Spokane Hatchery: Low Phosphorus Feed Study

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Background

December 2020: DOE issued total maximum daily loads (TMDLs) for dissolved oxygen, pH, and total phosphorus (TP) in the Little Spokane River

TP Discharge Limits for Spokane Hatchery: net concentration of 0.010 mg/L with a discharge flow of 21 cubic feet per second (cfs), and a wasteload allocation (WLA) of 0.51 kg/day

Hatchery tasked with reducing current net TP load by half during peak operations (March through October)

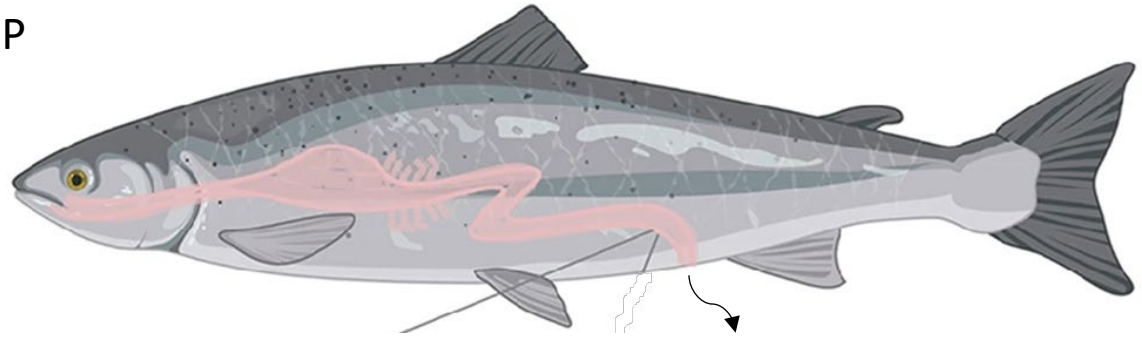
Nutrient Loading

- Increased nutrients lead to an increase in plant growth (eutrophication)
- Phosphorus is the rate-limiting nutrient in eutrophication of most freshwater ecosystems
- Increased algae growth can deplete dissolved oxygen in the water, killing aquatic organisms, and rendering the water unfit for human use.

Sources of Phosphorus in Discharge

- Fish waste
- Wasted feed, fine particulates
- Dead fish

Dietary P intake



P uptake (14-31%)

P waste (feces: insoluble or unavailable P; excretion: soluble P)

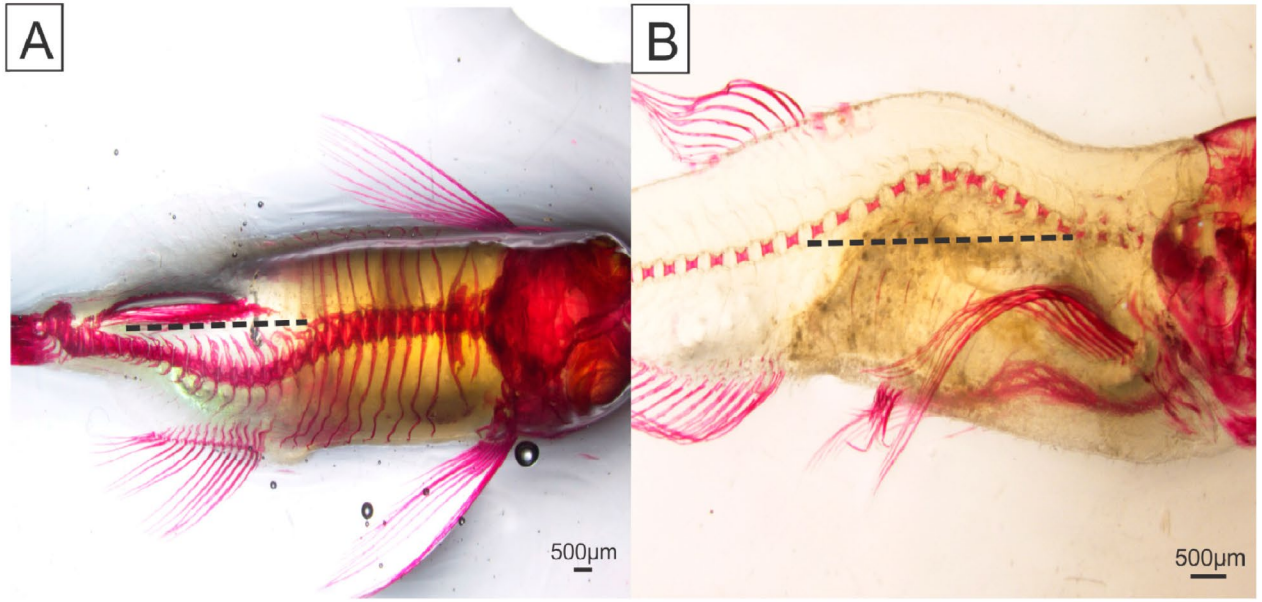
Most fish feeds have 1.2% P (1.2g/kg feed)

Only ~50% P in feed is bioavailable (digestible and absorbable).

