FORAGING ECOLOGY OF NONNATIVE TROUT IN THE COLORADO RIVER, GRAND CANYON: PREDATION ON NATIVE FISHES AND THE EFFECTS OF TURBIDITY

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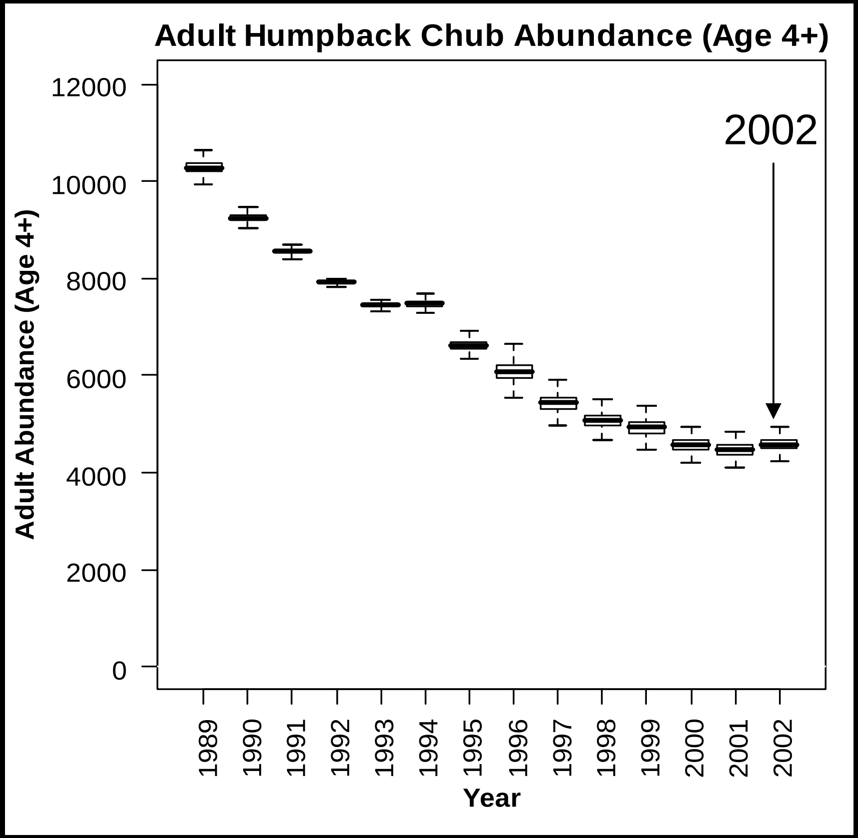
Preliminary results – subject to review and revision



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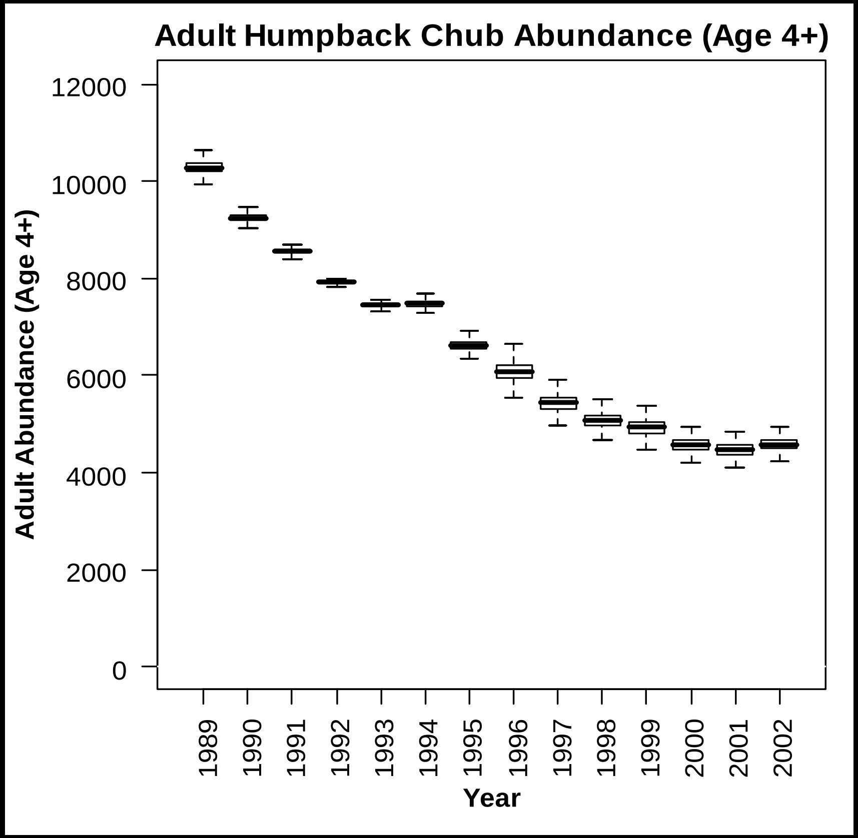

Preliminary results – subject to review and revision

OBJECTIVES

1. Determine the incidence of piscivory by rainbow trout and brown trout on native fishes

2. Compare the use vs. availability of different invertebrate and fish prey by these trout

3. Evaluate how turbidity affects prey availability and utilization, including the degree of piscivory.

   a. Model the effects of turbidity on drift foraging.

   b. Estimate the quantity of native fish consumed by nonnative trout under management scenarios with and without fish suppression

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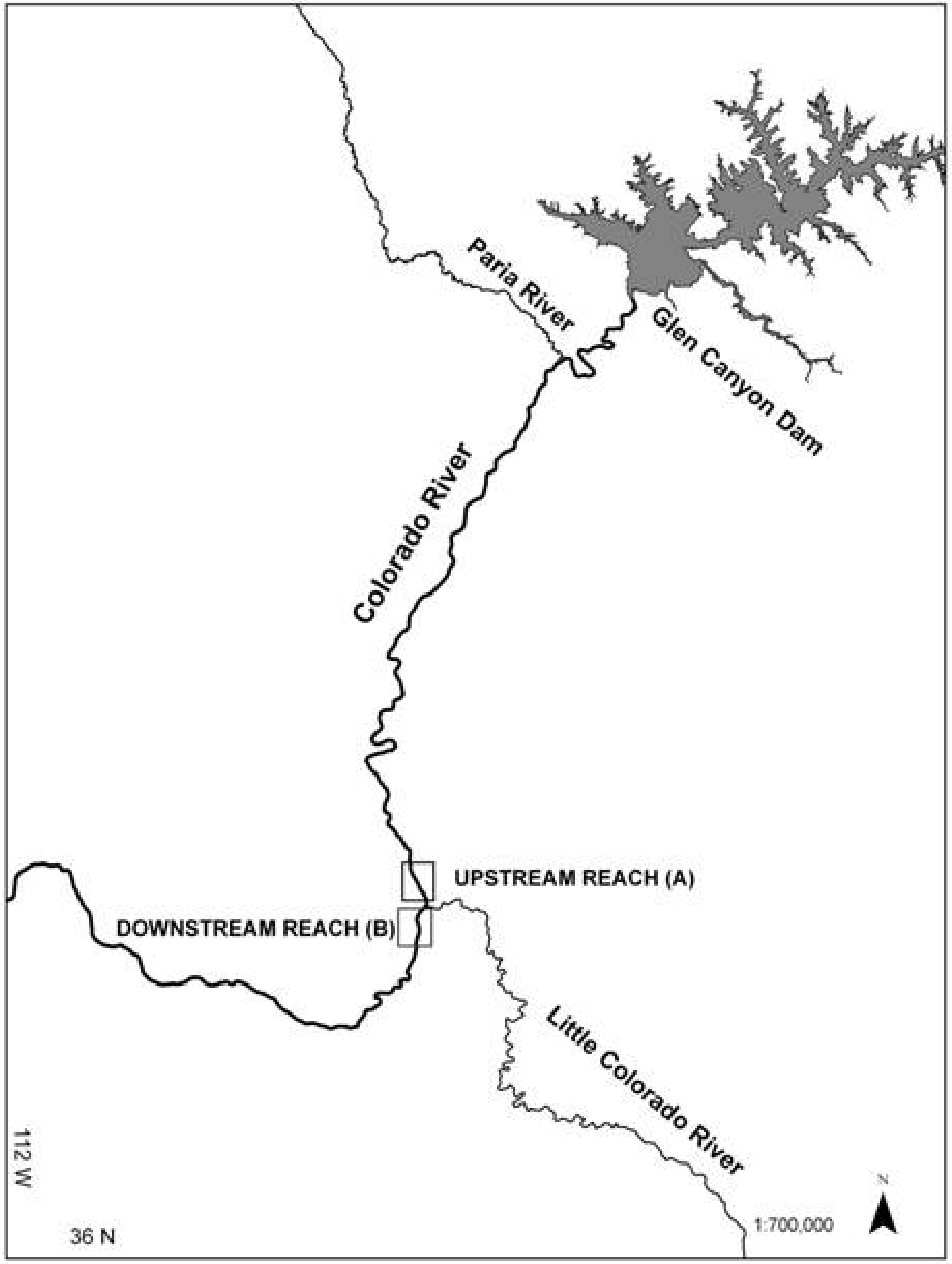

Preliminary results – subject to review and revision

Sampling Method (2003-2004)

- Fish Sampling
  - Electrofishing
    - Depletion passes
      - 2 to 5 passes / trip
      - 6 trips / year
      - 2 years (2003-2004)

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Sampling Method

- Fish Sampling
- Prey Availability
  - Drift Monitoring
    - Sampling (2003)
  - Benthic Monitoring
    - Sampling (2004)
  - Electrofishing CPUE
    - Sampling (2003-2004)

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Preliminary results – subject to review and revision

Diet Analysis

- Standard Fish Metrics
  - Abundance
  - Condition factors

Preliminary results – subject to review and revision

Diet Analysis

- Standard Fish Metrics
- Frequency of Occurrence

- Rainbow Trout (n = 17,258)
- Brown Trout (n = 479)

– Incidence of piscivory

– Stomach emptiness

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Diet Analysis

- Standard Fish Metrics
- Frequency of Occurrence

- Diet Composition
  - Stratified-random sampling
    - Trip
    - Species
    - Location
    - Size (adult > 250 mm TL)
  - Samples
    - Rainbow Trout (n = 956)
    - Brown Trout (n = 372)
  - Diet proportions (% Weight)

