Consequences of variation in body size, condition, physiological state, and in-river conditions for spawning migration success by Alaskan salmon: a three-year telemetry study of Copper River sockeye

P. Rand[1], K. Gorman[2], K. Kaukinen[3], T. Ming[3], S. Li[3], and K. Miller[3]

[1]*Prince William Sound Science Center, Cordova, AK*
[2]*College of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Fairbanks, AK*
[3]*Department of Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC*

Image: P. Rand

Image: T. Kline

Land Acknowledgement

Everywhere we live and work is Native land. We recognize, appreciate, and honor Indigenous peoples and their past, present, and future land stewardship. We are committed to building long-term reciprocal relationships with Indigenous organizations and knowledge holders to create relevant and actionable information regarding the long-term conservation and management of Alaska's biodiversity.
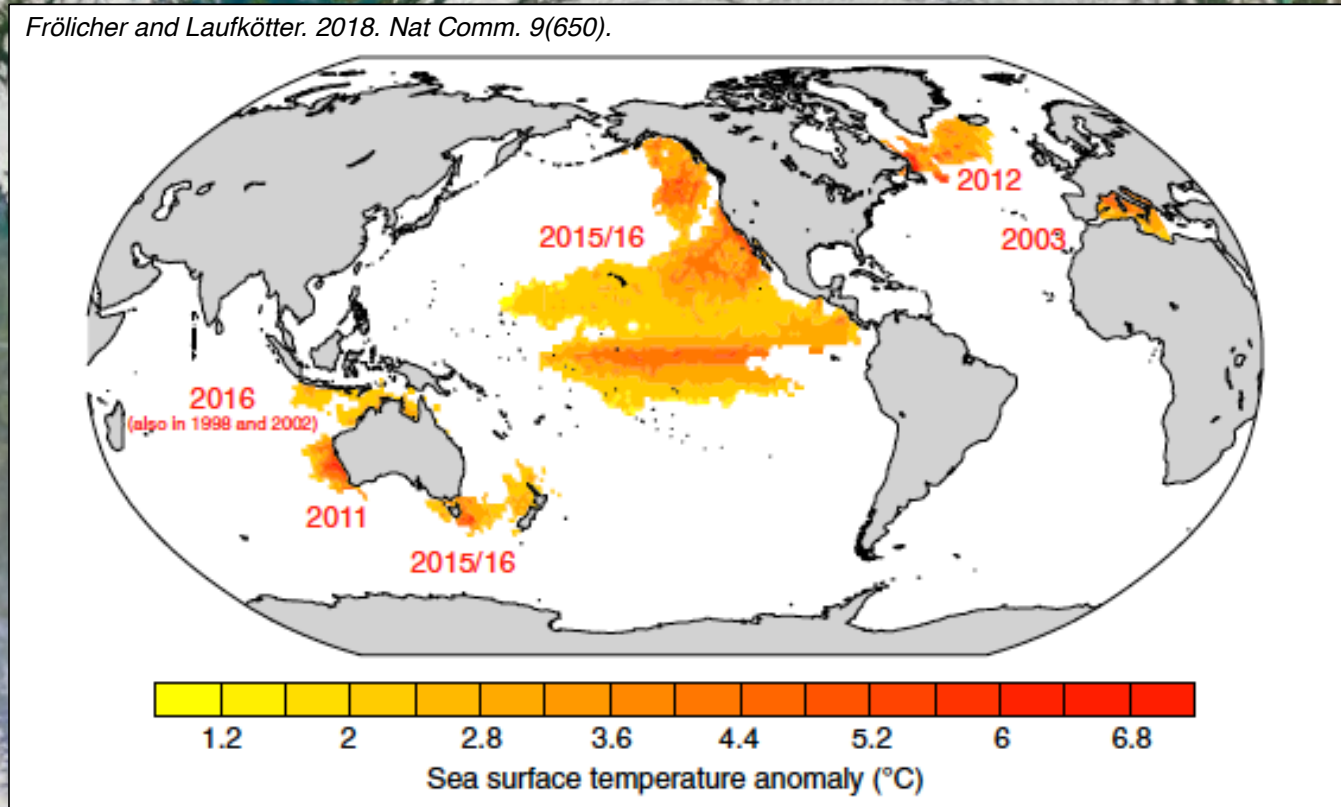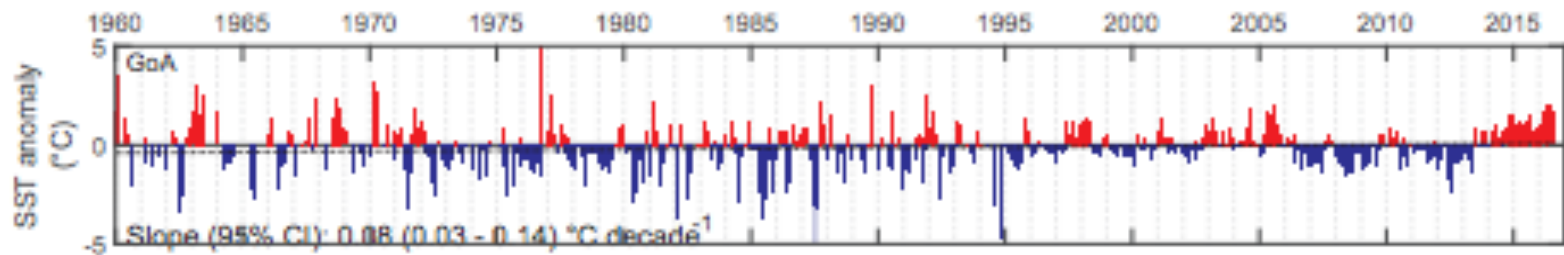
Image: P. Rand