Excreted P (urine) is the most available for plant growth

Role of P in fish

- Essential for bone mineralization
- Role in cell function
  - Component of organic phosphates (nucleotides, phospholipids, DNA/RNA, coenzymes)
  - Inorganic phosphates act as buffers to maintain pH of cellular fluids



Costa et al 2018. Int. J. Mol. Sci 19(2): 364.

How do we plan to reduce P discharge?

- Hatchery renovations to include:
  - Primary wastewater treatment – removal of solids (e.g. fish feces)
    - Micro-screening with drum filters
    - Settling of filter backwash in a pollution abatement pond
- Reduction of quantity of fish on station
- Low phosphorus feeds

Insoluble P

Both

Soluble P

The benefits of Low Phosphorus Feed

- USDA-WRAC:
  - No effect on weight gain or product quality
  - Feeding low P (0.8%) reduced phosphorus discharge by 33%
  - Addition of citric acid increased phosphorus bioavailability and reduced phosphorus loss in feces

- Recommendations for trout: feed standard diet (1.2% P) from hatch to 300g (~2fpp) then low P (0.3%) to market size (500g; <1fpp)

Relevant Reduced Phosphorus Lit Review

- NRC 2011. Nutrient Requirements of Fish and Shrimp
  - 0.7 – 0.8% P depending on life stage
- Lellis et al. Aquaculture 242 (2004): 607-616
  - *Fish survival and weight gain increased 4-fold with increased dietary phosphorus when started at 200-300g.*
  - *Fish <400g should not be given <0.6% P*
- Nathanailides et al. Fishes 8(9) 442 (2023):17p
  - Increase intestinal absorption with probiotics and good gut health
  - Temperature and size of fish will affect metabolism and absorption/need for P
- Others: lots of literature on effects of P deficiency. Some difficulty in comparison as terminology surrounding P levels is hard to compare. Common findings: low P affects bone mineralization, lots of bone and vertebral deformities, decreased growth and feed conversion
- **** Fish may be phosphorus deficient long before weight, deformities or other health issues noted*

Assumptions of P pollution

Ratio of mass pollutant to mass feed based on percent conversion[1]

Feed Type	Regular Feed (1.2 - 1.5% P)	Low P Feed (0.8% P)*
Settleable and Suspended Phosphorus (Organic P; Insoluble P)	0.0054 kg/kg feed fed	0.0036 kg/kg feed fed
Dissolved Phosphorus (Inorganic P; Soluble P)	0.0022 kg/kg feed fed	0.0015 kg/kg feed fed

[1]Standard waste generation per unit mass of feed fed as referenced by Castledine (1986) and reproduced in the Idaho Waste Management guidelines for Aquaculture Operations (IDEQ) for regular feed.

*Assuming FCR is same for Regular Feed vs Low Phosphorus Feed

Actual values at Spokane Hatchery

Ratio of mass pollutant to mass feed based on percent conversion after 5 d trial

Feed Type	Regular Feed (1.2 - 1.5% P)	Low P Feed (0.8% P)
Settleable and Suspended Phosphorus (Organic P; Insoluble P)	0.0065 kg/kg feed fed	0.0011 kg/kg feed fed
Dissolved Phosphorus (Inorganic P; Soluble P)	0.0001 kg/kg feed fed	0.00004 kg/kg feed fed

Experiment 1

Assess fish health impacts (if any) of feeding Spokane Rainbow Trout and Ford Brown Trout reduced phosphorous feed during the last three months of their production cycle

Characterize pollution concentrations of TP, OP, and TSS using Low P and Regular Feed

Hypothesis

There will be no difference in fish health outcomes between the two groups of either species

Methods

Rainbow Trout (Low P)	Rainbow Trout (C)	Brown Trout (Low P)	Brown Trout (C)
4 raceways	2 raceways	1 raceway	1 raceway
~38,000 fish	~19,000 fish	~9,000 fish	~9,000 fish
~4.5 FPP	~4.5 FPP	~ 6 FPP	~6 FPP

- Compare Regular vs Low P feed after 12 weeks (1/5/24 to 4/3/24)
- Feed: Regular (Bio Oregon BioBrood 4.0mm, switched to BioTrout 4.0mm for months 2&3); Low P (Rangen 450 LP 4.0 mm).
- Sample fish at start (30 fish/group/spp) and at end (60 fish/group/spp)

Methods cont.

