Monitoring the Impacts of Pathogens at Increasing Water Temperatures in Chinook Salmon in the Sacramento-San Joaquin Delta

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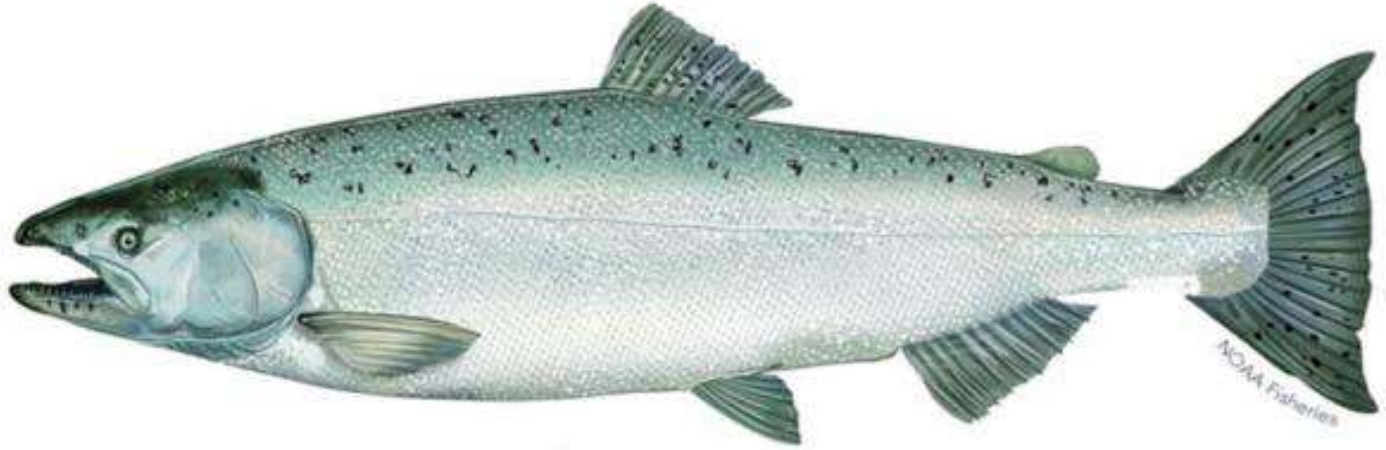

Winter-run Chinook salmon | Illustration: NOAA Fisheries

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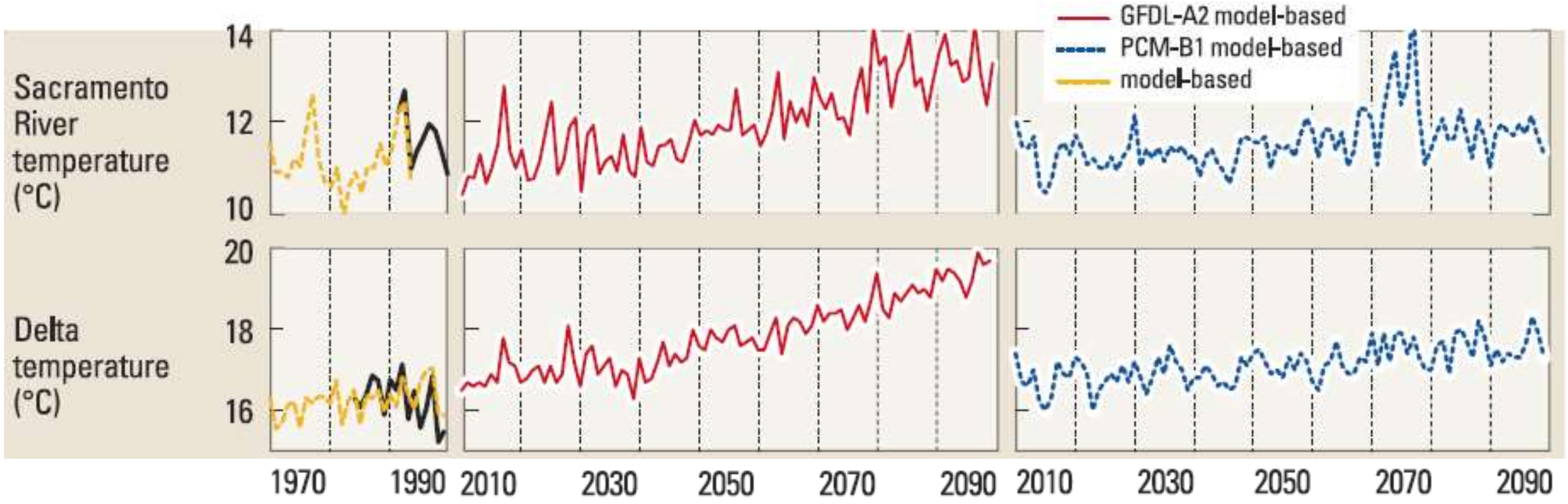
A Changing Environment



Cloern *et al.* (2011) *PLoS ONE*

A Changing Environment

Pathogen and Host interactions may change in different water temperatures!

