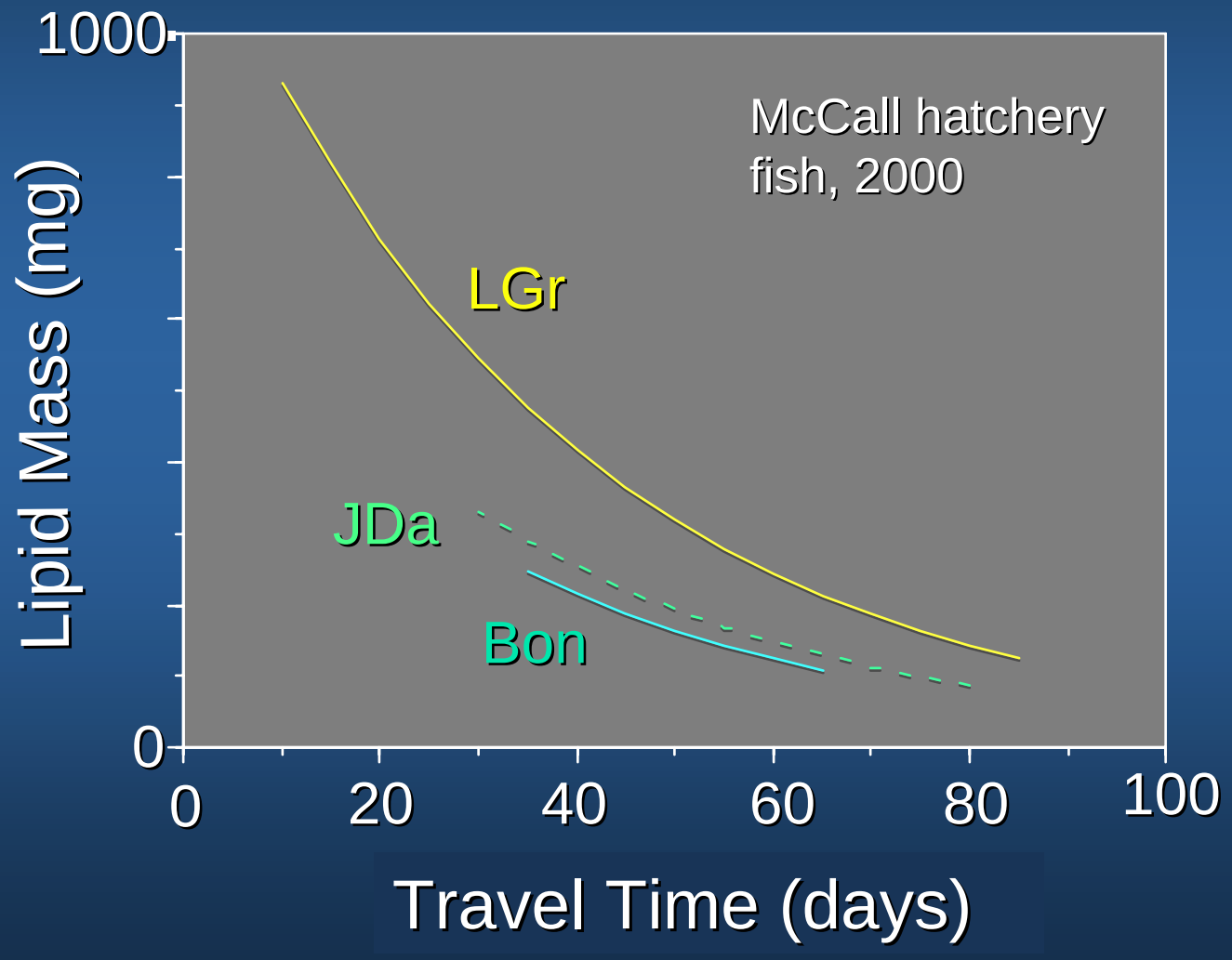
I. Field Studies, S/S Chinook salmon

Changes in energy stores (lipid and protein) during hydrosystem passage, 1999 - 2002.

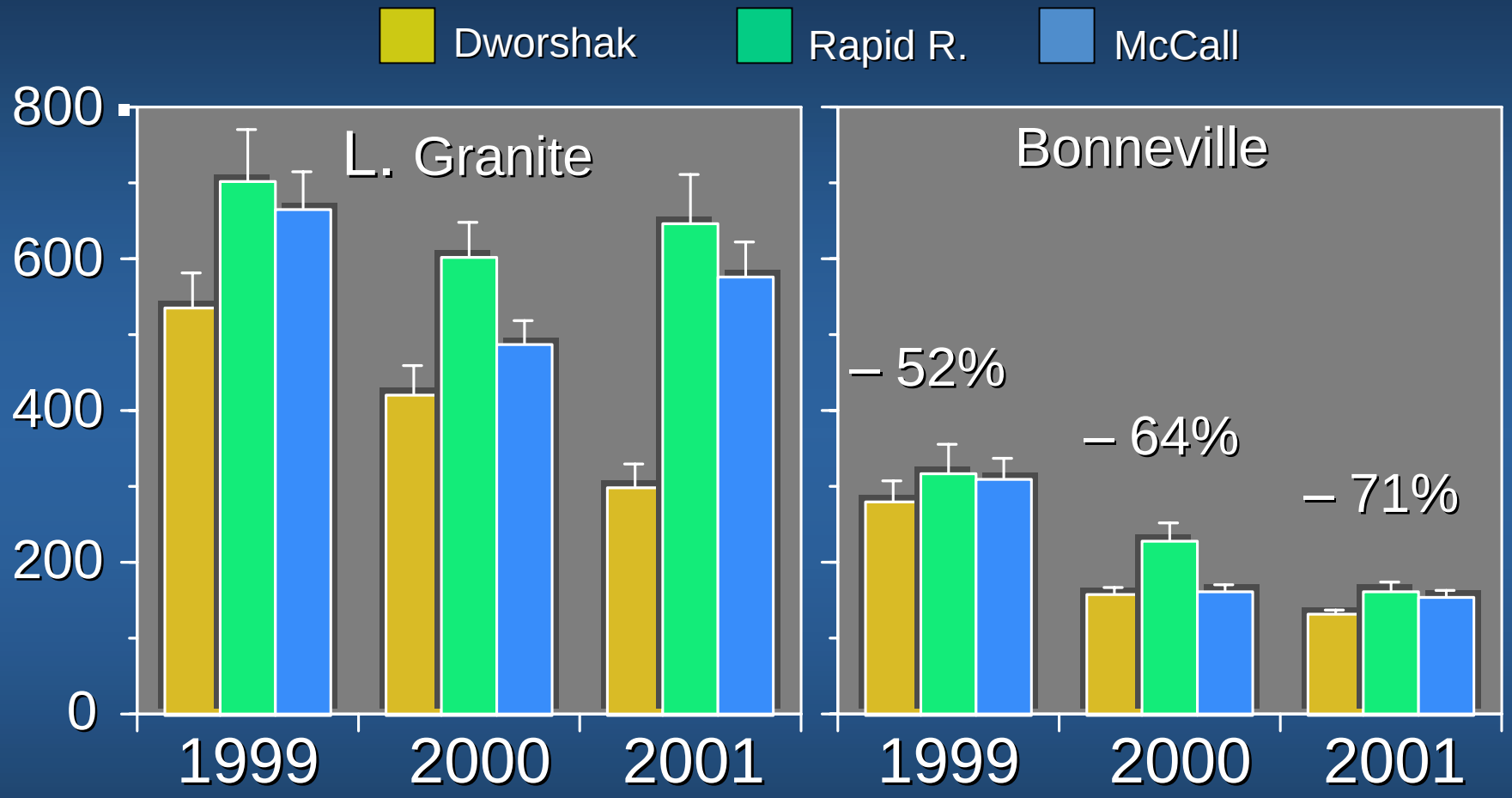
Example: log lipid mass versus log fork length regressions (all hatcheries, 2000)