Image: T. Kline

# High Latitude Marine Ecosystems are Changing
Gulf of Alaska

Frölicher and Laufkötter. 2018. Nat Comm. 9(650).

2012

2015/16

2003

2016
(also in 1998 and 2002)

2011

2015/16

Sea surface temperature anomaly (°C)

1.2 2 2.8 3.6 4.4 5.2 6 6.8

Walsh et al. 2018 Bull Amer Meteor Soc 99 (1), S1–S157

GoA

SST anomaly (°C)

Slope (95% CI): 0.08 (0.03 – 0.14) °C decade⁻¹

NASA

High Latitude Marine Ecosystems are Changing
Gulf of Alaska
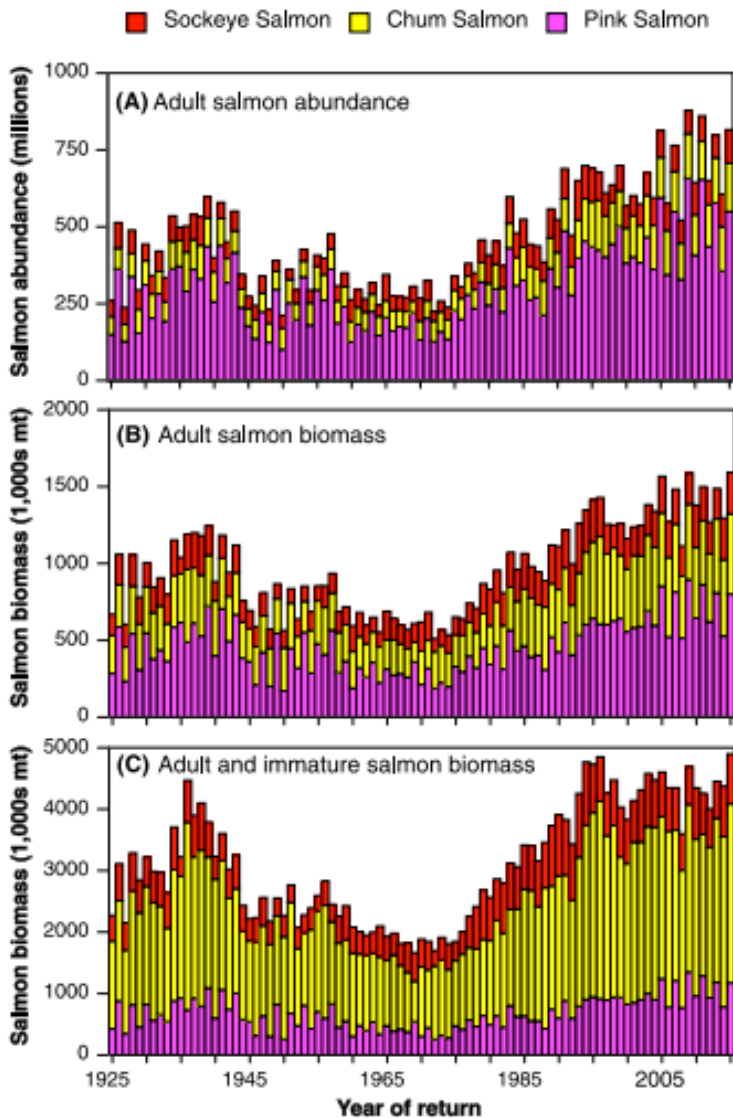