Pathogen

- Pathogenicity may increase/decrease
- Life cycles are faster in warmer water

Host (Chinook salmon)

- Timing of migration – earlier in warmer water
- May be stressed, may not mount sufficient immune response

Objectives

- Screen for pathogens on outmigrating winter run Chinook salmon
- Assess physiological response of winter run Chinook salmon to infection

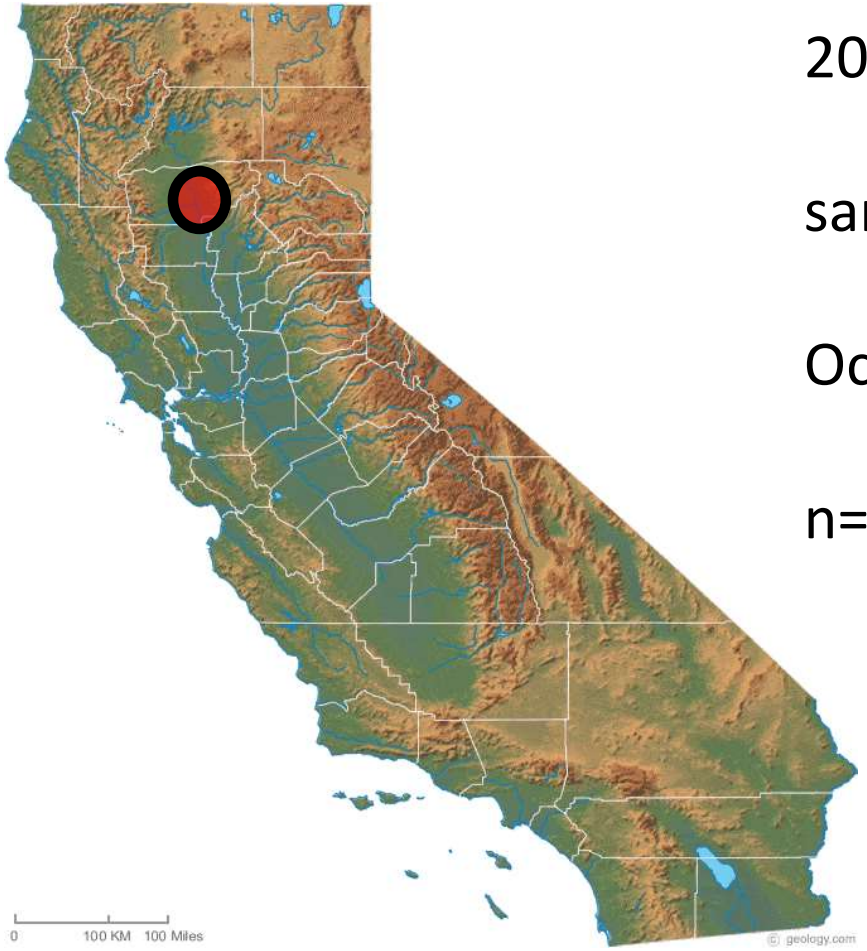
Pathogen Screening

- 49 different pathogens
  - 14 bacteria
  - 1 fluke
  - 21 parasites
  - 13 viruses

Physiological Response

- 30 Biomarkers
  - Immune system:
    - innate
    - adaptive
  - General stress system
  - Gene expression: measured through qPCR