Preliminary results – subject to review and revision

Diet Analysis

- Standard Fish Metrics
- Frequency of Occurrence
- Diet Composition

- Diet Indices
  - Stomach Fullness
  - Drift Electivity Index

Preliminary results – subject to review and revision

Diet Analysis

- Standard Fish Metrics
- Frequency of Occurrence
- Diet Composition
- Diet Indices

- Models
  - Encounter Rates
  - Piscivory Estimates

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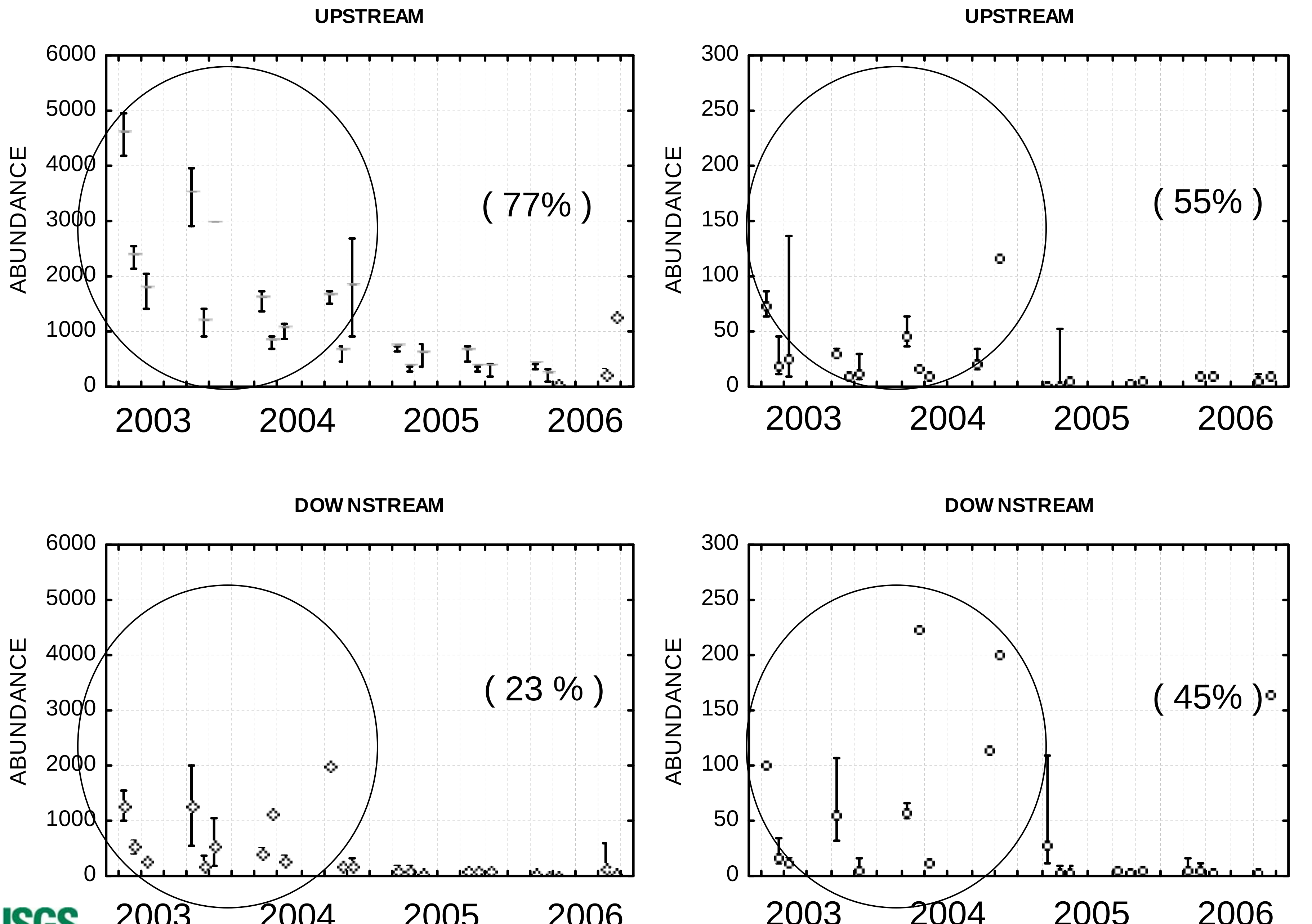
Preliminary results – subject to review and revision

RAINBOW TROUT

BROWN TROUT



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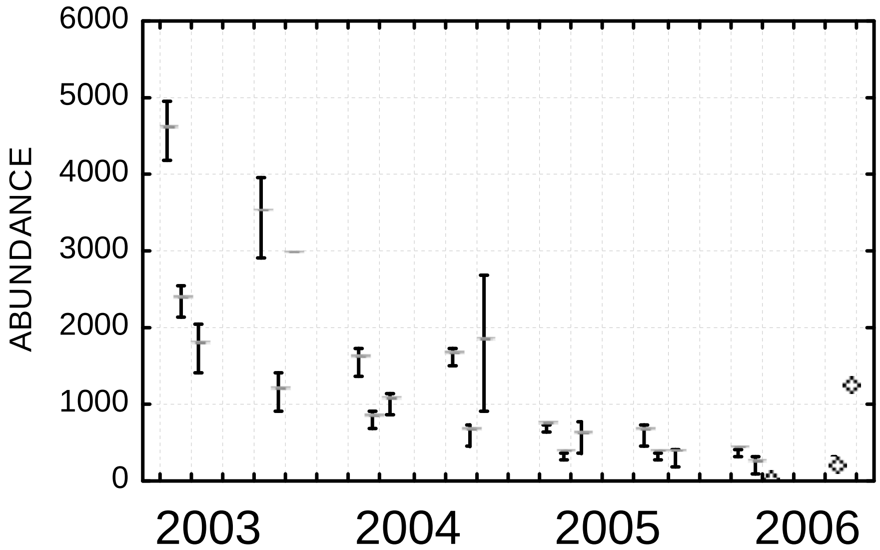
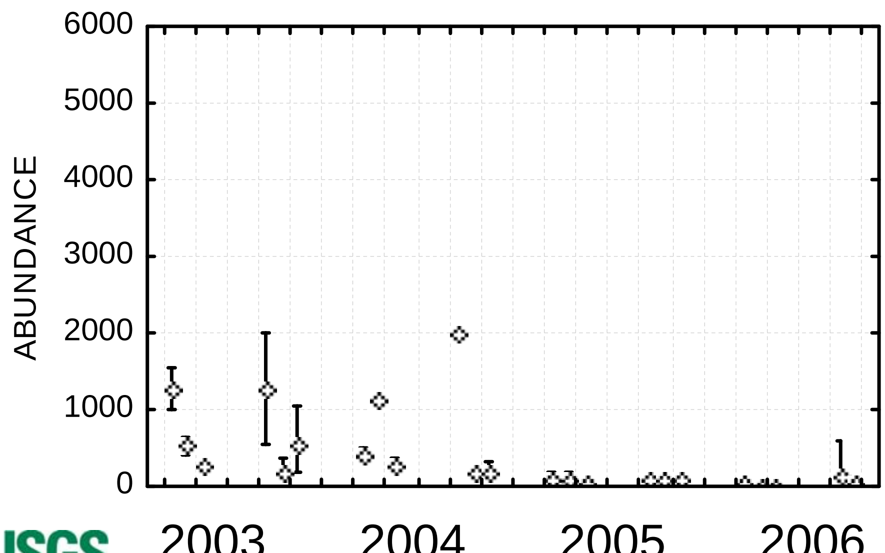
RAINBOW TROUT

UPSTREAM



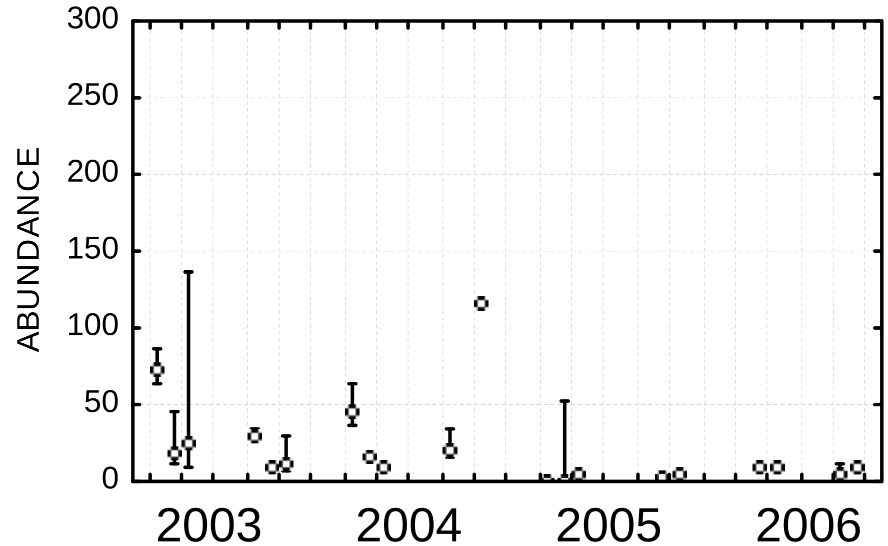
(98%)