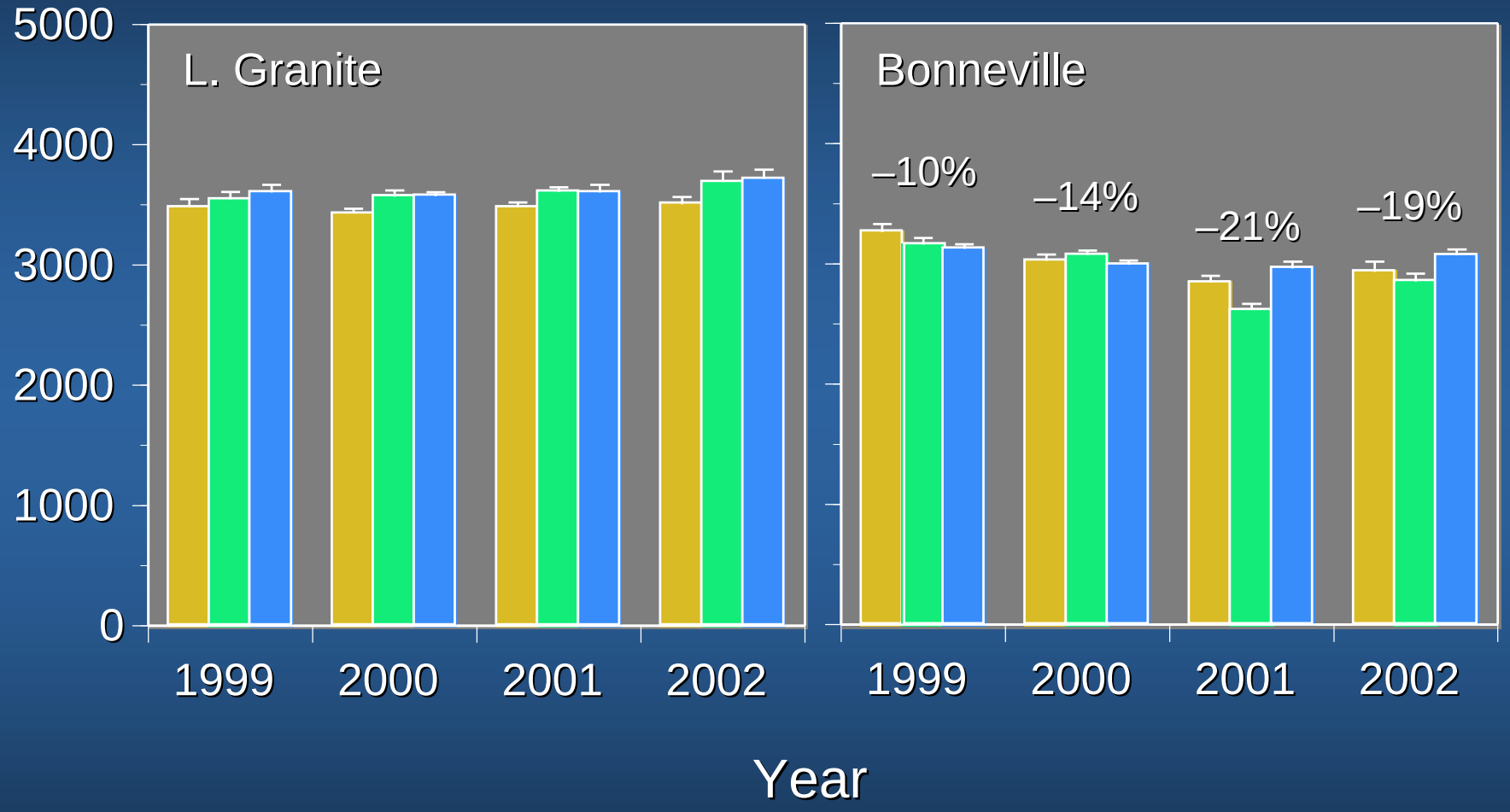
Example, ANCOVA model results: Effect of travel time (release site to each dam) on lipid reserves (length-controlled, 135 mm fish).



Length-controlled Lipid Mass (mg) by Year



Length-controlled Protein Mass (mg) by year



Conclusions

Use of energy reserves by S/S Chinook salmon.

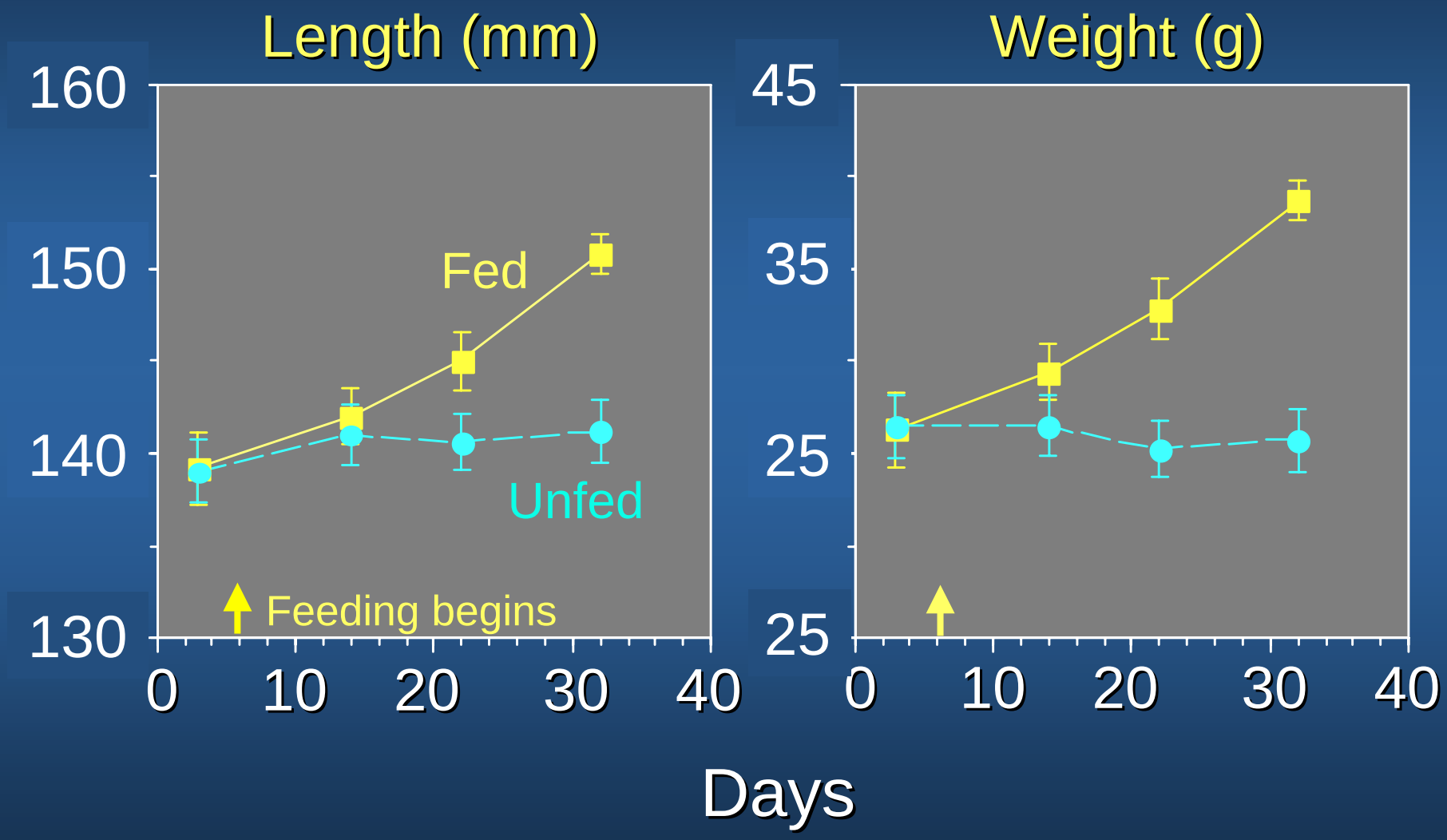
- The rate of lipid use varied little between years; however, because travel times were longer in lower-flow years, lipid reserves were depleted at points further upstream.
- Lipid reserves were depleted (<1% body weight) in fish reaching Bonneville Dam in all years.
- The rate of protein use increased after lipid was depleted.
- Protein use was greatest in 2001, the lowest-flow year.

II. Lab and Field Studies, blood-chemistry indices of nutritional condition in S/S CS

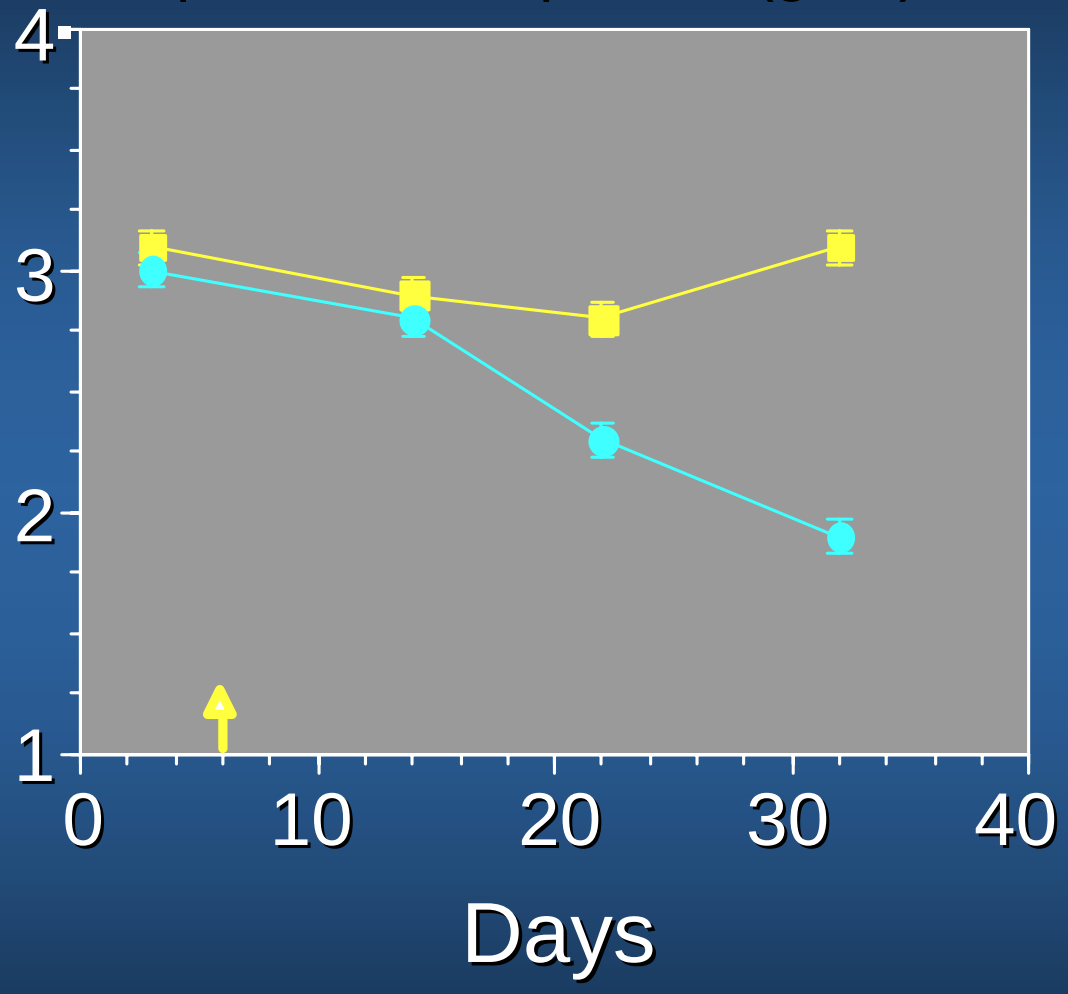
- Lab experiments were performed to determine effects of fasting & feeding on blood chemistry indices in migrating smolts (captured at Lower Granite Dam and transported to the UI wet lab, 2001).