Parameters to be assessed:

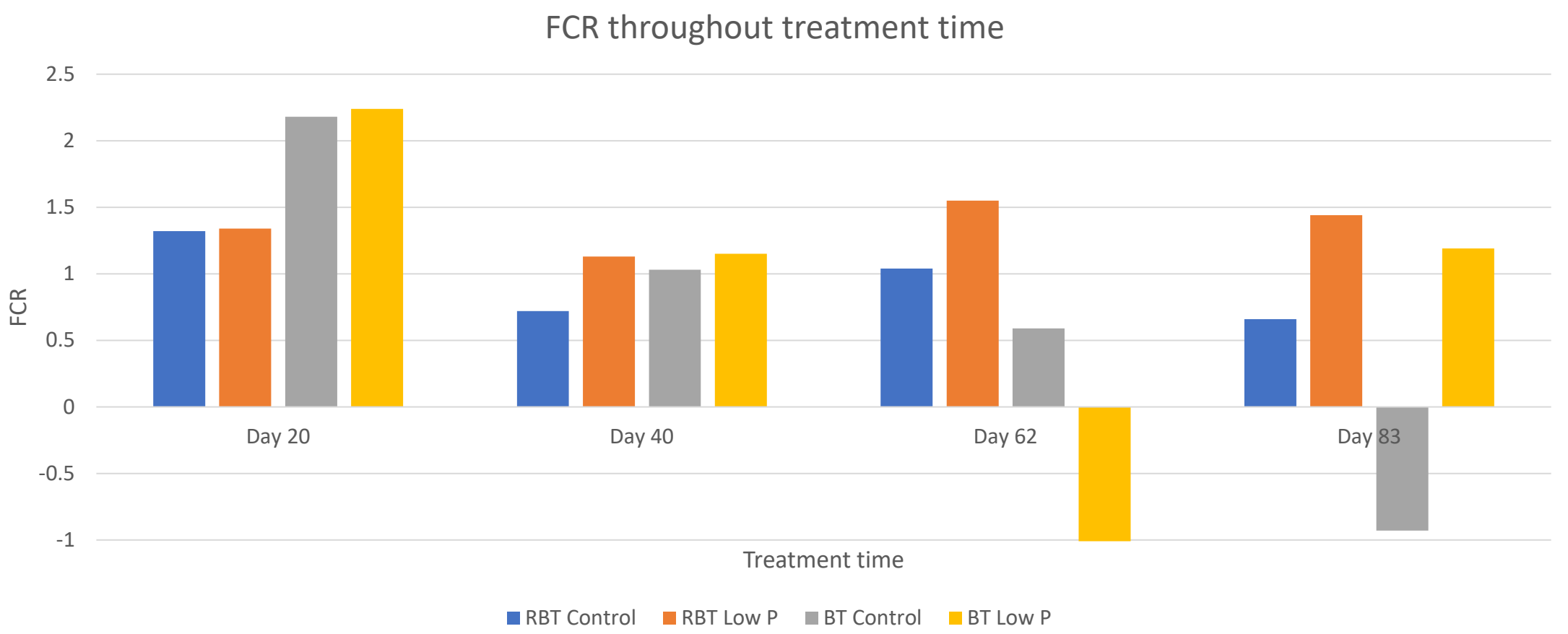
- Length
- Weight
- K factor
- Hepatosomatic index
- Opercular confirmation
- Gross signs of disease:
  - Spinal curvature
  - Infectious agent
  - Fin condition
- Samples collected for histopathology (spinal cord, vertebrae) using von Kossa stain

Results

Diet	Mean growth		Final		
	Length (mm)	Weight (g)	K	LSI	FPP
RBT Control	4.75	73.7	1.13	0.46	2.8
RBT Low P	3.94	56.48	1.13	1.00	2.3
BT Control	1.23	10.88	1.02	1.02	4.9
BT Low P	6.66	34.97	1.00	0.98	4.5

- No significant differences in growth, condition factor, or LSI detected
- Lots of variation in size of fish in both groups sampled
- Some difference in final FPP

Results – FCR


FCR throughout treatment time
2.5
2
1.5
1
0.5
0
-0.5
-1
FCR
Day 20
Day 40
Day 62
Day 83
Treatment time
RBT Control
RBT Low P
BT Control
BT Low P