DOWNSTREAM



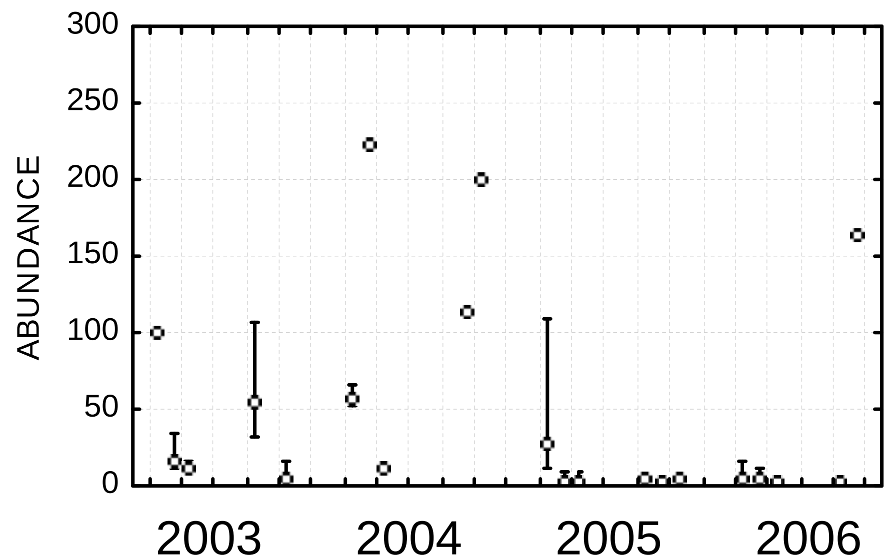
BROWN TROUT

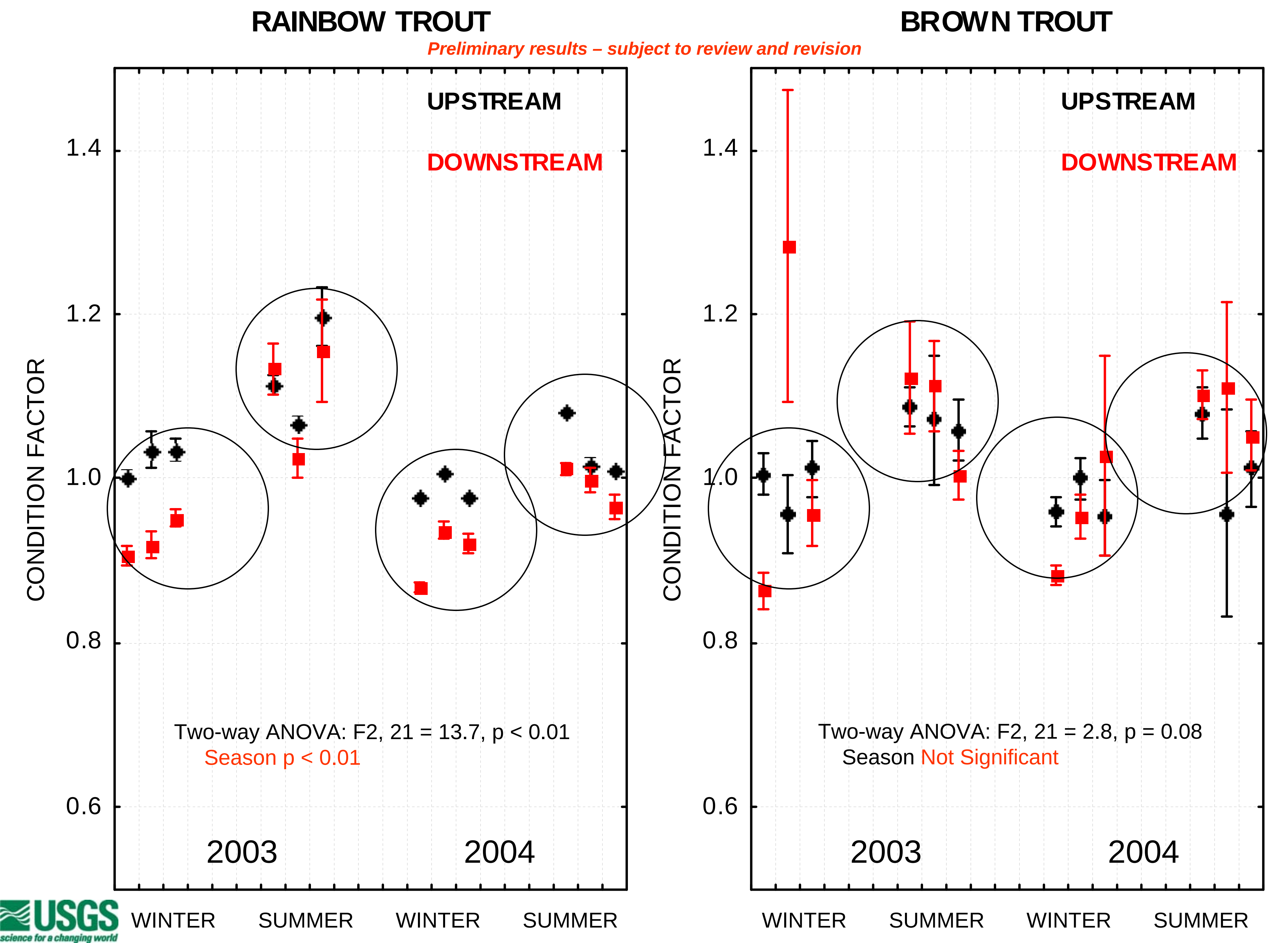
UPSTREAM



(2%)

DOWNSTREAM




RAINBOW TROUT
BROWN TROUT
Preliminary results – subject to review and revision
UPSTREAM
DOWNSTREAM
CONDITION FACTOR
1.4
1.2
1.0
0.8
0.6
Two-way ANOVA: F2, 21 = 13.7, p < 0.01
Season p < 0.01
Two-way ANOVA: F2, 21 = 2.8, p = 0.08
Season Not Significant
2003
2004
WINTER
SUMMER
WINTER
SUMMER
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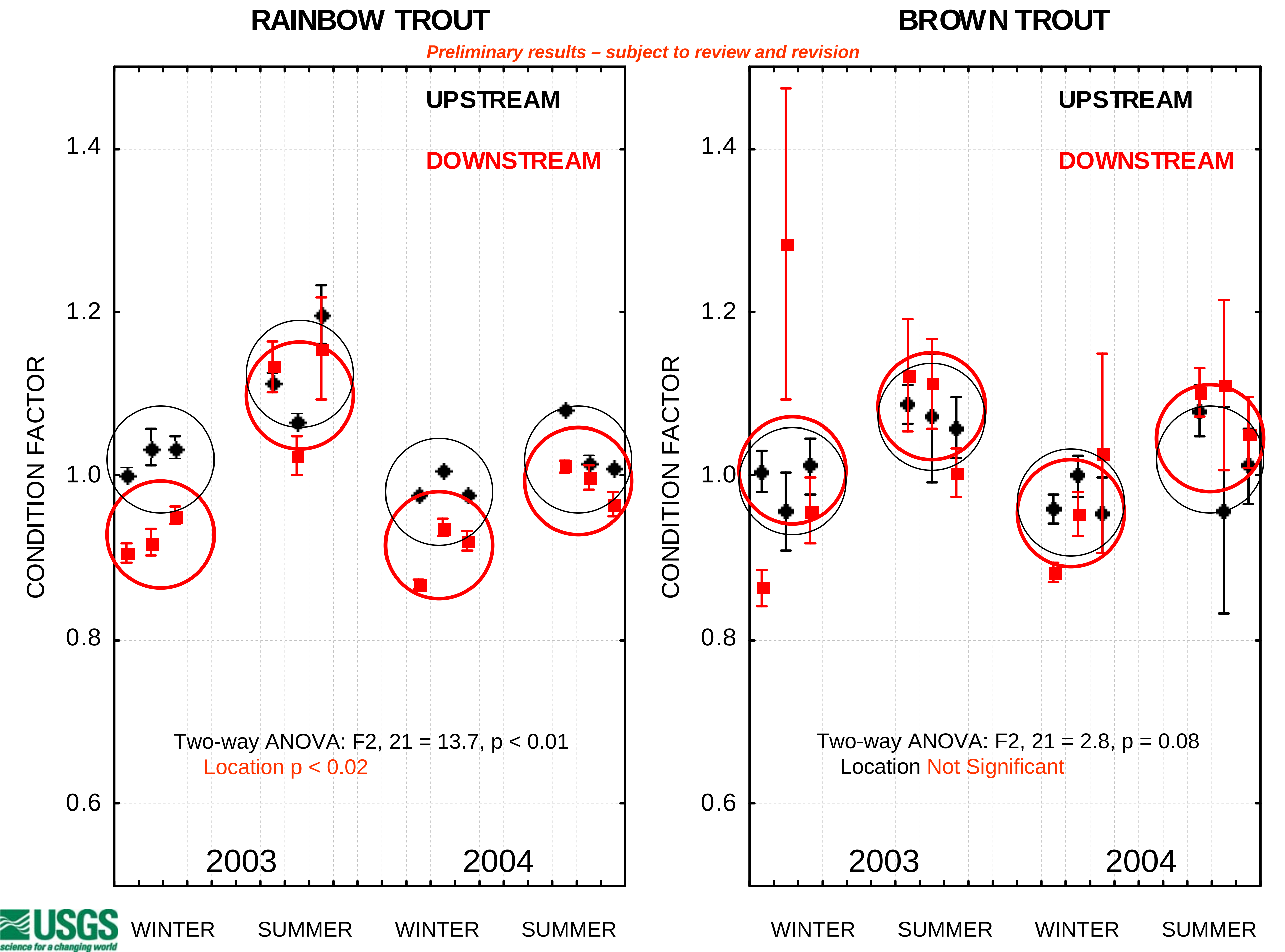
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UPSTREAM
DOWNSTREAM
CONDITION FACTOR
1.4
1.2
1.0
0.8
0.6
Two-way ANOVA: F2, 21 = 13.7, p < 0.01
Location p < 0.02
Two-way ANOVA: F2, 21 = 2.8, p = 0.08
Location Not Significant
2003
2004
WINTER
SUMMER
WINTER
SUMMER
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Research Questions

- Why were there differences among trout?

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- Why were fish abundance levels and condition factors different between upstream and downstream sites?

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- Why were there differences among trout?
- Why were fish abundance levels and condition factors different between upstream and downstream sites?
- Were these spatial differences related to food availability?
- And how did prey availability and turbidity contribute to the incidence of piscivory?