- Nutritional indices in laboratory-fasted and fed fish were compared with indices in migrating fish sampled at Lower Granite and Bonneville Dams.

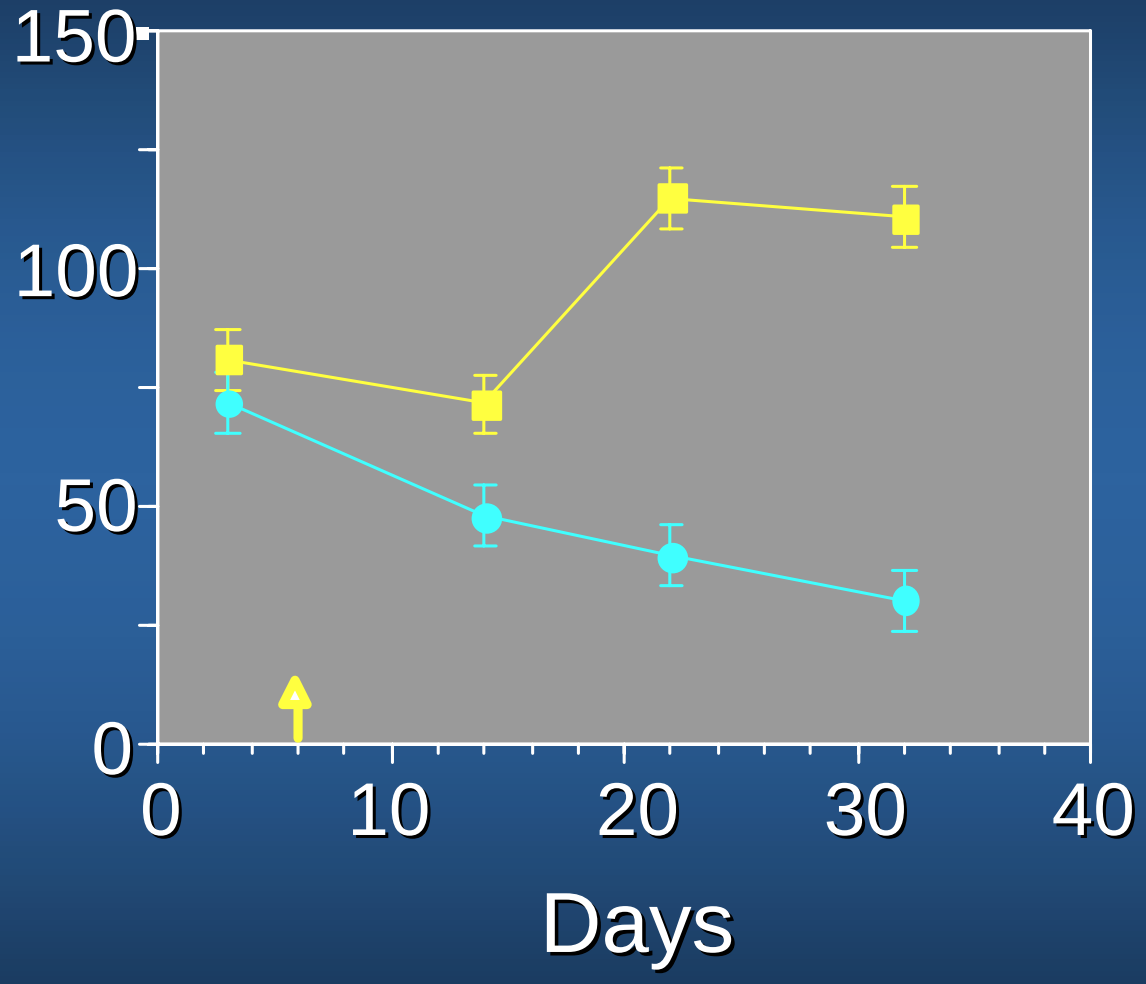
Food deprivation experiment 2001



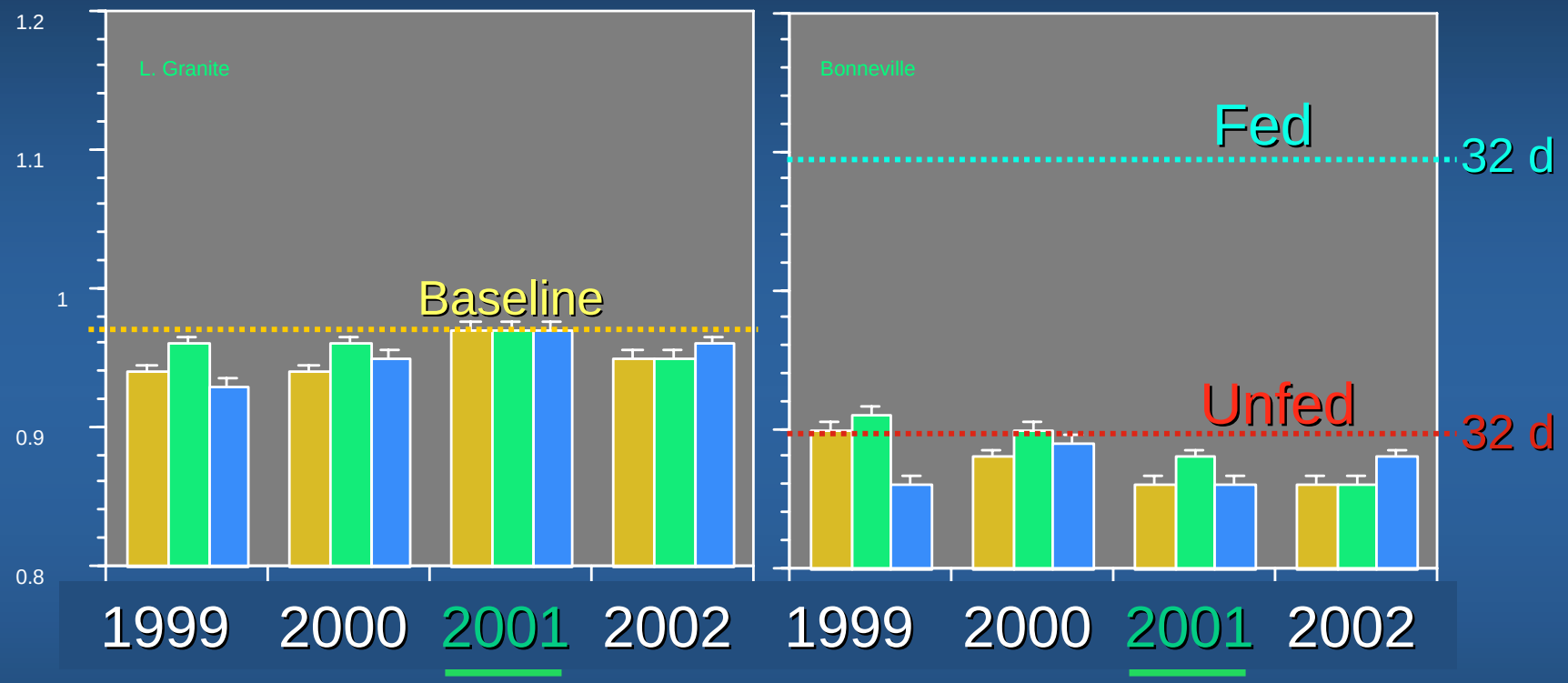
Lab fasting/feeding experiment: plasma total protein (g/dL)



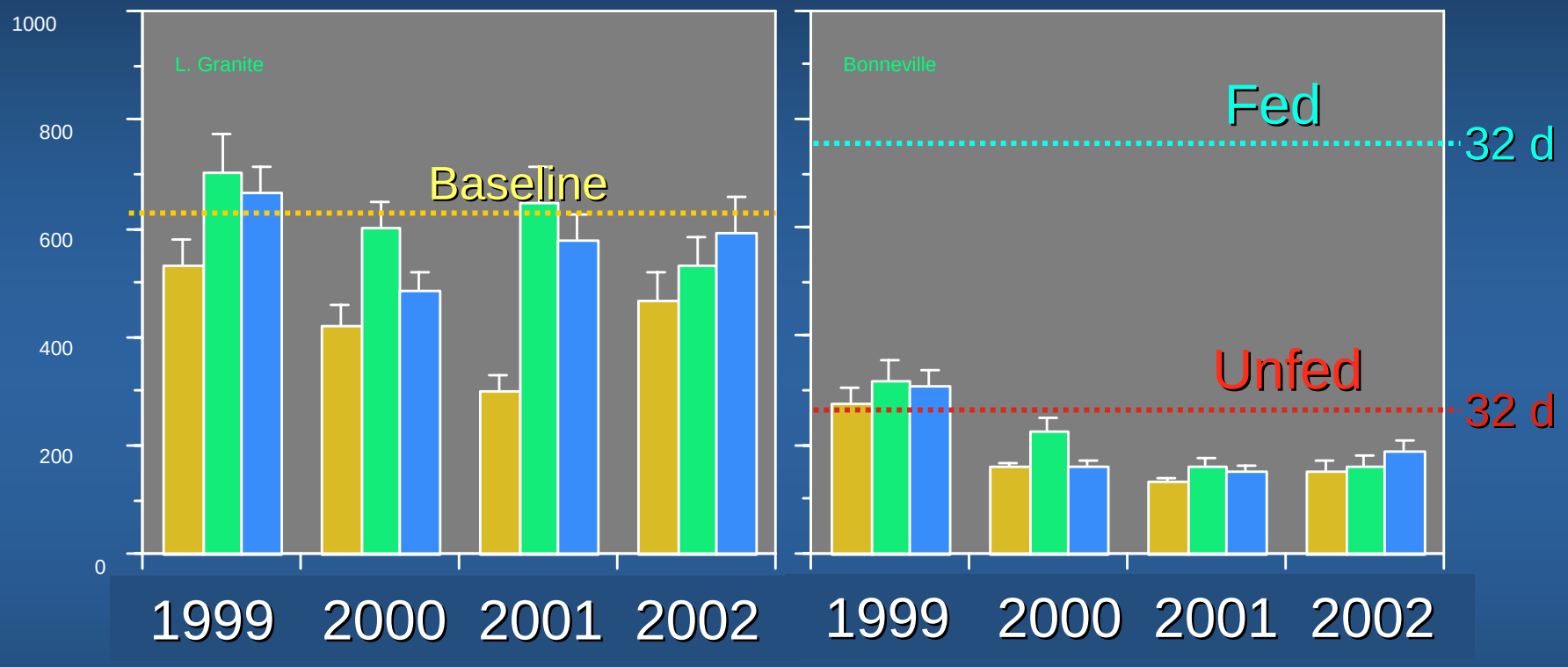
Lab fasting/feeding experiment: plasma alkaline phosphatase (U/L)