FCR for entire population

	Low P				Reg P		Low P	Reg P
	RBT1	RBT2	RBT3	RBT4	RBT5	RBT6	BT1	BT2
Feed Fed	1311	1311	1311	1311	1311	1311	870	870
Lbs Gain	1284	1191	949	913	1486	1784	423	464
FCR	1.02	1.10	1.38	1.44	0.88	0.73	2.05	1.88
AVG	**1.24**				**0.81**			

Discussion

- No significant differences in length, weight, LSI, K data
- No signs of disease or grossly visible deformity
- Histopathology was not performed
- **FCR is poorer in low P feed**
  - Is this an indicator of early P deficiency??
  - Staff didn’t notice any appreciable difference in groups

Water quality

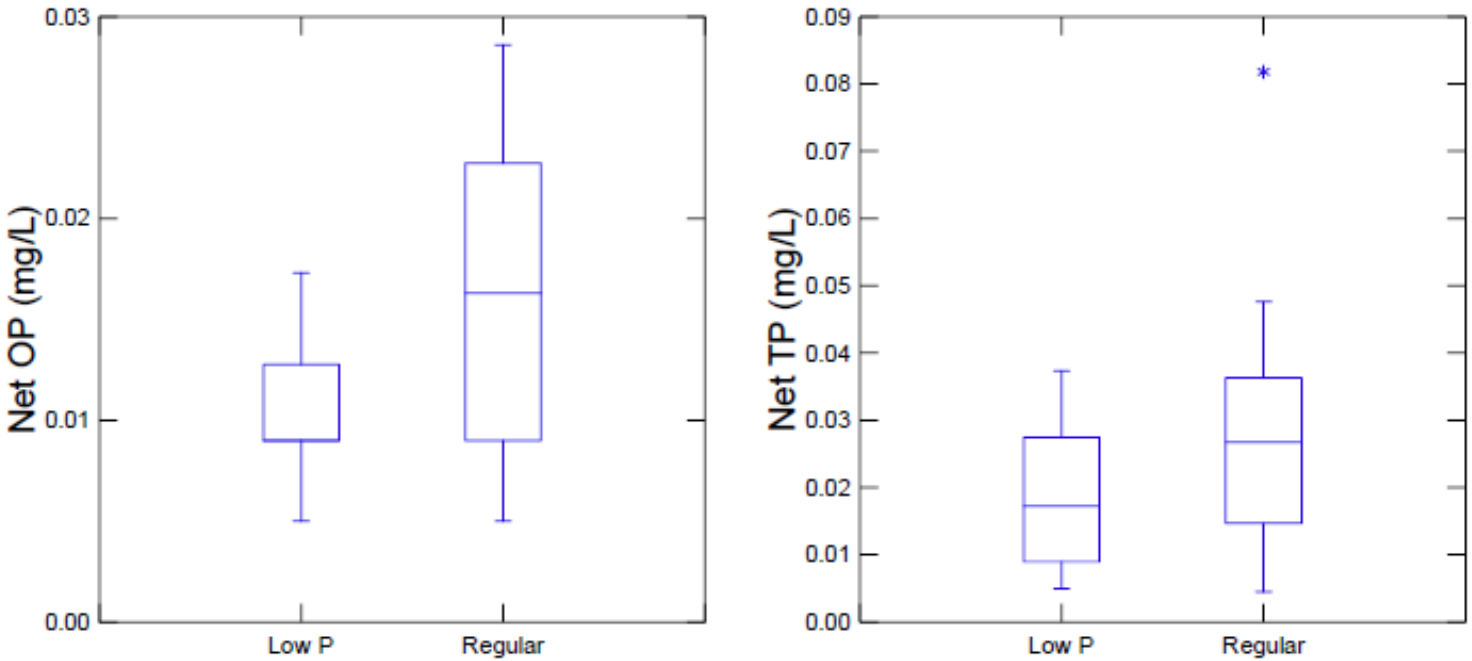


Figure 3-1. Net orthophosphate (OP) and total phosphorus (TP) effluent concentrations when using regular and Low P feed.