Preliminary results – subject to review and revision

INCIDENCE OF PREDATION

(Rainbow and Brown Trout)

VERTEBRATE PREY

ORIGIN	TYPE	PREY PROPORTIONS
AQUATIC	FISH	90.3%
TERRESTRIAL	OTHER	2.5%
	LIZARDS	1.2%
	BIRDS	0.8%
	BATS	0.2%
UNKNOWN	VERTEBRATE	5.0%

Preliminary results – subject to review and revision

INCIDENCE OF PISCIVORY

	Season	Location	OBSERVATIONS xP	OBSERVATIONS N	PARAMETERS MIP	PARAMETERS sd	PARAMETERS CV
RAINBOW TROUT	WINTER 2003	Upstream	46	5,347	0.9%	0.001	0.025
		Downstream	25	1,260	2.0%	0.004	0.079
	SUMMER 2003	Upstream	22	2,742	0.8%	0.002	0.034
		Downstream	39	1,528	2.6%	0.004	0.081
	WINTER 2004	Upstream	13	2,382	0.5%	0.002	0.030
		Downstream	11	1,030	1.1%	0.003	0.064
	SUMMER 2004	Upstream	5	924	0.5%	0.002	0.048
		Downstream	23	772	3.0%	0.006	0.122
BROWN TROUT	WINTER 2003	Upstream	4	84	8.3%	0.030	0.603
		Downstream	16	48	33.3%	0.068	1.361
	SUMMER 2003	Upstream	4	42	9.5%	0.045	0.906
		Downstream	29	63	46.0%	0.063	1.256
	WINTER 2004	Upstream	6	59	10.2%	0.039	0.787
		Downstream	50	109	45.9%	0.048	0.955
	SUMMER 2004	Upstream	4	25	16.0%	0.073	1.466
		Downstream	11	40	27.5%	0.071	1.412

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INCIDENCE OF PISCIVORY

(Rainbow and Brown Trout)

IDENTIFIABLE FISH PREY

TYPE	COMMON NAME	SPECIES	PREY PROPORTIONS
NATIVE FISH	FLANNELMOUTH SUCKER	*(Catostomus latipinnus)*	10.6%
	BLUEHEAD SUCKER	*(Catostomus discobolus)*	3.0%
	UNIDENTIFIABLE SUCKER	*(Catostomus sp.)*	28.8%
	HUMPBACK CHUB	*(Gila cypha)*	27.3%
	SPECKLED DACE	*(Rhinichthys osculus)*	15.2%
NON-NATIVE FISH	FATHEAD MINNOW	*(Pimephales promelas)*	7.8%
	RAINBOW TROUT	*(Oncorhynchus mykiss)*	7.3%

IDENTIFIABLE FISH PREY

TYPE	PREY PROPORTIONS	COMMUNITY COMPOSITION
NATIVE FISH	85.0%	30.0%
NON-NATIVE FISH	15.0%	70.0%

Preliminary results – subject to review and revision

Empty Stomachs

- Rainbow trout stomachs
  - Upstream
    - Summer 15.9%
    - Winter 3%
  - Downstream
    - Summer 66.7%
    - Winter - 10.2%
- Brown trout stomachs
  - Upstream
    - Summer 59.1%
    - Winter 58.7%
  - Downstream
    - Summer 81.2%
    - Winter 74.6%

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Preliminary results – subject to review and revision

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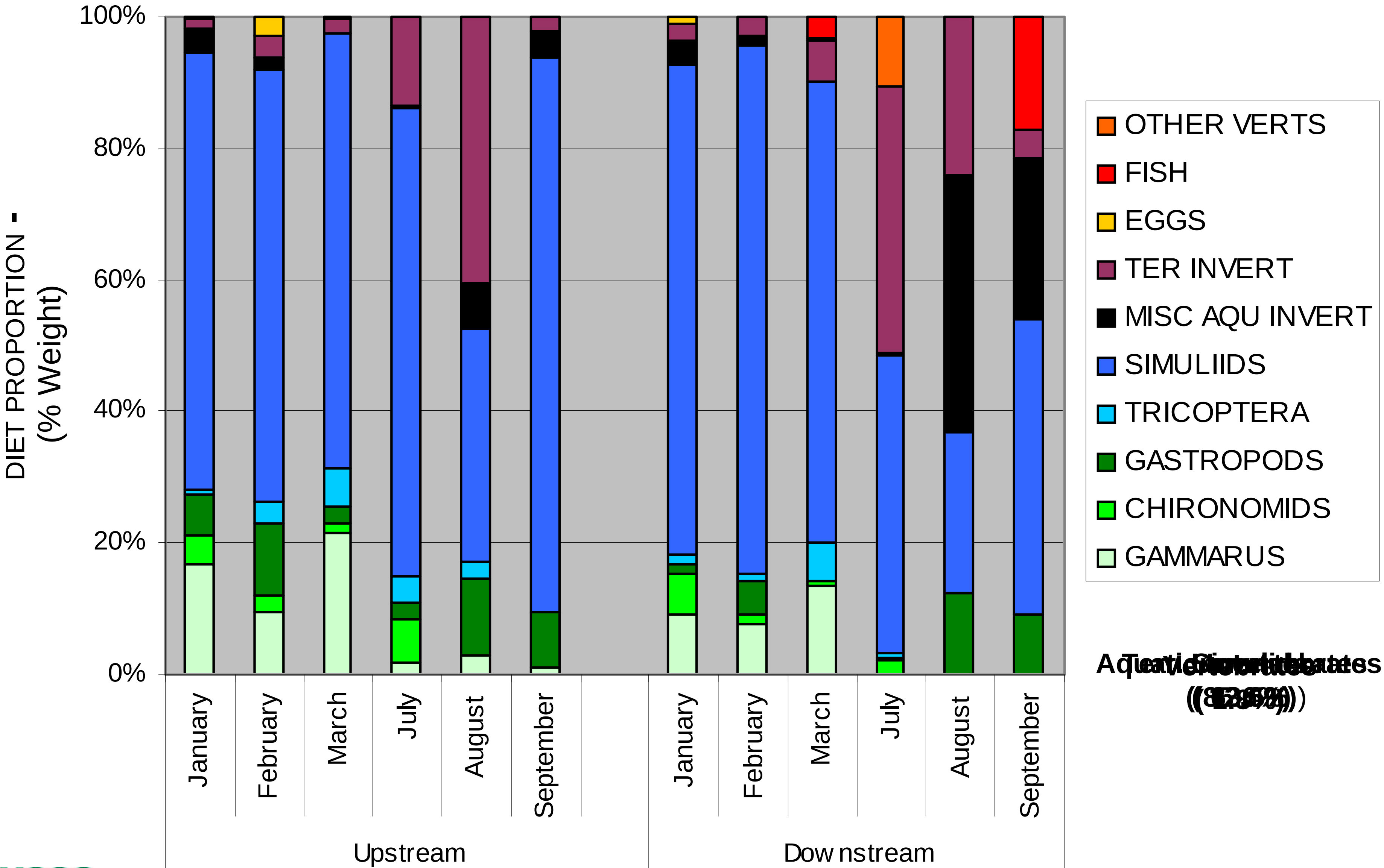
Preliminary results – subject to review and revision

Primary
Aquatic Invertebrate
Prey Available

Preliminary results – subject to review and revision

RAINBOW TROUT
2003-2004

N = 956



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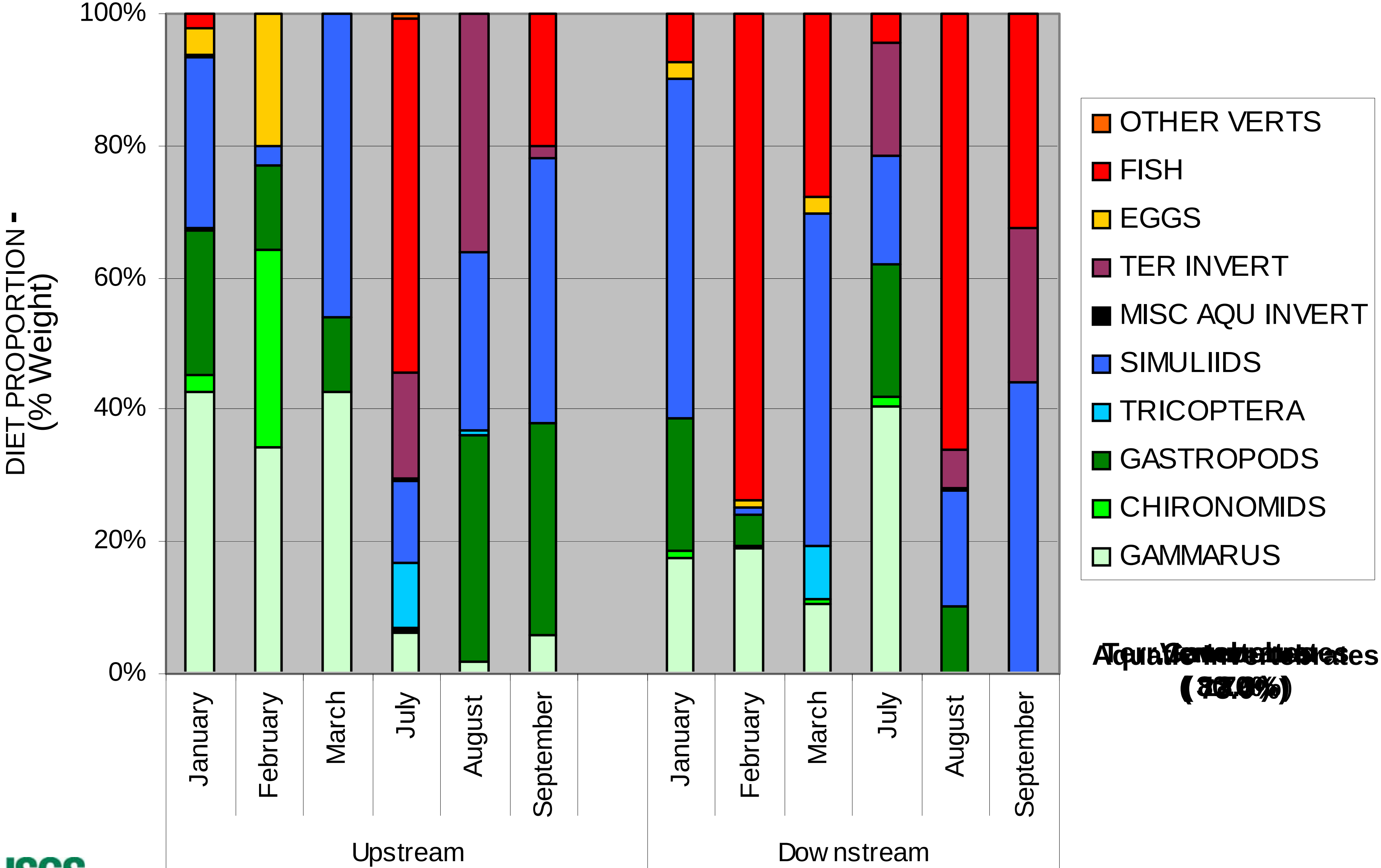
BROWN TROUT
2003-2004