Condition factor, migrating and fasted/fed fish

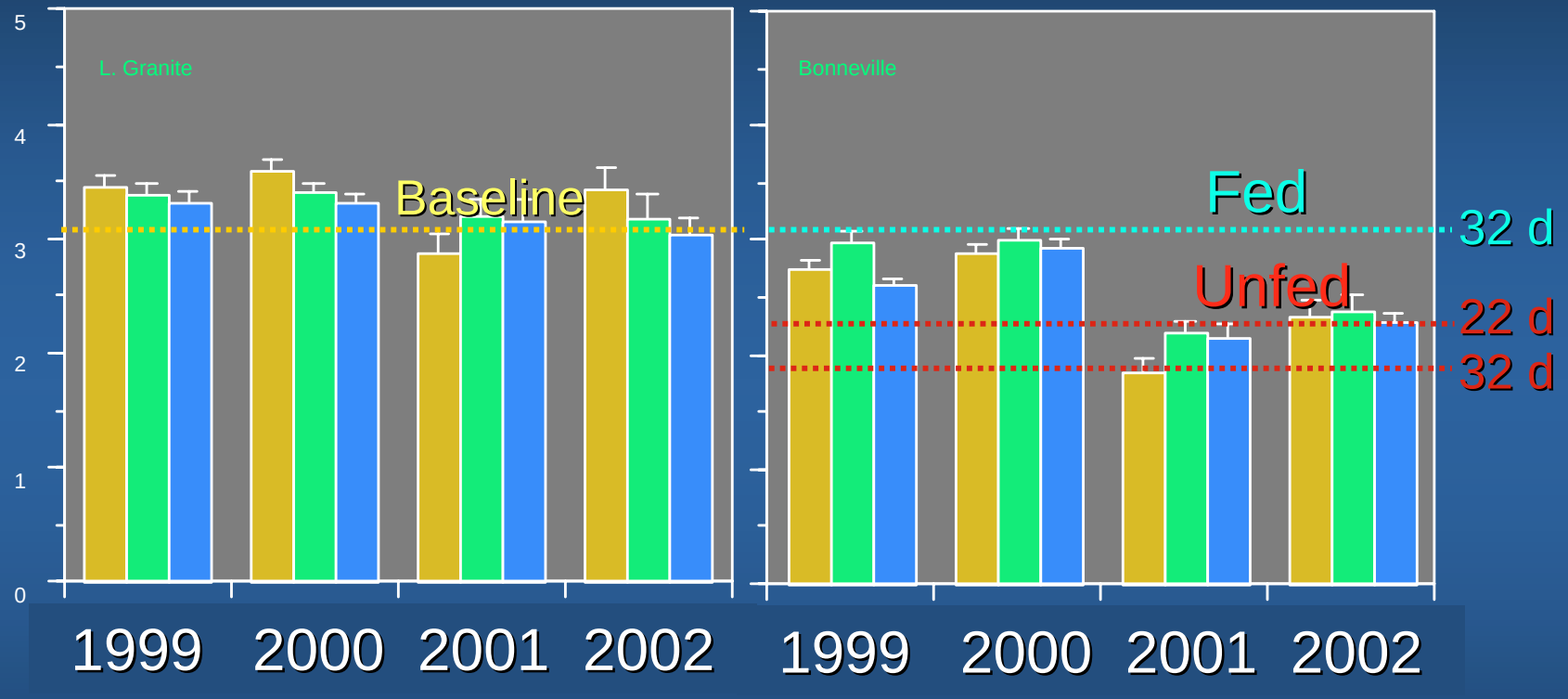


Body lipid mass*, migrating and fasted/fed fish

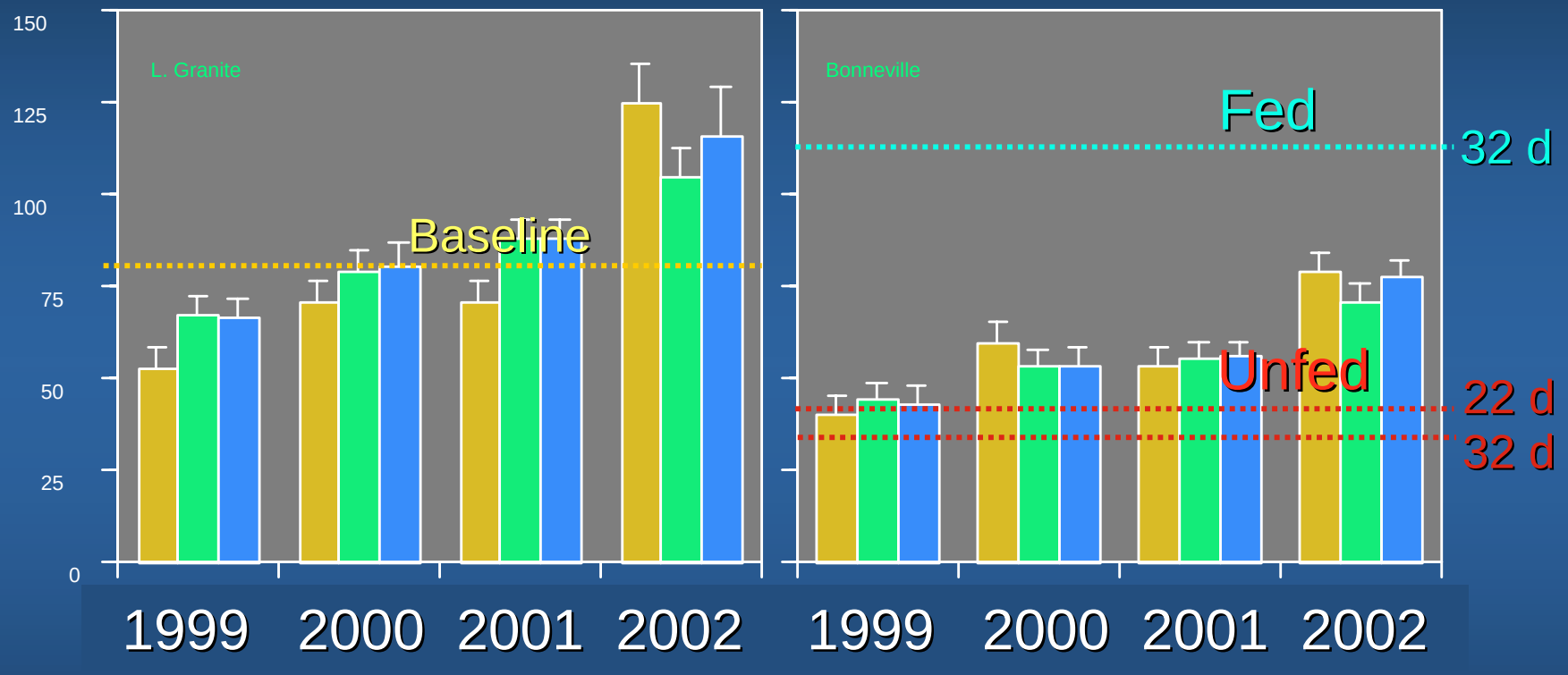


*length-controlled, mg

Plasma total protein (g/L), migrating and fasted/fed fish

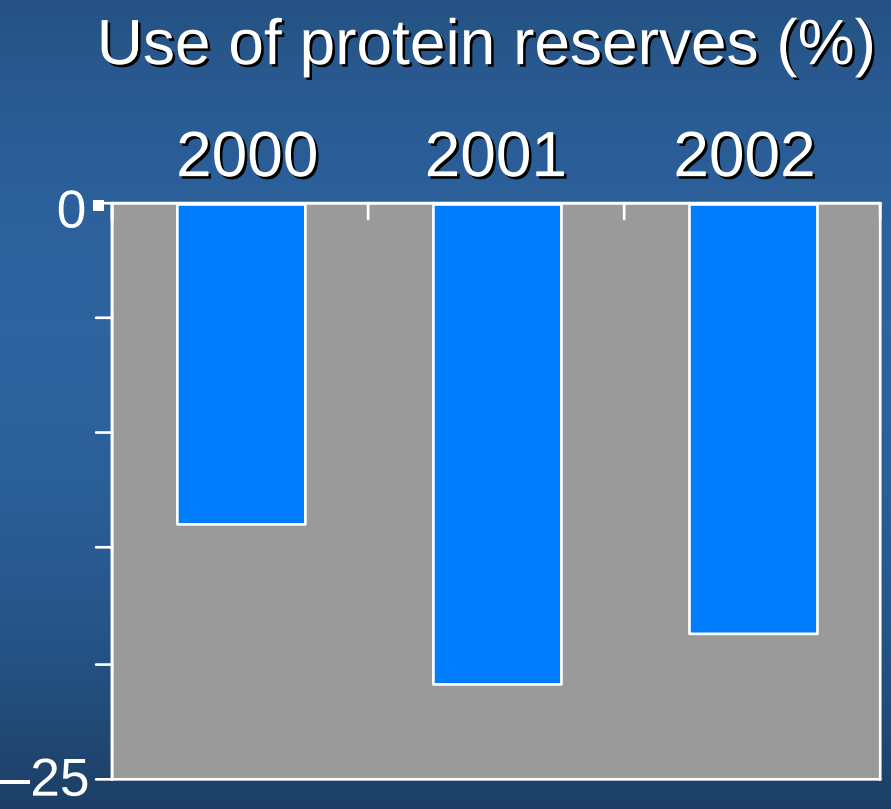


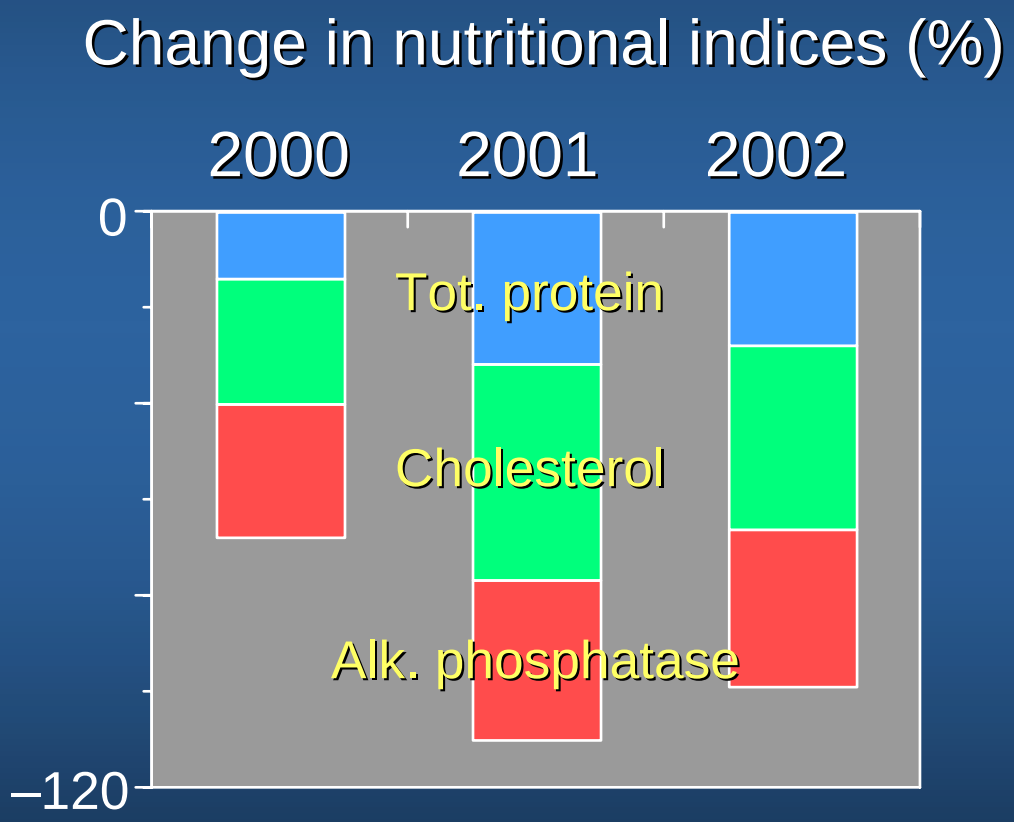
Plasma AP* activity, migrating and fasted/fed fish



*Alkaline phosphatase, U/L

Changes in body protein reserves and in plasma nutritional indices during travel through the hydropower system (LGR to BON), 2000-2002





Conclusions
Nutritional Indices in migrating S/S CS