Sampling at Red Bluff Diversion Dam



2015 juvenile Winter Run Chinook Salmon

sampled by rotary screw trap

Oct 15th –Nov 29th 2015

n=80, 10 per week

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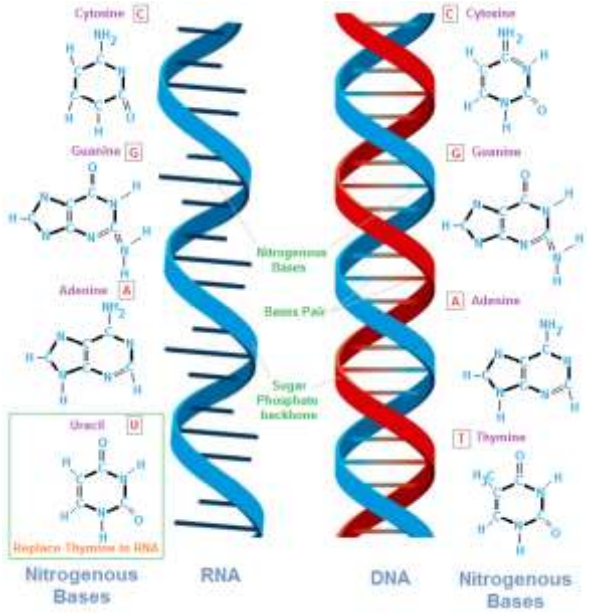
Sampling Plan

- Tissues
  - Brain
  - Gill
  - Liver
  - Kidney
  - Heart
- Preserved in RNA later
- Stored at -80°C
- RNA & DNA extractions



Resource: https://www.pinterest.com/pin/488077678340563356
11-30-2016

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Analyses by qPCR (Fluidigm)

Pathogen Screening

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Pathogen Screening

Pathogen Full Name	Abbreviation	Type
Aeromonas hydrophila	ae_hyd	Bacterium
Aeromonas salmonicida	ae_sal	Bacterium
Candidatus Branchiomonas cysticola	c_b_cys	Bacterium
Flavobacterium psychrophilum	fl_psy	Bacterium
Gill chlamydia	sch	Bacterium
Moritella viscosa	mo_vis	Bacterium
Piscichlamydia salmonis	pch_sal	Bacterium
Piscirickettsia salmonis	pisck_sal	Bacterium
Renibacterium salmoninarum	re_sal	Bacterium
Rickettsia-like organism	rlo	Bacterium
Tenacibaculum maritimum	te_mar	Bacterium
Vibrio anguillarum	vi_ang	Bacterium
Vibrio salmonicida	vi_sal	Bacterium
Yersinia ruckeri	ye_ruc	Bacterium
Nanophyetus salmincola	na_sal	Fluke
Ceratomyxa shasta	ce_sha	Parasite
Cryptobia salmositica	cr_sal	Parasite
Dermocystidium salmonis	de_sal	Parasite
Facilispora margolisi	fa_mar	Parasite
Gyrodactylus salaris	gy_sal	Parasite
Ichthyophonus hoferi	ic_hof	Parasite
Ichthyophthirius multifiliis	ic_mul	Parasite
Kudoa thyrsites	ku_thy	Parasite
Loma salmonae	lo_sal	Parasite
Myxobolus arcticus	my_arc	Parasite
Myxobolus cerebralis	my_cer	Parasite
Myxobolus insidiosus	my_ins	Parasite
Neoparamoeba perurans	ne_per	Parasite
Nucleospora salmonis	nu_sal	Parasite
Paranucleospora theridion (syn. Desmozoon lepeophtherii)	pa_ther	Parasite
Parvicapsula kabatai	pa_kab	Parasite
Parvicapsula minibicornis	pa_min	Parasite
Parvicapsula pseudobranchicola	pa_pse	Parasite
Sphaerothecum destructuens	sp_des	Parasite

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Gene Name	Abbreviation
Ammonium transporter	Amt-RhCG1
Beta-2-Microglobulin	B2M
Chemokine Interleukin 1β	IL-1ß
Chemokine Interleukin 8	IL-8
Chemokine Receptors 5	CXCR5
Chemokine Receptors 6	CXCR6
Chemokine Receptors 7	CXCR7
Classical Immunoglobulin	IgM
Cold inducible RNA Binding Protein	CIRBP
Complement factor BF-2	BF2 CFB-2
Complement factor CF3	CF3
C-type Lysozyme	C-Lys
Glutathione-s-Transferase 3	GST3
Glutathione-s-Transferase alpha	GSTα
Cytochrome P450 Family 1A1	CYP1A1 CYP450
Heat Shock Protein 90 kDa	HSP 90 AA1-inducibe form
Heat Shock Protein 90 kDa alpha Beta 1	HSP 90 AB1
Heat Shock protein serpin H1	HSP47
Major Histocompatibility complex II	MHC2
MX protein	MX
Serum amyloid protein A	SAA
T-cell receptor alpha	TCRα
T-cell receptor beta	TCRβ
Toll like receptors 1	TLR1
Toll like receptors 2	TLR2
Toll like receptors 3	TLR3
Tumor necrosis factor alpha	TNF-α
60S Ribosomal gene 7l	RPL7
Ribosomal Protein S9	RPS9
Glyceraldehyde-3-Phosphate Dehydrogenase	GAPDH