N = 372



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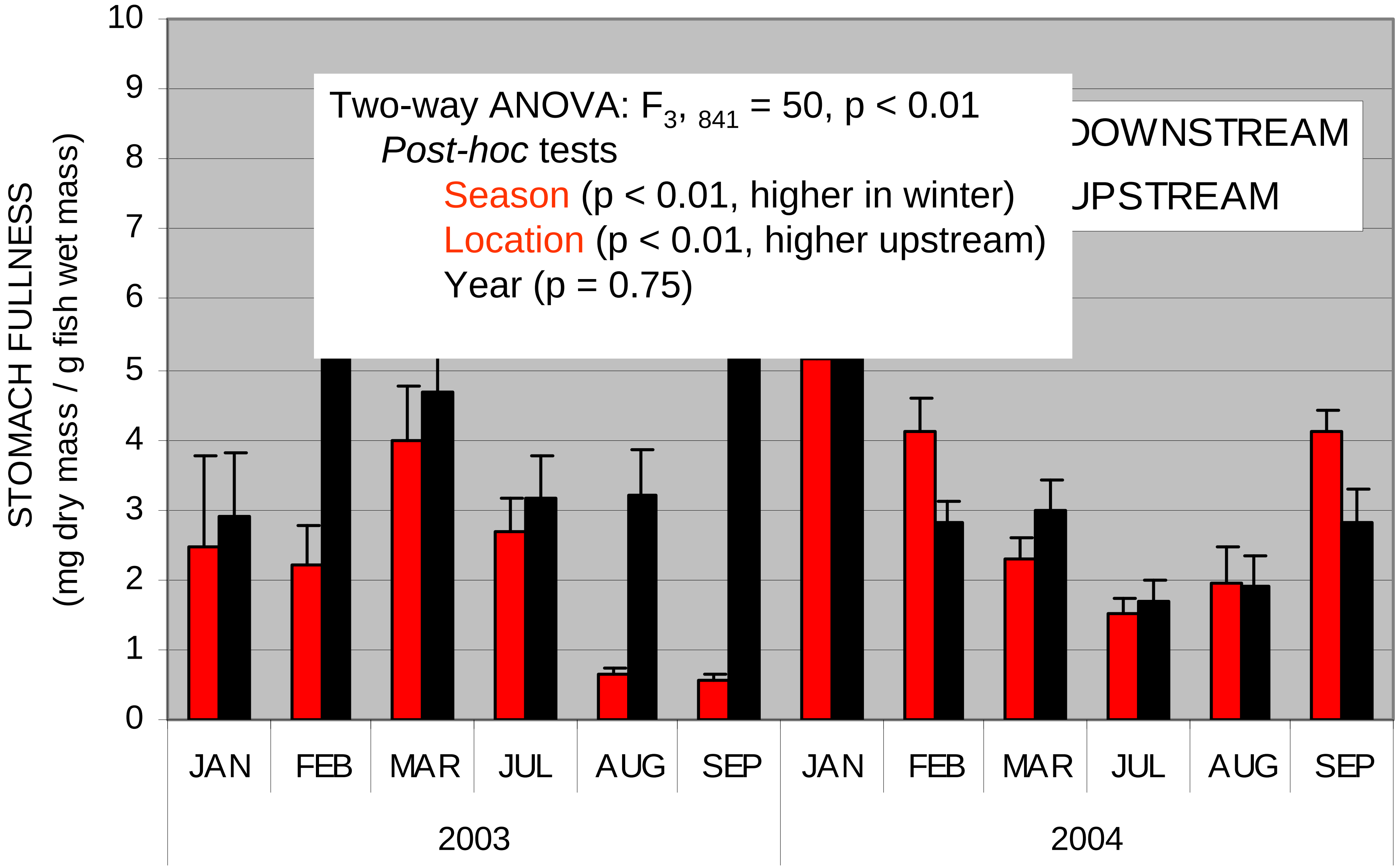
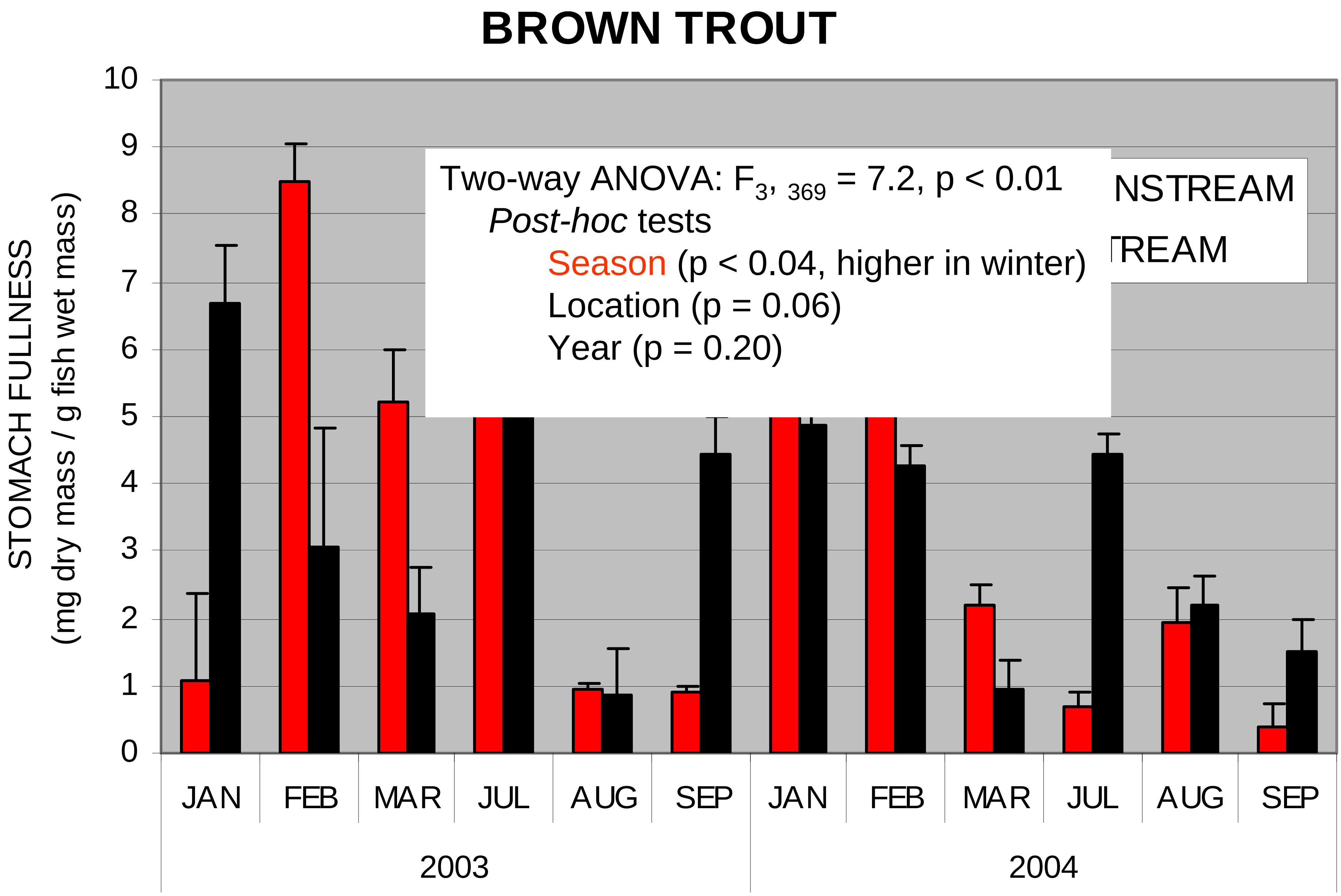
RAINBOW TROUT





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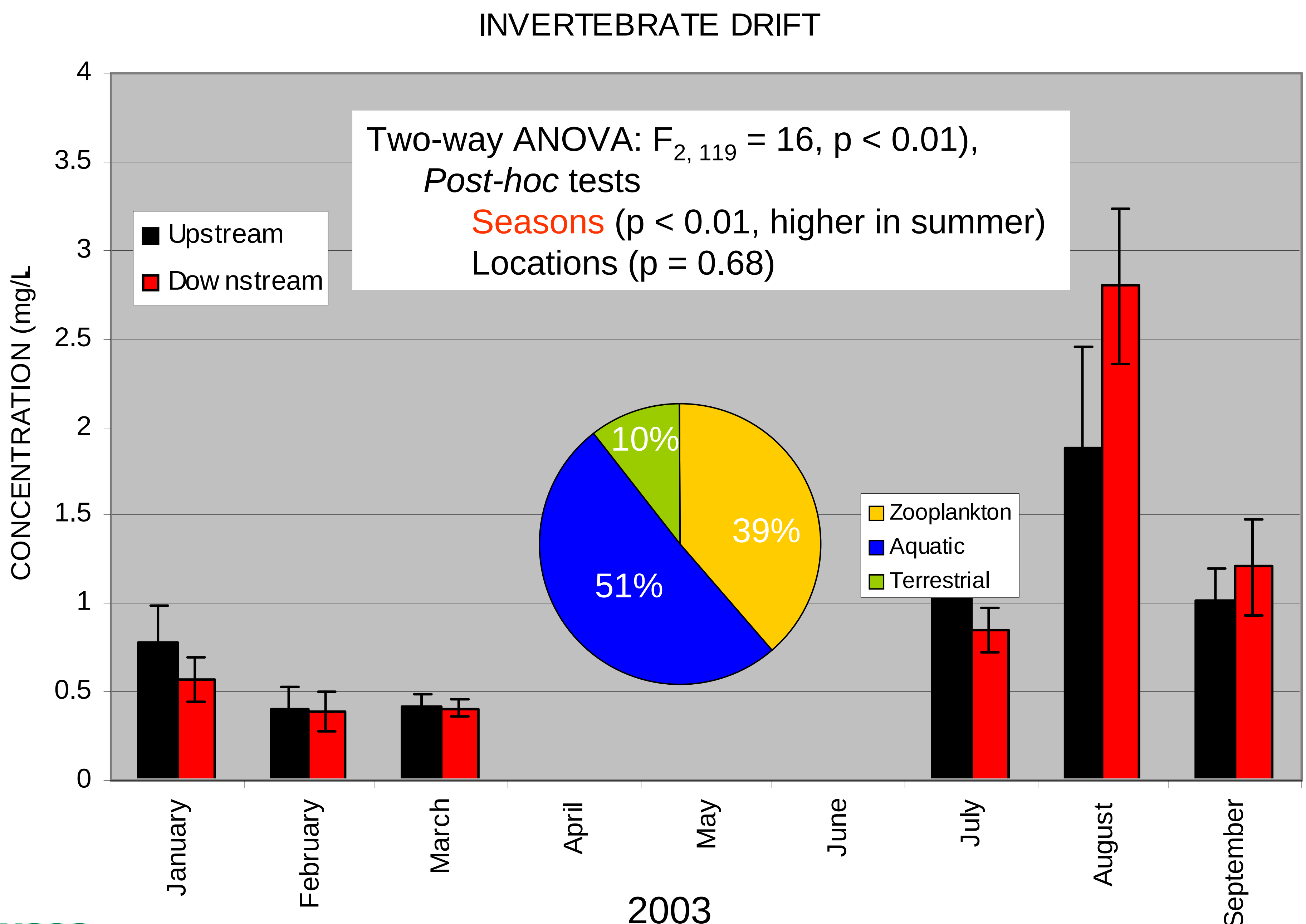
- Why are there spatial differences for rainbow trout?