- Some nutritional indices (condition factor, lipid stores, cholesterol) declined to an even greater extent in migrating fish than in fish fasted for over 30 d in the laboratory, suggesting (1) limited food intake by migrating fish and (2) higher energy costs than for fish held in the laboratory.
- Alkaline phosphatase activity was, however, higher in fish sampled at BON than in fasted fish, indicating some feeding by migrating fish.
- The data did not indicate that increased food intake in a lower-flow, warmer year (2001) compensated for the effects of longer migration times.

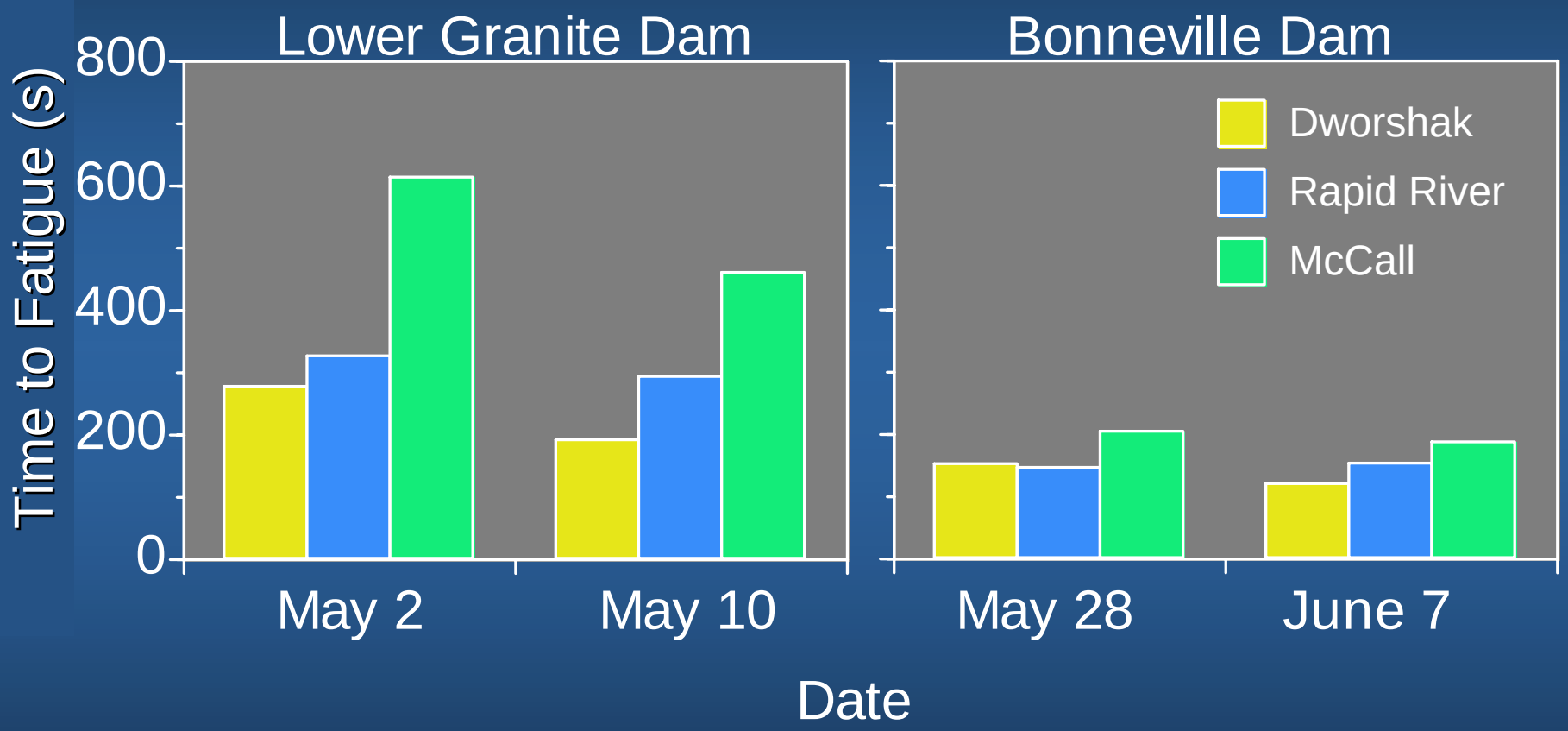
III. Performance testing of S/S Chinook salmon before and after hydrosystem passage

- Swimming performance
- Reponse to seawater challenge

Also:

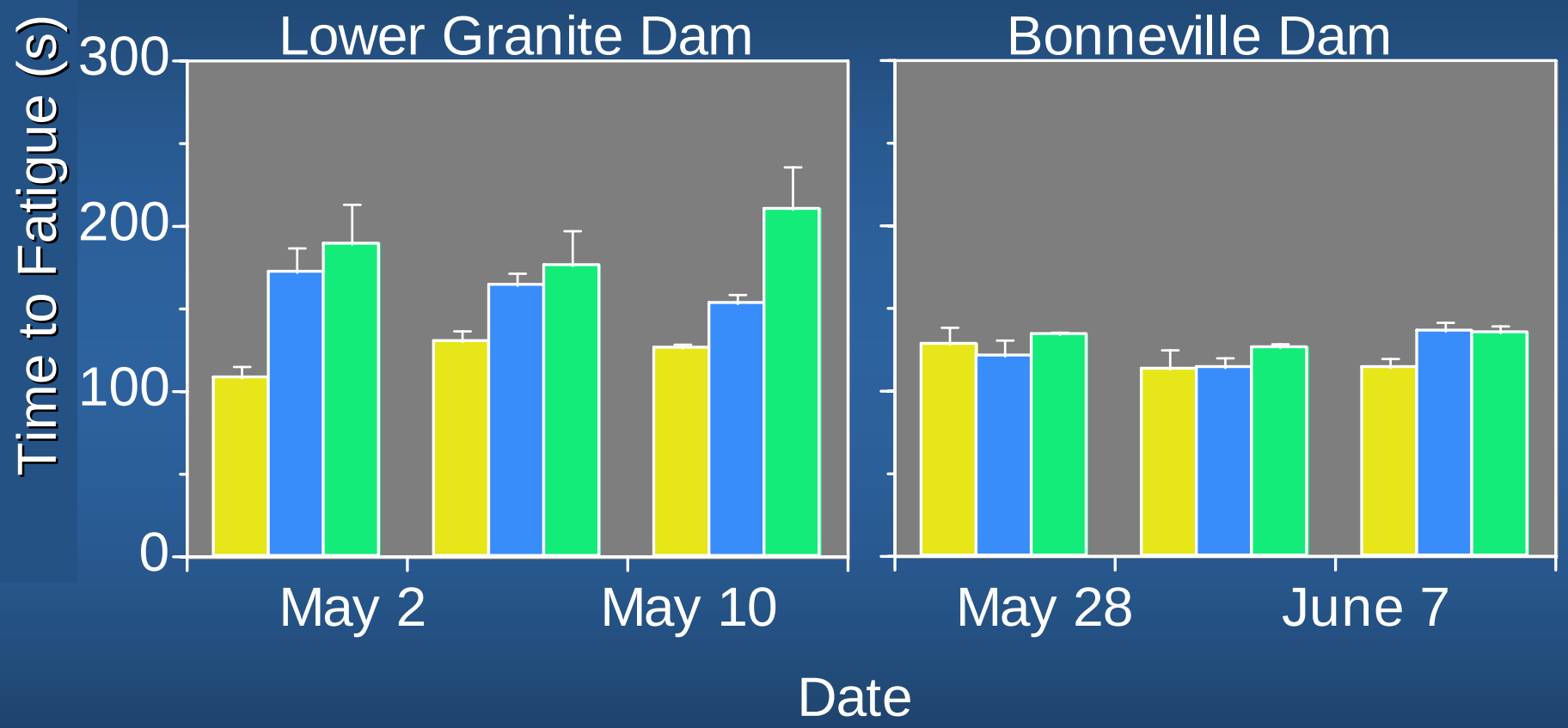
- Gill Na^+,K^+–ATPase activity
- Muscle enzyme activities (LDH, CS).

Mean Time to Fatigue in Fixed-Velocity Swimming Test, 2001



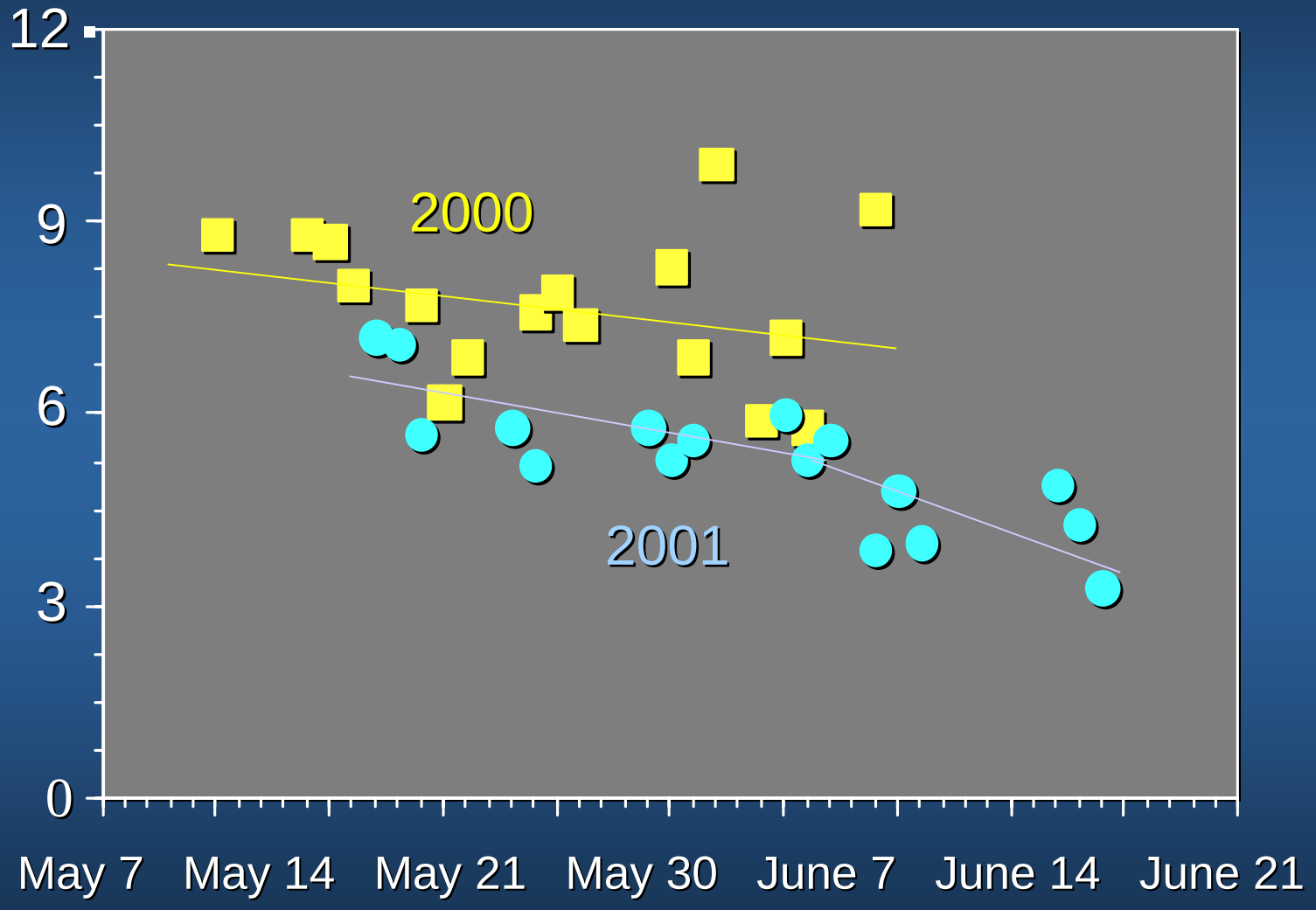
M.S. Thesis in progress, Derek Fryer, U.I.

Mean Time to Fatigue in Fixed-Velocity Swimming Test, 2002



M.S. Thesis in progress, Derek Fryer, U.I.

Gill Na^+, K^+ –ATPase activities in migrating fish sampled at Bonneville Dam, 2000 and 2001.



Overall Conclusions (1/4)

- Body lipid reserves were depleted (< 1% body weight) in migrating fish in all years.
- Use of body protein reserves increased after lipid reserves were exhausted.
- Migrating fish used 10% of body protein reserves in 1999, 14% in 2000, 21% in 2001, and 19% in 2002.

Conclusions (2/4)

- Some performance capabilities decreased during migration through the HP system:
  - Sprint swimming ability (2001, 2002)
  - Gill Na^+,K^+–ATPase activities (late-season 2001) and osmoregulatory ability (1999, 2000, 2001; data not shown).
- Activities of some key metabolic enzymes (LDH, CS) were lower in fish sampled at BON than at LGR (2000, 2001; data not shown).

Conclusions (3/4)

- Blood-chemistry indices indicated low rates of food consumption by migrating fish.
- Depletion of lipid & protein reserves did not seem to be counteracted by increased food availability later in the season.
- Depletion of energy reserves may be the primary reason for poorer in-river survival of later-migrating fish.
- …and may also reduce early marine survival.

Conclusions/qualifications (4/4)

- Depletion of energy reserves would be most likely to adversely affect survival:
  - Of later-migrating fish.
  - In lower-flow years.
  - In years when conditions are less favorable in the marine environment.