Physiological Response

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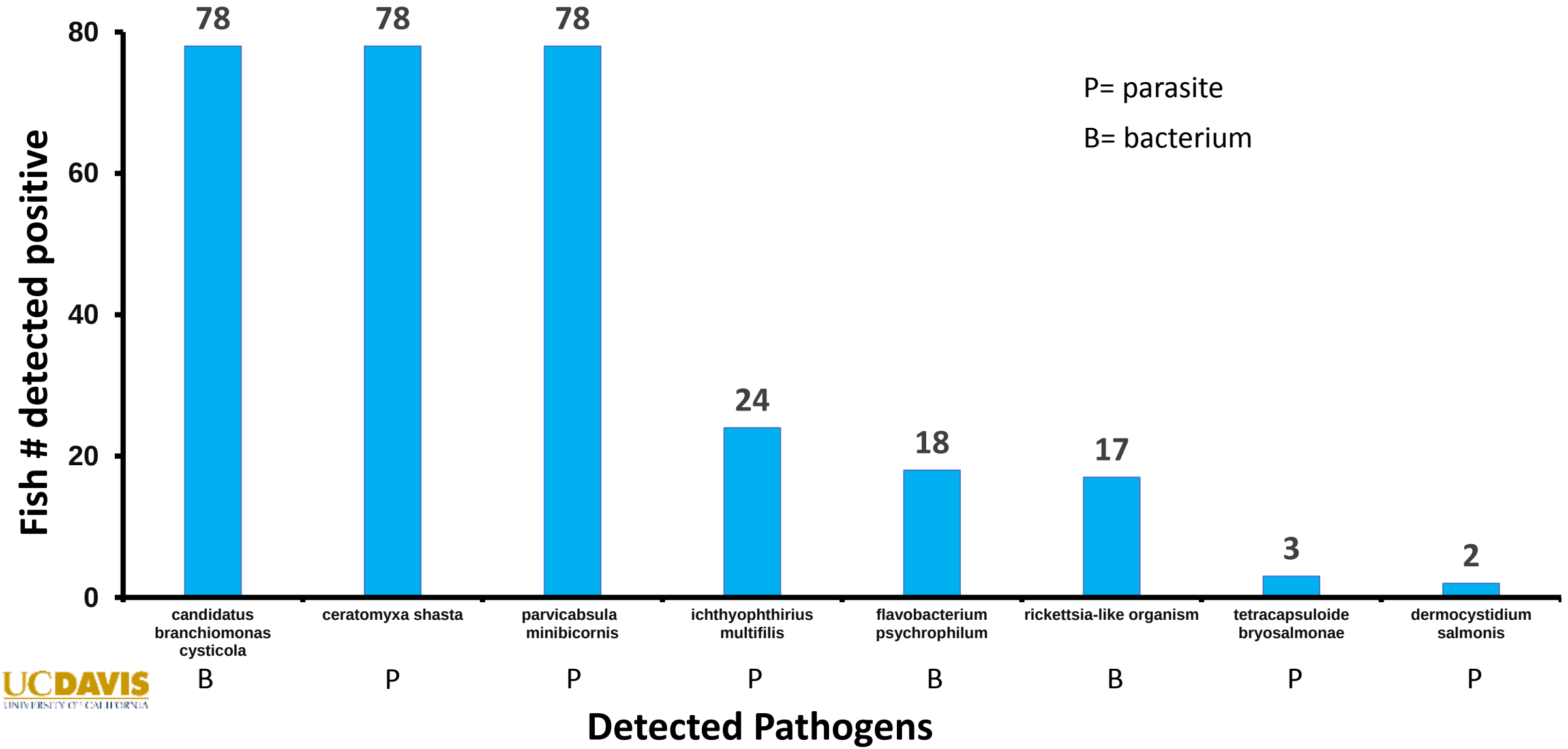
Results - Multiple Infections