- Is food availability limited downstream?



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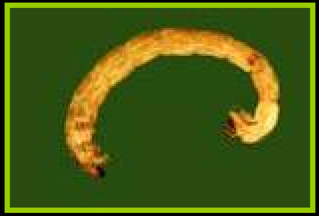

RAINBOW TROUT

ELECTIVITY INDEX
BASED ON DRIFT

	UPSTREAM	DOWNSTREAM
Gammarus	0.042	0.002
Chironomidae	-0.261	-0.203
Simulidae	0.290	0.263

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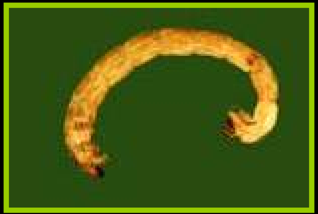
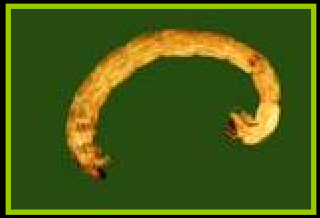


BROWN TROUT

ELECTIVITY INDEX
BASED ON DRIFT

	UPSTREAM	DOWNSTREAM
Gammarus	0.400	0.389
Chironomidae	-0.283	-0.274
Simulidae	-0.158	0.104

Preliminary results – subject to review and revision



BROWN TROUT

ELECTIVITY INDEX

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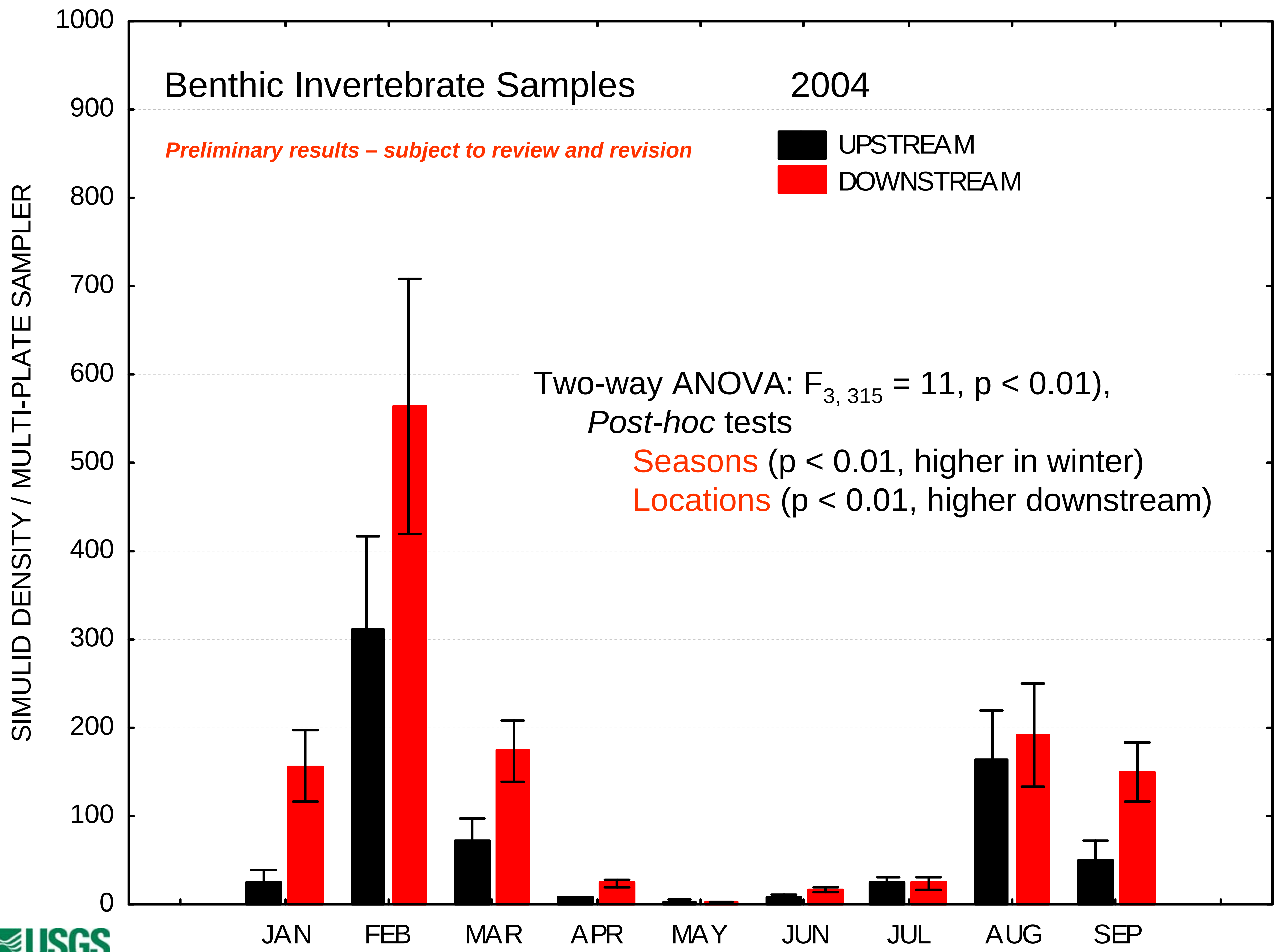

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Rainbow Trout

DIET PATTERNS

- Abundance is less downstream (23%)
- Condition factor is less downstream
- Stomachs are frequently empty downstream
- Stomachs are frequently empty in summer
- Stomach fullness is less downstream
- Stomach fullness is less in summer
- Diet composition remains the same upstream and downstream

PREY AVAILABILITY

- Drift prey availability is higher in summer
- Drift prey availability remains the same upstream and downstream
- Benthic prey availability is higher in winter
- Benthic prey availability is higher downstream

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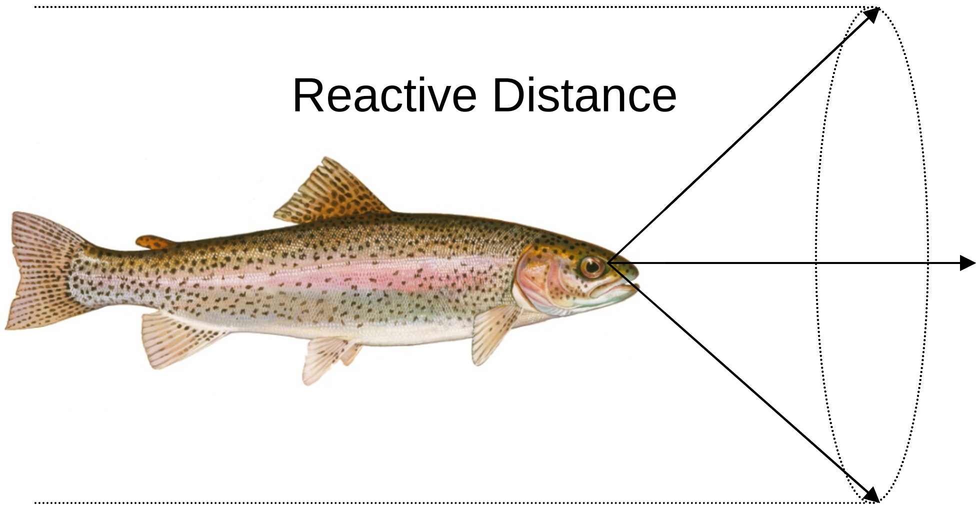
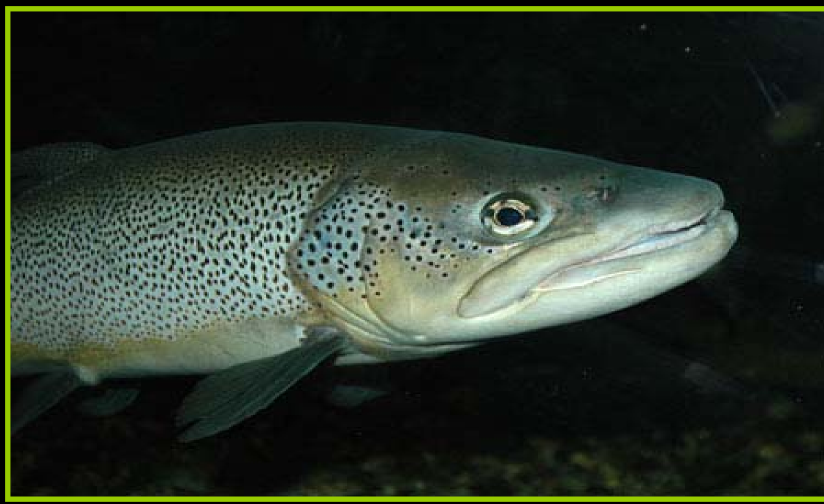
$$EncounterRate = SV \cdot p_i \cdot DT$$