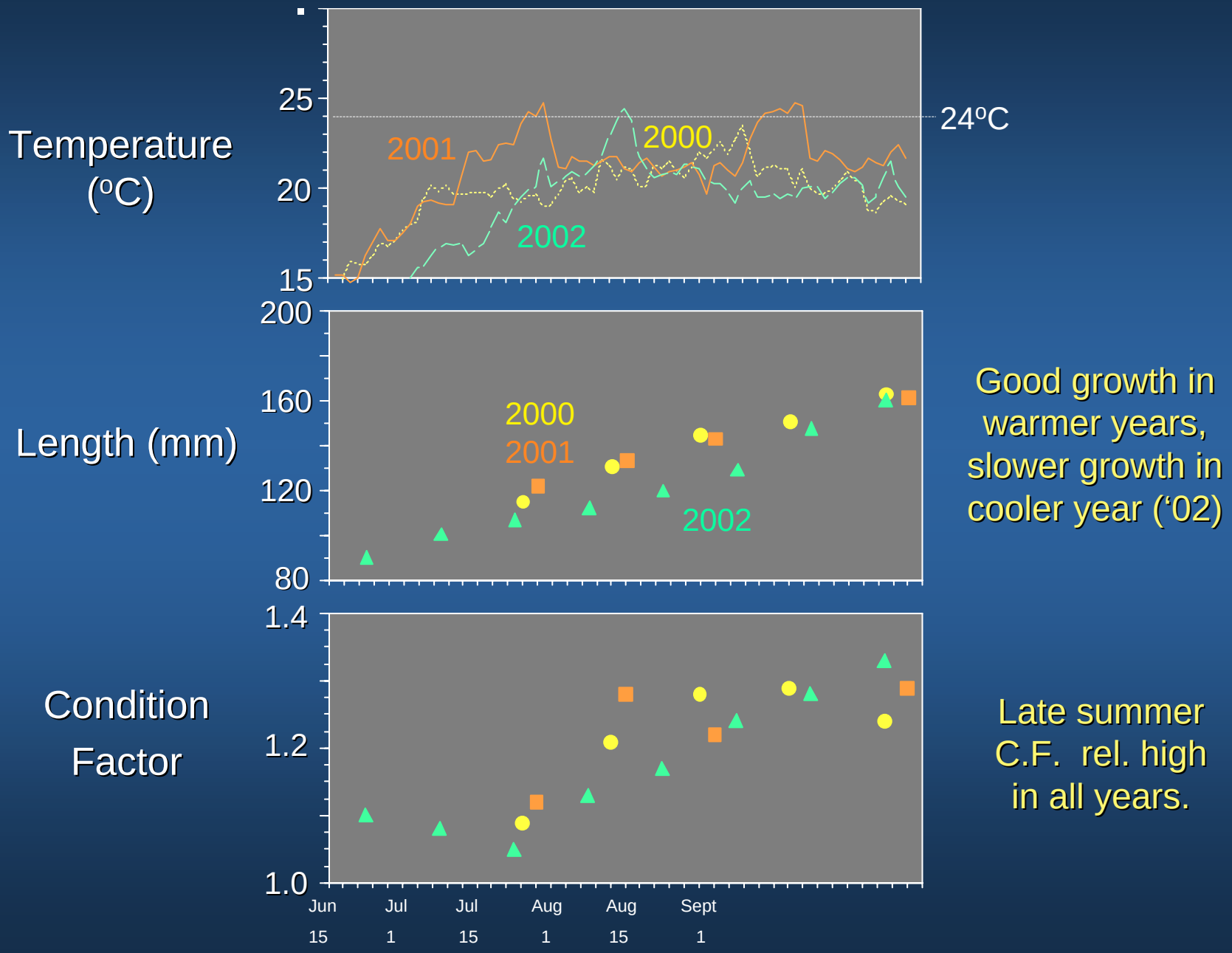
IV. Field Studies, Fall Chinook salmon

PIT-tagged 0-age Chinook salmon were diverted at Lower Granite Dam (2000, 2001, 2002) and Bonneville Dam (2002, $n = 27$).

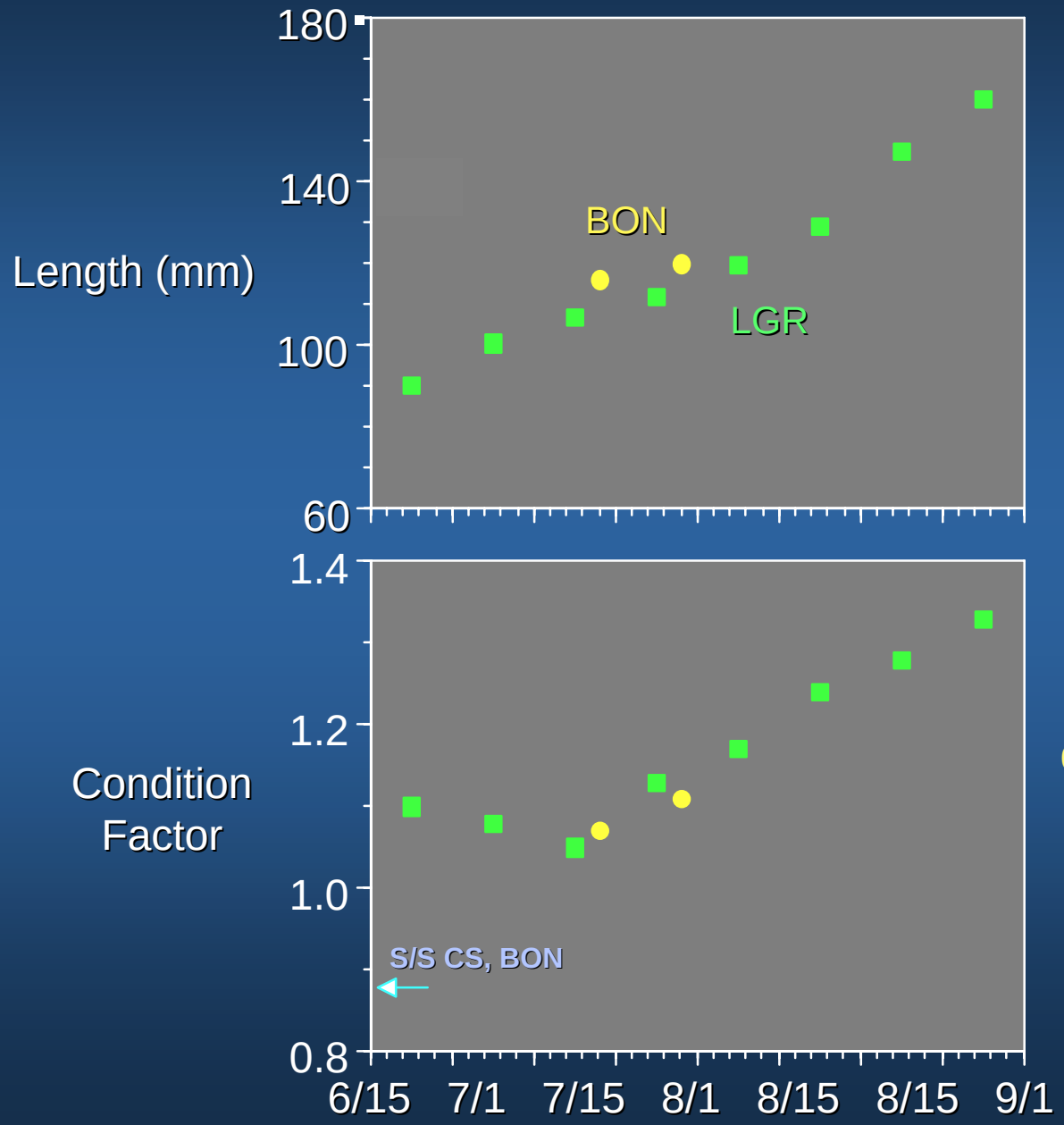
Some data for:

- Fish that migrated through the hydrosystem in early summer (sampled at BON).
- Fish that passed (migrating?) LGR later in the summer

Temperature (ºC, WQM), Fork Length, and Condition Factor (*n* = 6 to 22 per date) of age-0 Chinook salmon passing Lower Granite Dam, 2000-2003



Fork length and *condition factor* of 0-age CS sampled at LGR and BON, 2002.

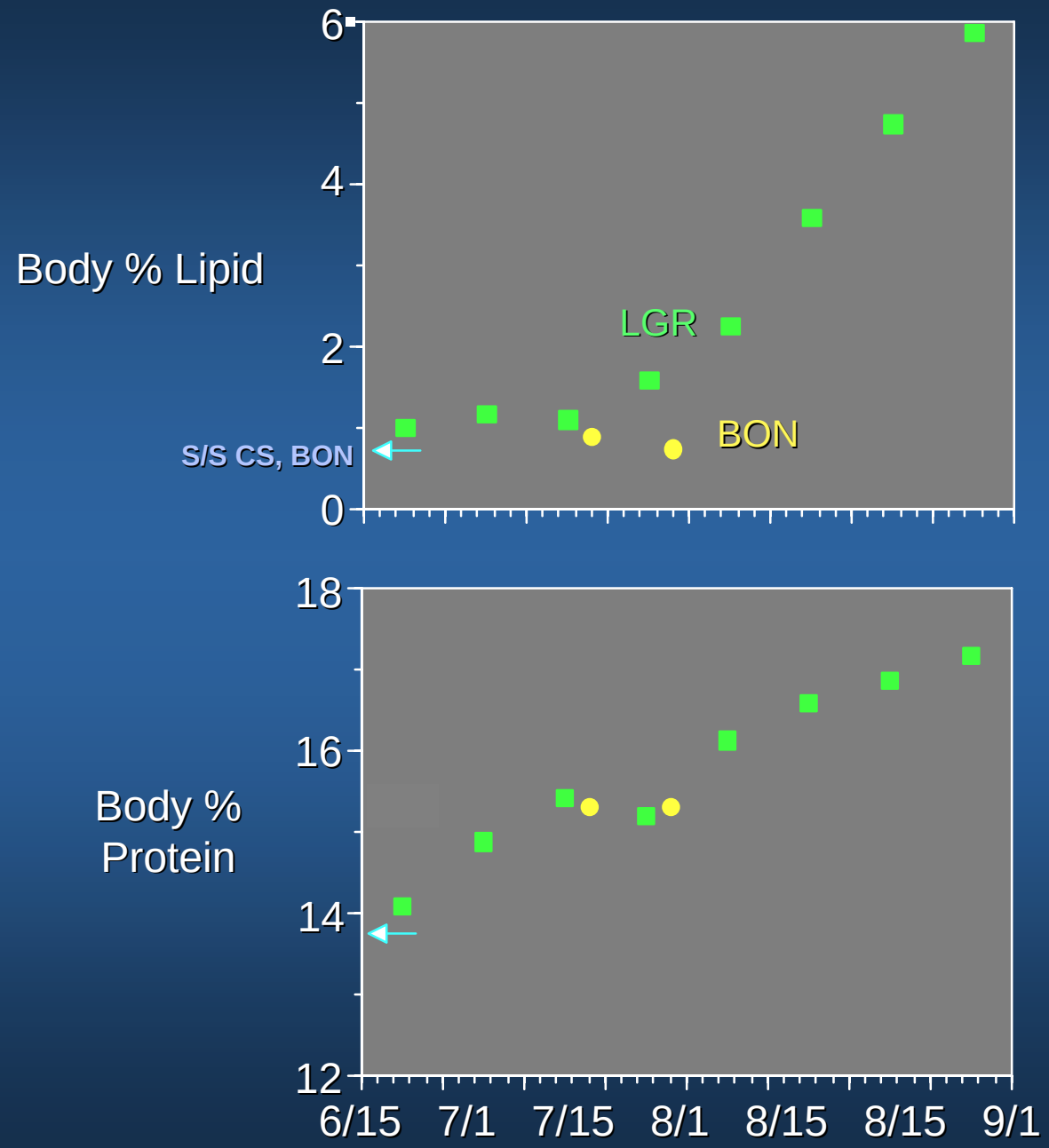


Two life-history types.