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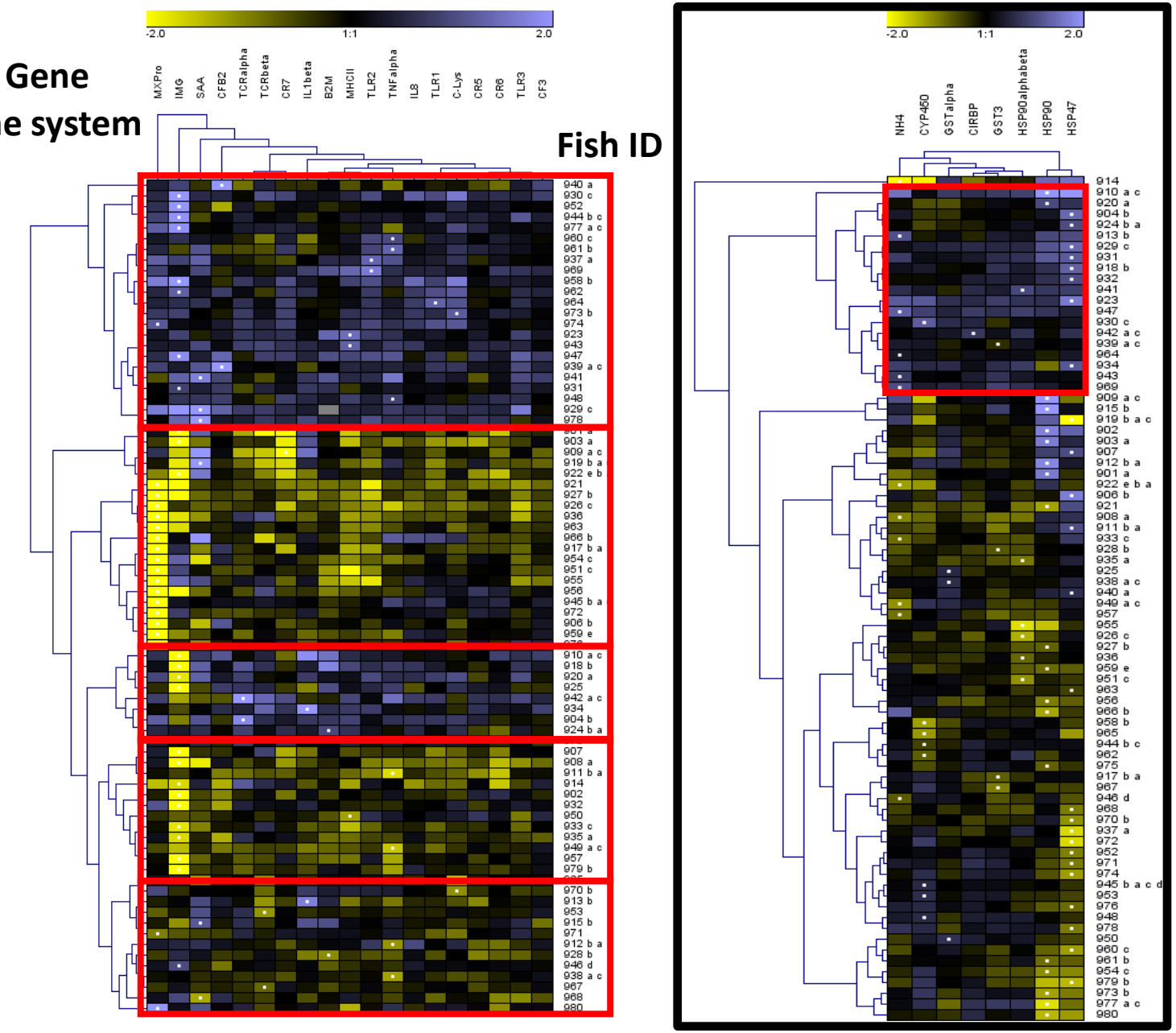
Physiological Response