Reactive Distance

Prey Availability



Sweka and Hartman 2001
Barrett et al 1992
Gerritsen and Strickler 1979



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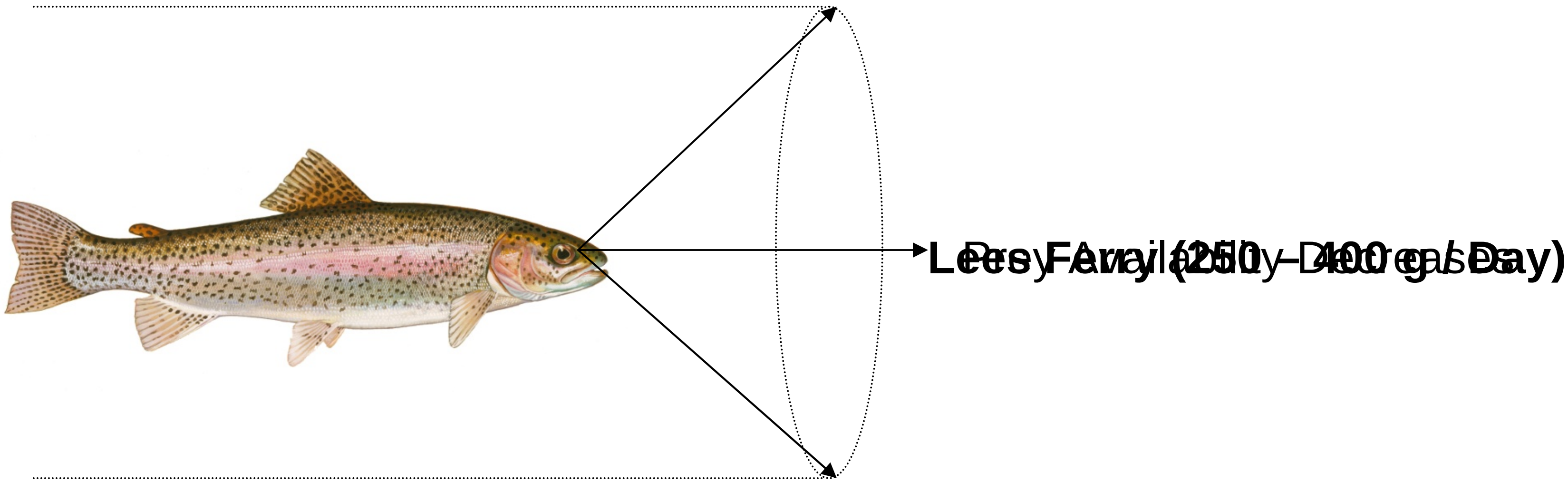

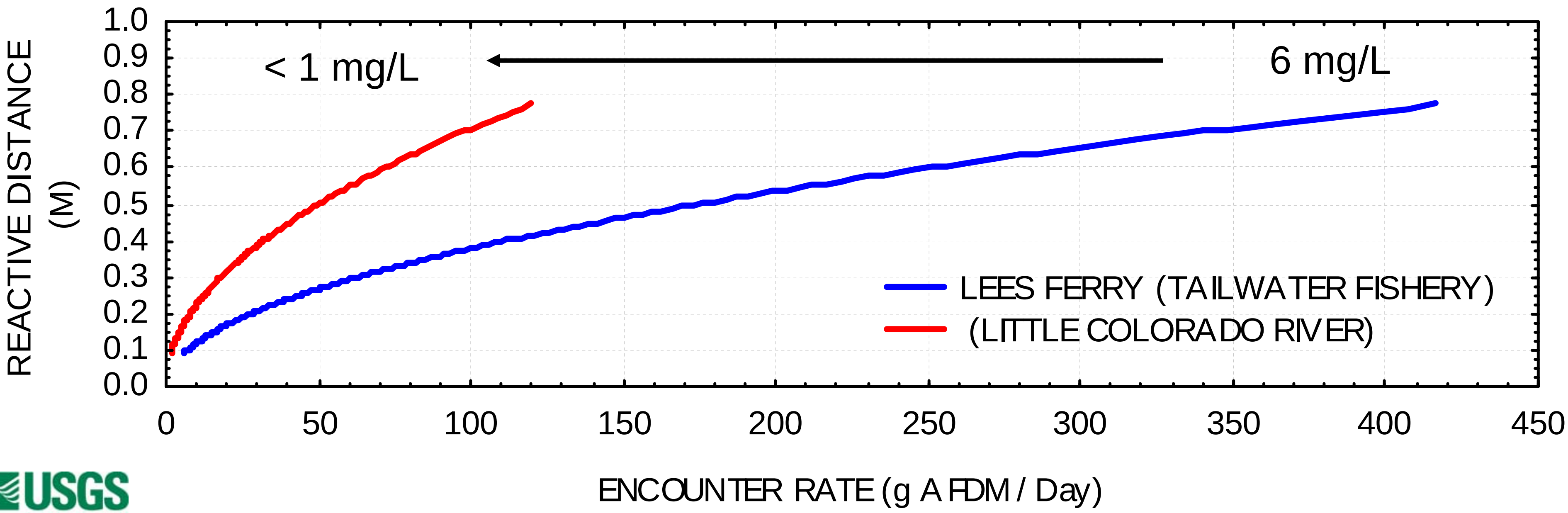

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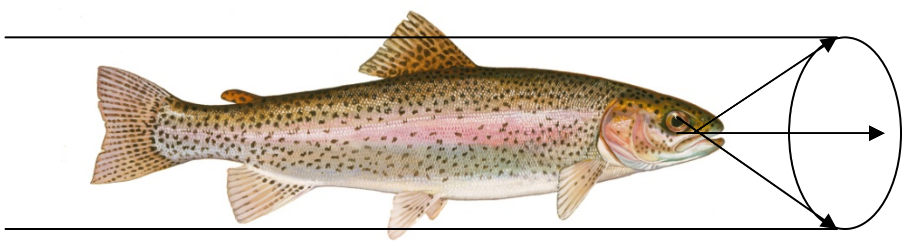
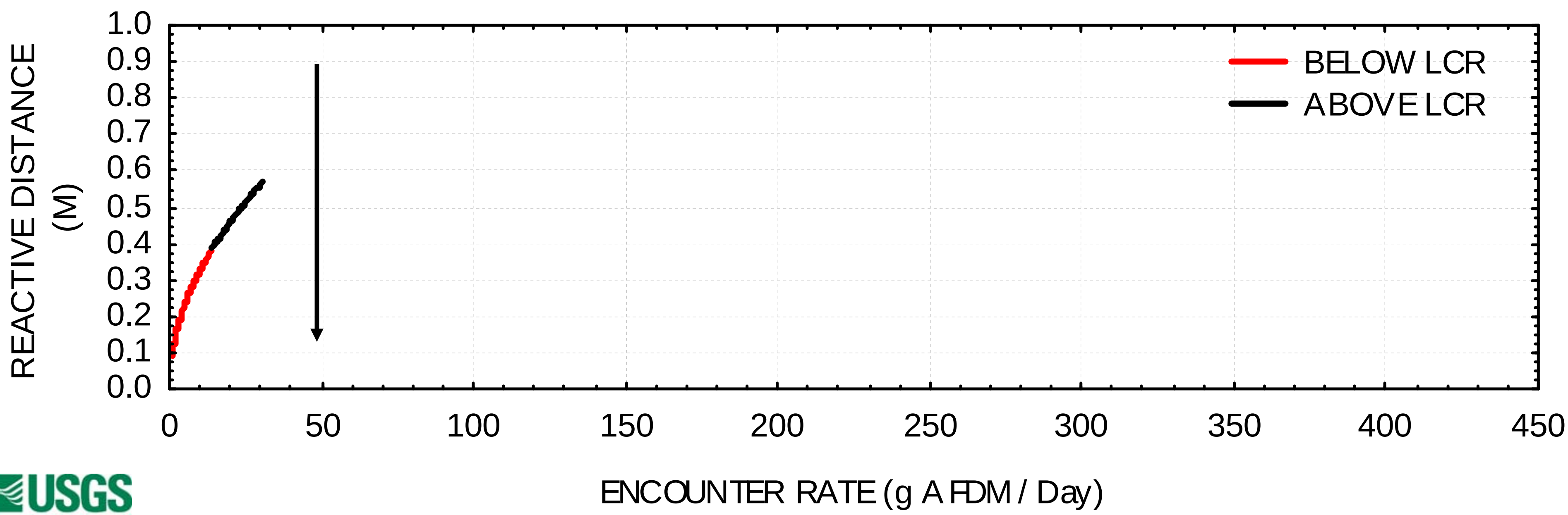
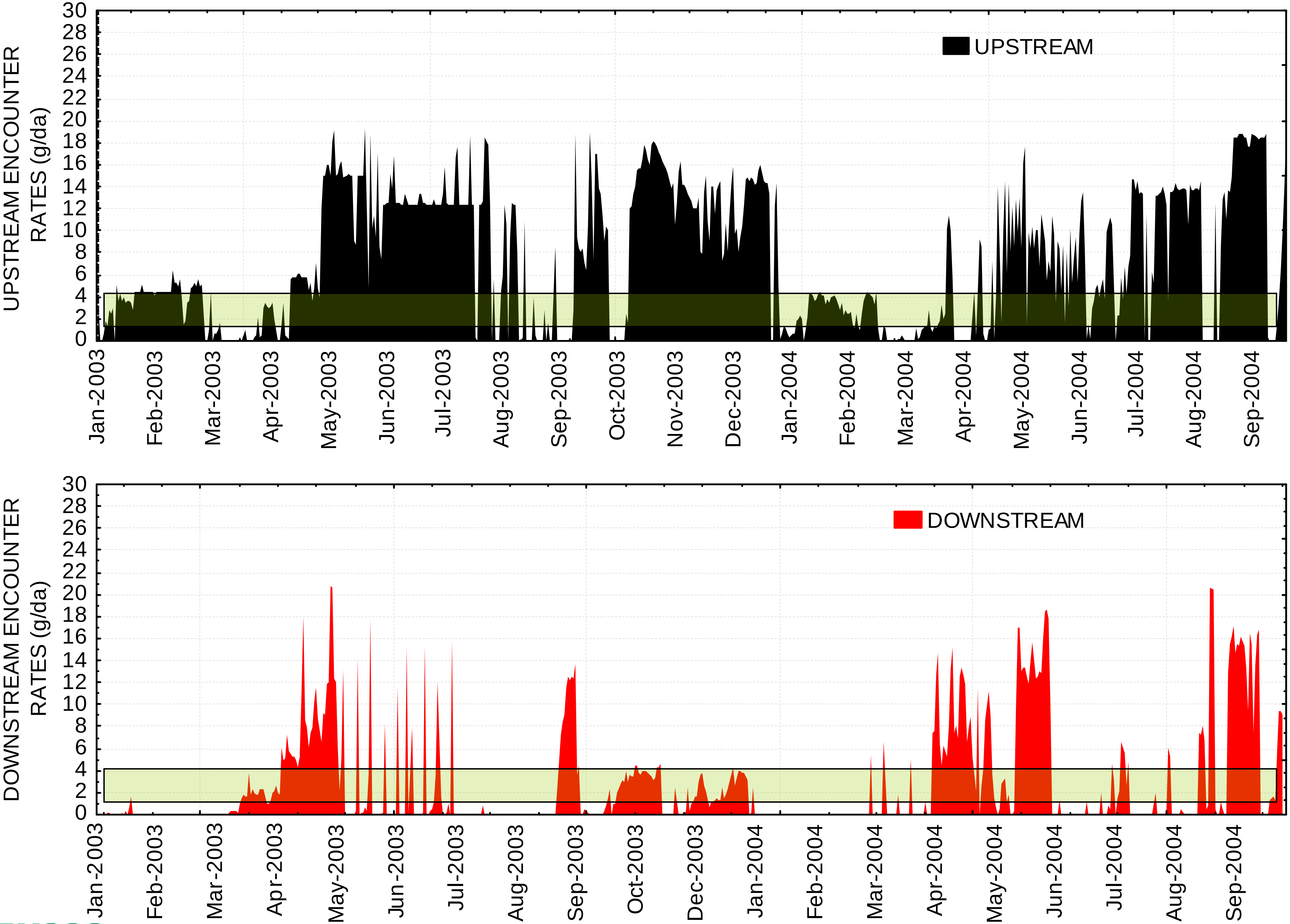