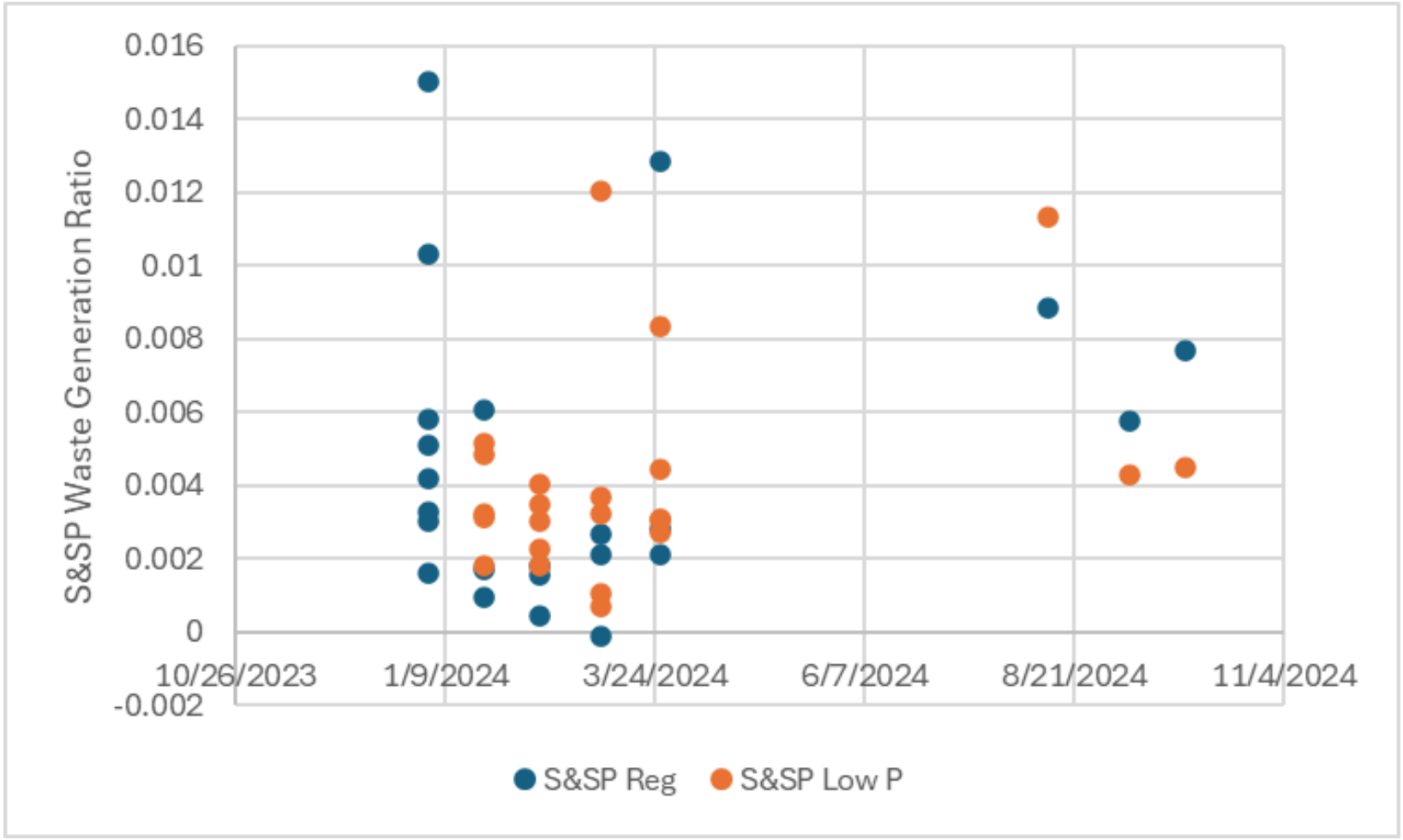


Figure 3-4. Settleable and Suspended Phosphorus (S&S P) WGRs when using regular and Low P feed over the course of the study.

Conclusions

- Feeding low P feed reduces the OP and TP enough that solids removal may be effective for meeting WLA
- There is some difference in FCR but may not be enough to preclude use
- Low P feed is more expensive and harder to procure
- Can it be used in younger fish??

Low Phosphorus and FCR

- Several studies have shown reduced feed conversion and growth in fish fed low P (Baerverfjord et al. 1998, Lellis 1994)
- If fish reach a state of phosphorus deficiency then feed conversion and growth will decrease
- This is often the earliest visible indication of deficiency
- Other clinical signs may develop: lethargy, listlessness, darkened pigmentation, deformities, and mortality
- If phosphorus levels are increased before CS develop or progress then they can recover

Experiment 2

Assess fish health impacts (if any) of feeding fingerling Spokane Rainbow Trout reduced phosphorous feed from July-Sept (75 fpp -20 fpp)

Quick Summary

- Fish from both groups had BCWD that required 1-2 treatments of 10d Aquaflor medicated feed.
- Medication cannot be added to Low P feed so days on experimental feed ranged from 56-76.
- BCWD causes skeletal deformities, lethargy, skin pigmentation changes, and damage to fins and cartilage.
- Sick fish do not eat as well and growth/FCR will be reduced.