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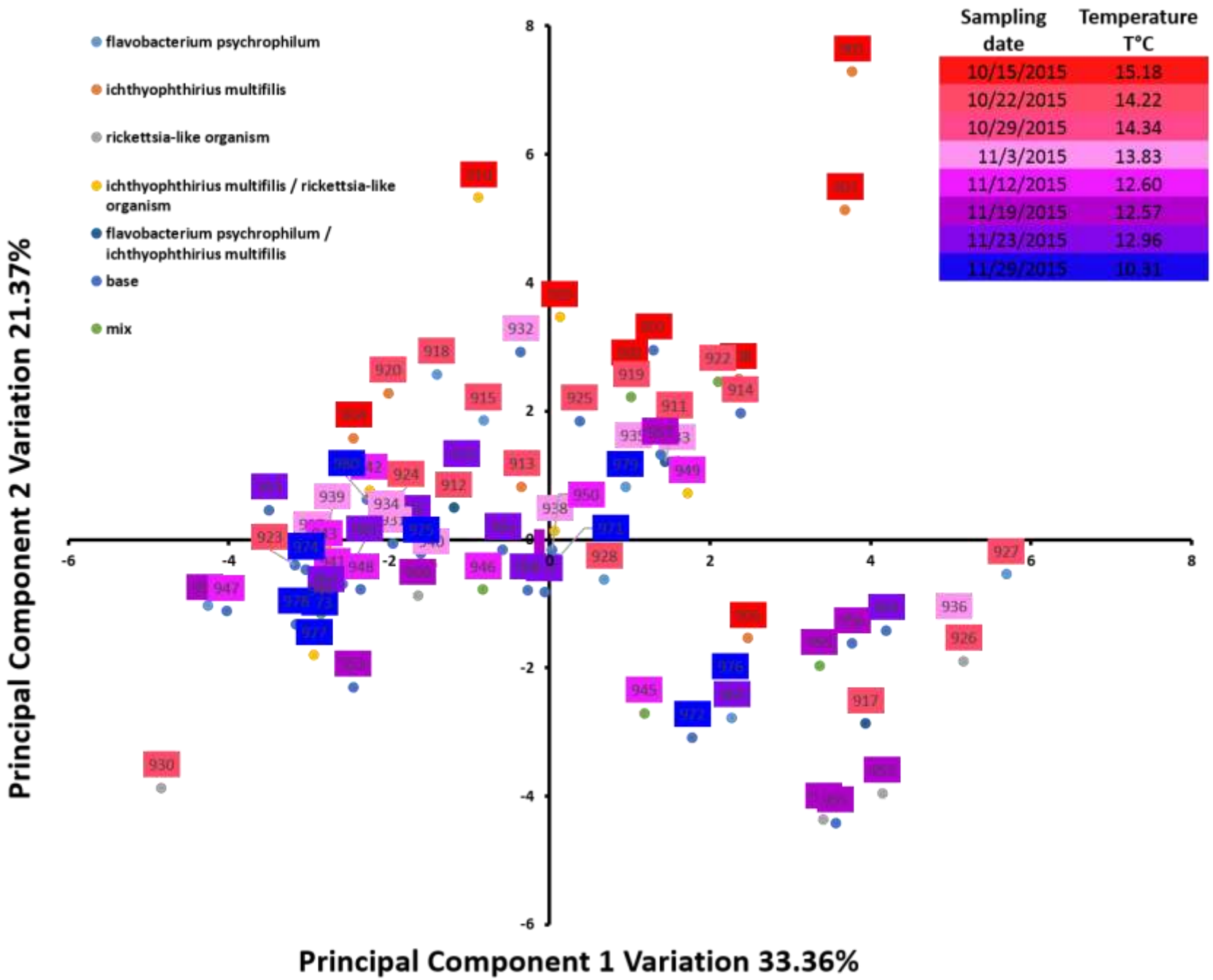