Reactive Distance Decrease

LCR (40 – 0 g / Day)





UPSTREAM ENCOUNTER RATES (g/da)
UPSTREAM
DOWNSTREAM ENCOUNTER RATES (g/da)
DOWNSTREAM
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Jan-2003 Feb-2003 Mar-2003 Apr-2003 May-2003 Jun-2003 Jul-2003 Aug-2003 Sep-2003 Oct-2003 Nov-2003 Dec-2003 Jan-2004 Feb-2004 Mar-2004 Apr-2004 May-2004 Jun-2004 Jul-2004 Aug-2004 Sep-2004

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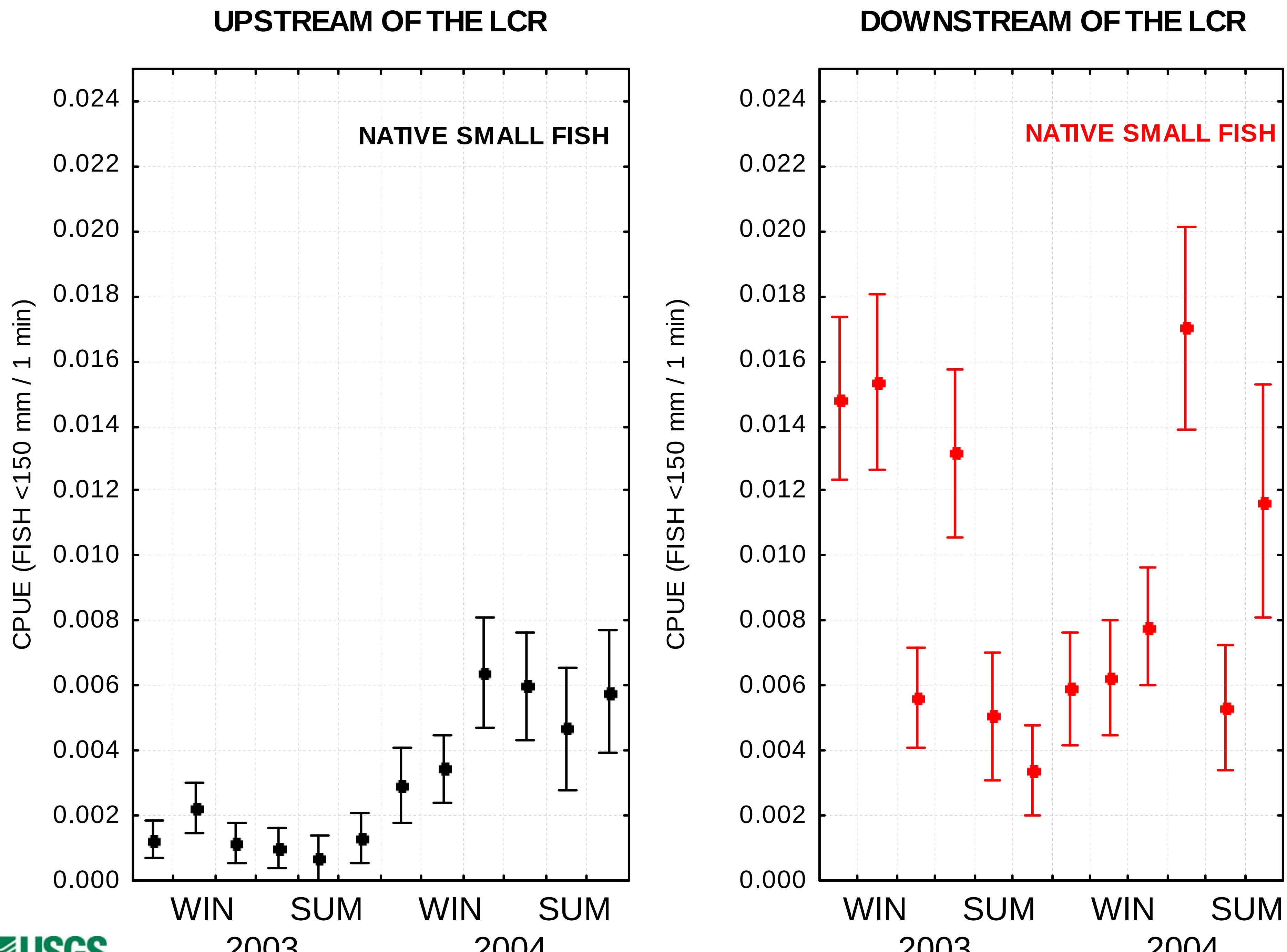

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Piscivory Estimates

$$\hat{C} = \hat{N} \cdot \hat{p}$$

$\hat{C}$ Is the estimated number of fish consumed

$\hat{N}$ Is the product of the estimated number of predators

$\hat{p}$ Is the probability that a predator had consumed a prey fish

FISH CONSUMPTION ESTIMATES

		FISH SUPPRESSION			WITHOUT FISH SUPPRESSION[a]		
Year	Species	Upstream	Downstream	Total	Upstream	Downstream	Total
RAINBOW	2003	4,334	5,751	10,086	9,701	16,061	25,762
	2004	1,389	4,682	6,071	6,830	8,545	15,375
	Total	5,724	10,433	16,157	16,530	24,606	41,137
BROWN	2003	626	7,088	7,713	1,948	17,644	19,593
	2004	311	5,181	5,491	2,017	11,189	13,206
	Total	936	12,269	13,205	3,965	28,834	32,799
COMBINED	2003	4,960	12,839	17,799	11,649	33,706	45,355
	2004	1,700	9,863	11,563	8,847	19,734	28,581
	Total	6,660	22,702	29,362	20,496	53,440	73,936

[a] Rainbow trout picivory rates expanded by largest abundance estimate (upstream = 4,977; downstream = 1,727)

Brown trout picivory rates expanded by largest abundance estimate (upstream = 109; downstream = 136)

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RAINBOW	2003	4,334	5,751	10,086	9,701	16,061	25,762
	2004	1,389	4,682	6,071	6,830	8,545	15,375
	Total	5,724	10,433	16,157	16,530	24,606	41,137
BROWN	2003	626	7,088	7,713	1,948	17,644	19,593
	2004	311	5,181	5,491	2,017	11,189	13,206
	Total	936	12,269	13,205	3,965	28,834	32,799
COMBINED	2003	4,960	12,839	17,799	11,649	33,706	45,355
	2004	1,700	9,863	11,563	8,847	19,734	28,581
	Total	6,660	22,702	29,362	20,496	53,440	73,936

[a] Rainbow trout picivory rates expanded by largest abundance estimate (upstream = 4,977; downstream = 1,727)

Brown trout picivory rates expanded by largest abundance estimate (upstream = 109; downstream = 136)

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FISH CONSUMPTION ESTIMATES

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FISH CONSUMPTION ESTIMATES

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FISH CONSUMPTION ESTIMATES

- Piscivory appears to be a large source of mortality for native fishes
- Consumption estimates represent a single predation event and are conservative (based on 1 fish prey/24 h.)
  - 14% of Rainbow trout consumed more than one fish (2-4).
  - 32% of Brown trout consumed more than one fish (2-4).
- 77% of all fish were consumed downstream
- 85% of all fish consumed were native fishes
- We estimate that 20,000 humpback chub would have been consumed in 2003-2004 had trout removal not occurred

Conclusion

RAINBOW TROUT

- Detect ability rather than food availability appear to explain differences in rainbow spatial distribution and condition factors.
- Drift feeding appears to be an inadequate strategy for providing daily rations
- Higher electivity for larger prey items
- Foraging strategy may shift from visual sight feeding to a more mobile, searching strategy under increased turbidity
- At high densities cumulative effects from piscivory may exceed brown trout

Conclusion

BROWN TROUT

- Highly piscivorous, but the least abundant trout
- Brown trout distribution and condition are not correlated to increased turbidity
- Diet is not correlated with invertebrate drift availability
- Incidence of piscivory is correlated with prey availability of native fish
- Incidence of piscivory is not influenced by turbidity
- Brown trout use a mobile foraging strategy that includes epibenthic feeding and piscivory

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THE END

INCIDENCE OF PISCIVORY

- Rainbow Trout
  - MIP was low and varied with location and season
    - Seasons ($p < 0.01$, summer 1.7%, and winter 1.05%)
    - Locations ($p < 0.01$, upstream 0.61%, downstream 2.1%)
    - Years ($p = 0.59$)
- Brown Trout
  - MIP was high and varied with location
    - Seasons ($p = 0.09$)
    - Locations ($p < 0.01$, upstream 11.6%, downstream 36%)
    - Years ($p = 0.6$)

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