No apparent drop in C.F. during migration.

C.F. high relative to S/S CS at all times.

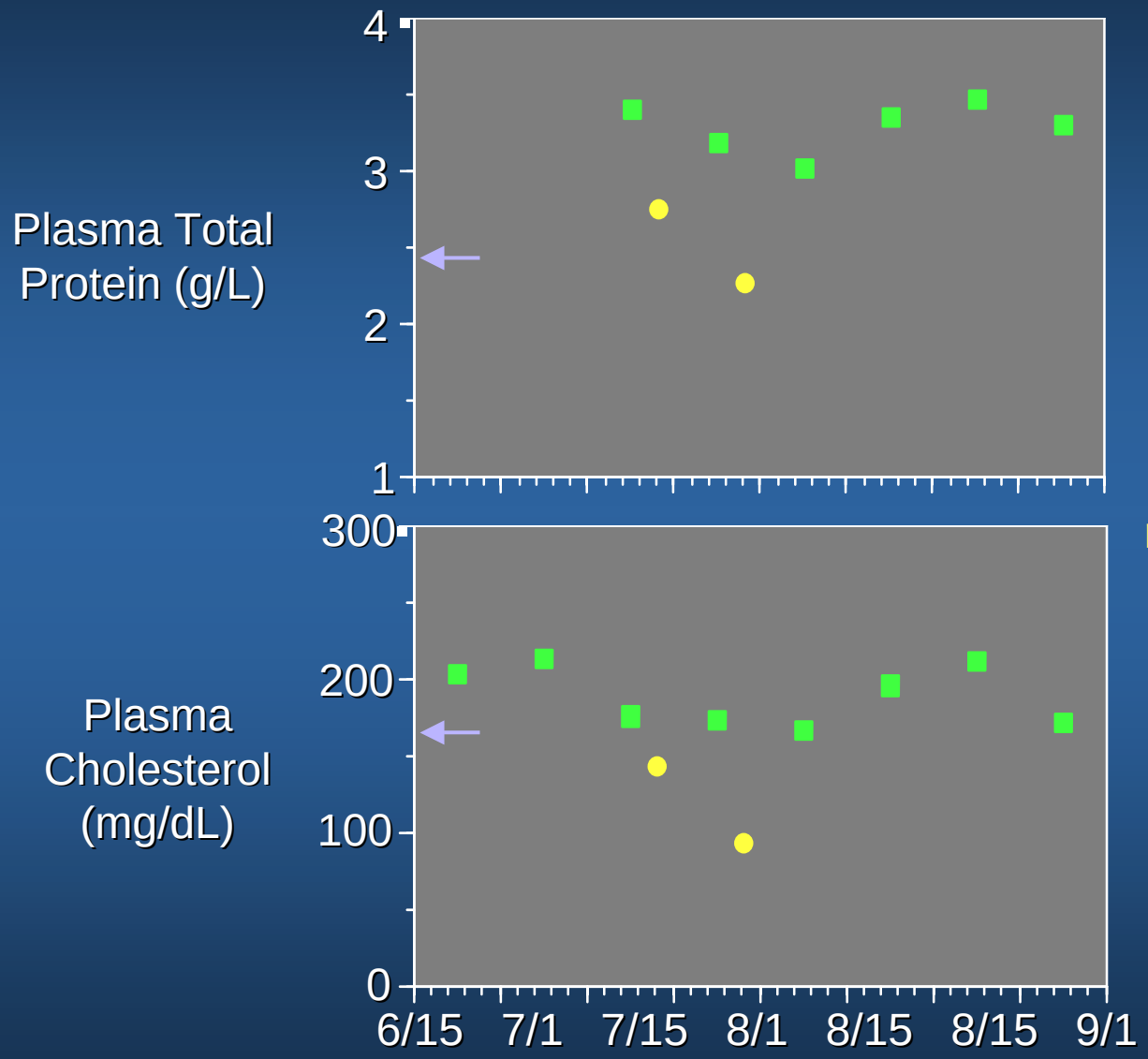
Indices of *body composition* in 0-age CS sampled at LGR and BON, 2002.



Lipid reserves of migrating fish are depleted, as in S/S Chinook S.

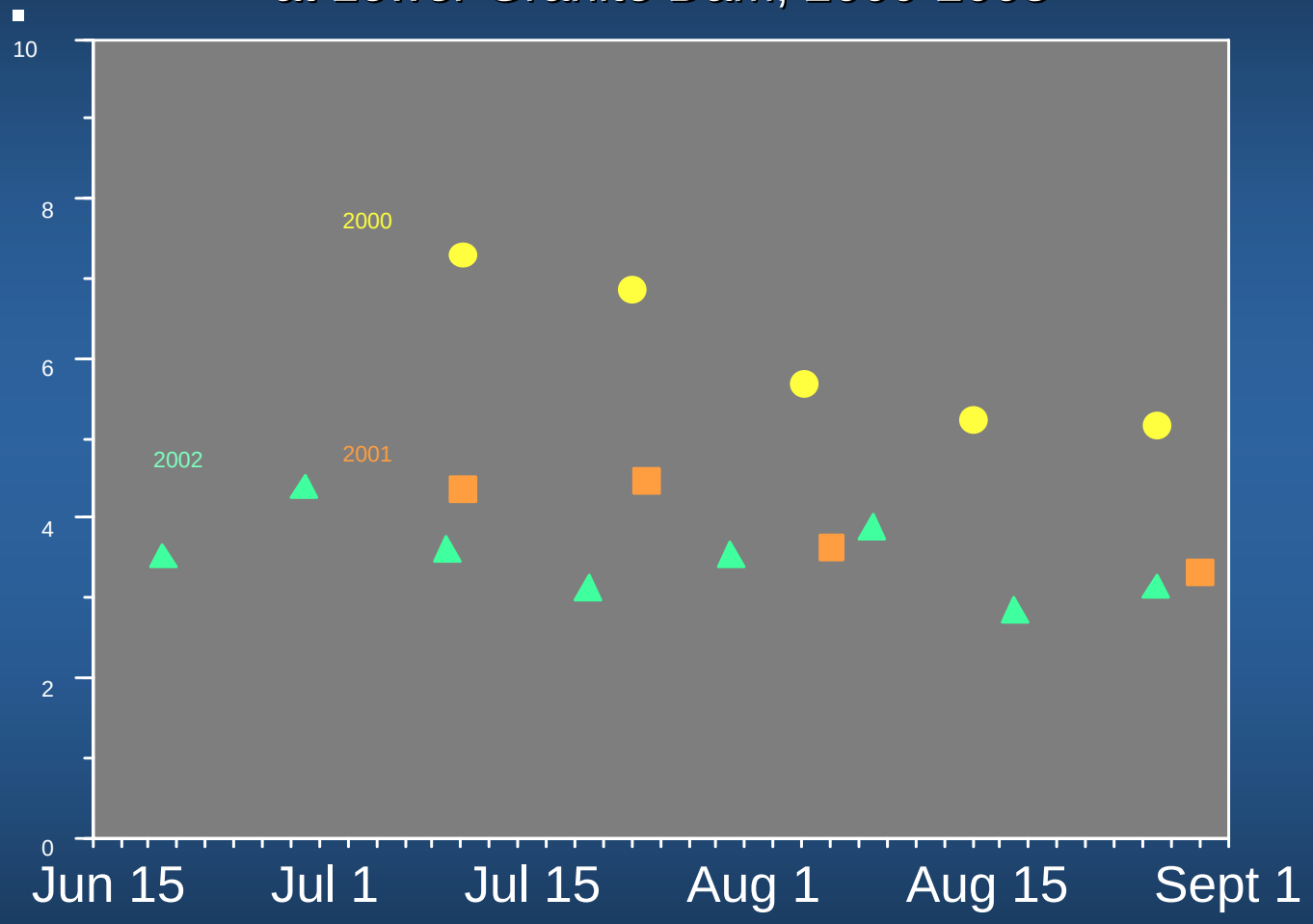
Body protein is not depleted.

Indices of *feeding activity* in 0-age CS sampled at LGR and BON, 2002.



Feeding of migrating fish appears to be low relative to fish that remain in LGR reservoir.

Gill Na^+, K^+–ATPase, age-0 Chinook salmon at Lower Granite Dam, 2000-2003



Summary, Fall CS (1/2)

- The lipid reserves of 0-age Chinook salmon that migrated through the hydropower system in early summer, 2002, were depleted (similar to migrating S/S Chinook salmon), but protein reserves were maintained. [Caveat: Flows (high in June) and temperatures (low) may have been particularly favorable in 2002]

- 0-age Chinook salmon that remained in Lower Granite reservoir until mid- to late summer continued to grow and accumulate energy reserves (2000, 2001, 2002). [The fish passing LGR were in good condition, but survival rates in the reservoir are not known]

Summary, Fall CS (2/2)

- Gill Na^+, K^+– ATPase activities) were higher in 2000 (an intermediate temperature and flow year) than in either 2001 (a warm, low-flow year) or 2002 (a cool, higher-flow year). These differences may have been related to temperature, to flow, or to other factors.

- The smoltification status (as indicated by gill Na^+, K^+– ATPase activities) of the fish that remained in Lower Granite reservoir declined throughout the summer. The probability of downstream migration may also decline over time.

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- NOAA Fisheries
- Many individuals