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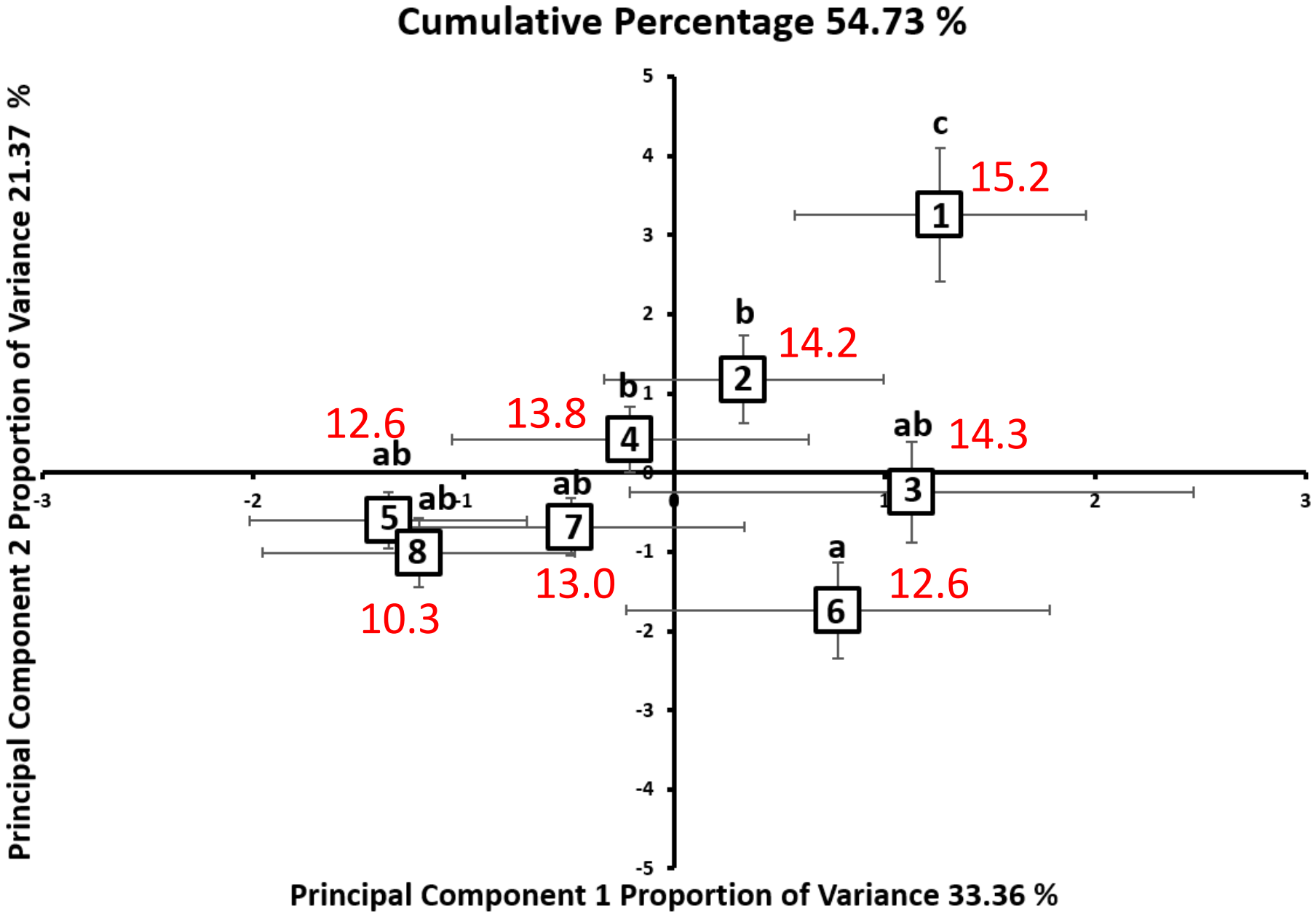

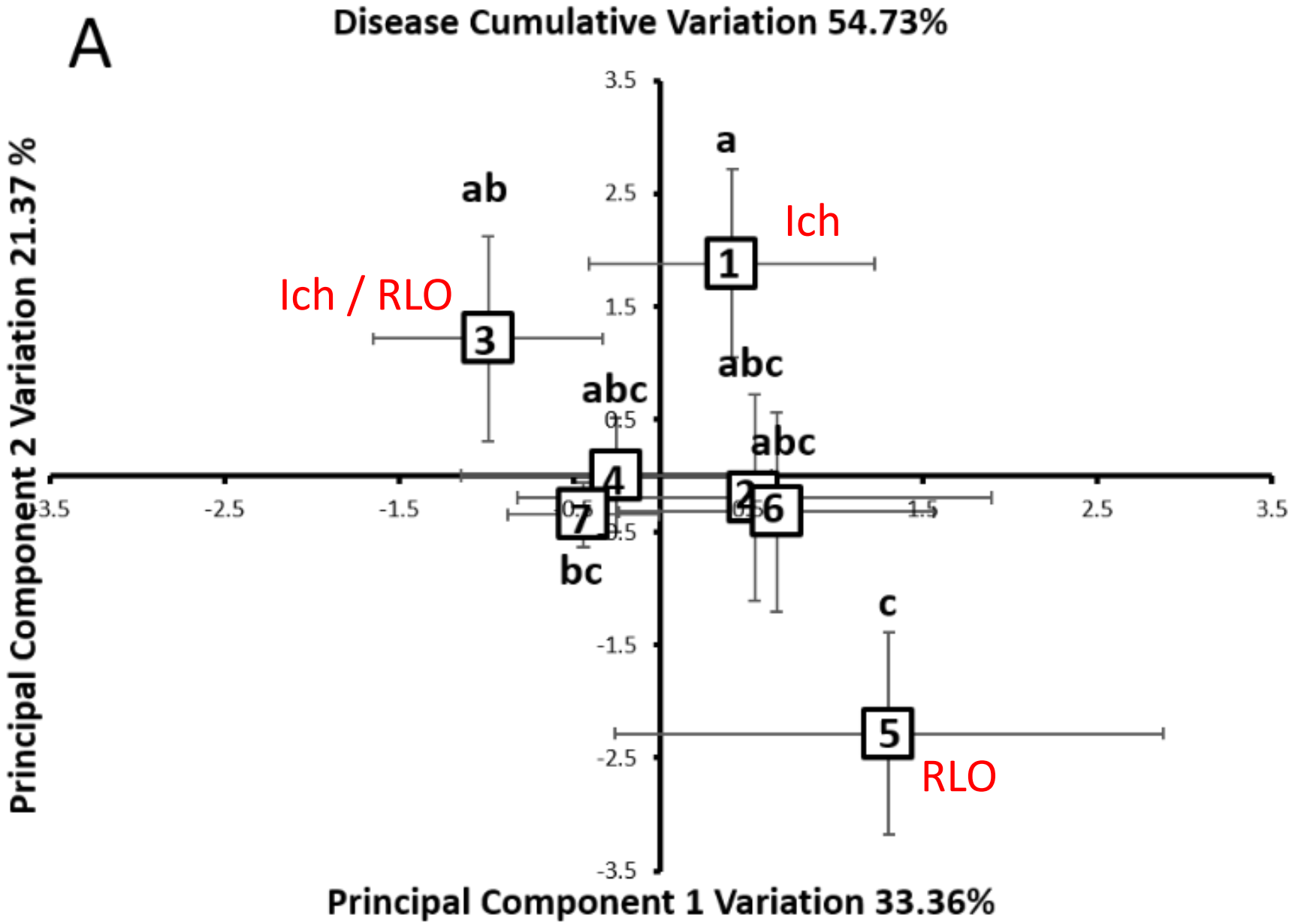

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Ongoing & Future work

- Linking physiological responses to pathogen load and histopathological results (winter run samples)
- Establish the pathogen screening system at UC Davis
- Field Caging experiments combined with laboratory studies (March and April, 2017, 2018)
- Changes in predation as a factor of infection – are sick fish eaten faster? Avoided?

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Study 1A

Study 1C

Transport

Environment

Hatchery Control

Laboratory

Cage

Tank

Substrate

12°C

≤18°C

Endpoints measured in the lab:

- Body scrapes
- Gene expression (kidney and gill)
- Pathogen presence
- Swimming performance
- Metabolic response
- Predation Susceptibility

Study 1B

eDNA on ambient water samples

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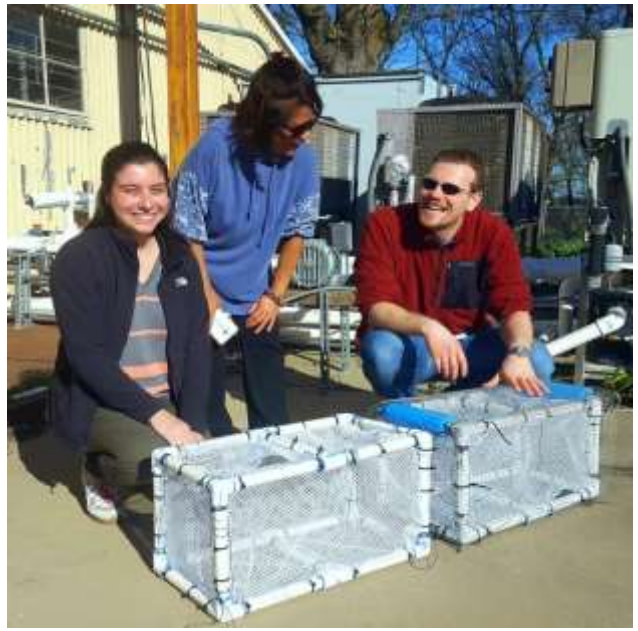
Upcoming Studies



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