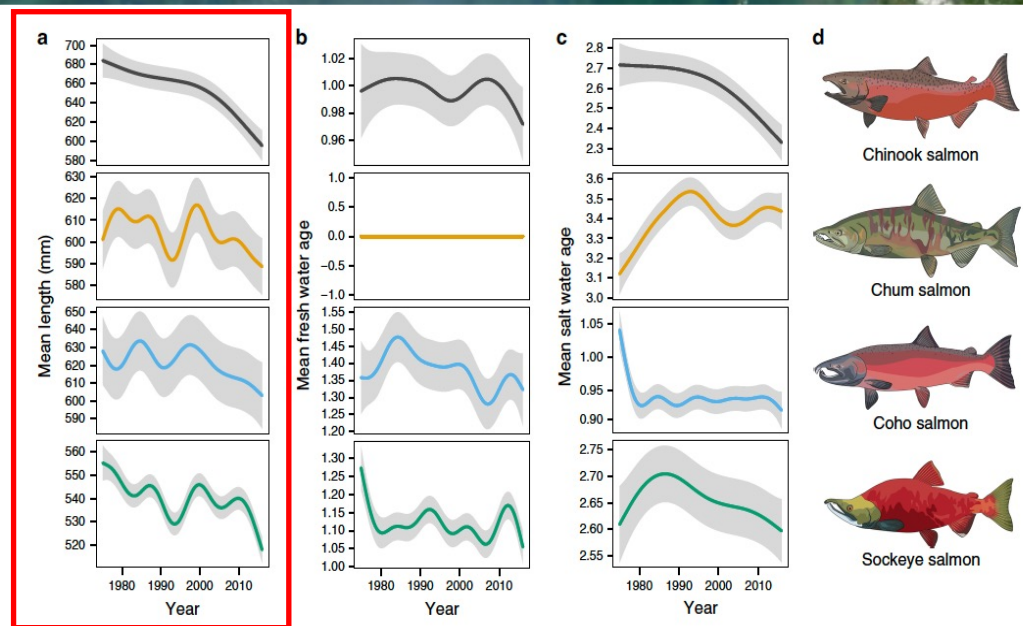*Ruggerone and Irvine. 2018. Mar. Coast. Fish. 10:152–16.*

# Recent declines in salmon body size impact ecosystems and fisheries

K. B. Oke [1,2✉], C. J. Cunningham[2,3], P. A. H. Westley [4✉], M. L. Baskett[5], S. M. Carlson [6], J. Clark[7], A. P. Hendry[8], V. A. Karatayev[5], N. W. Kendall[9], J. Kibele [7], H. K. Kindsvater [10], K. M. Kobayashi[1], B. Lewis[11], S. Munch[1,12], J. D. Reynolds[13], G. K. Vick[14] & E. P. Palkovacs [1✉]
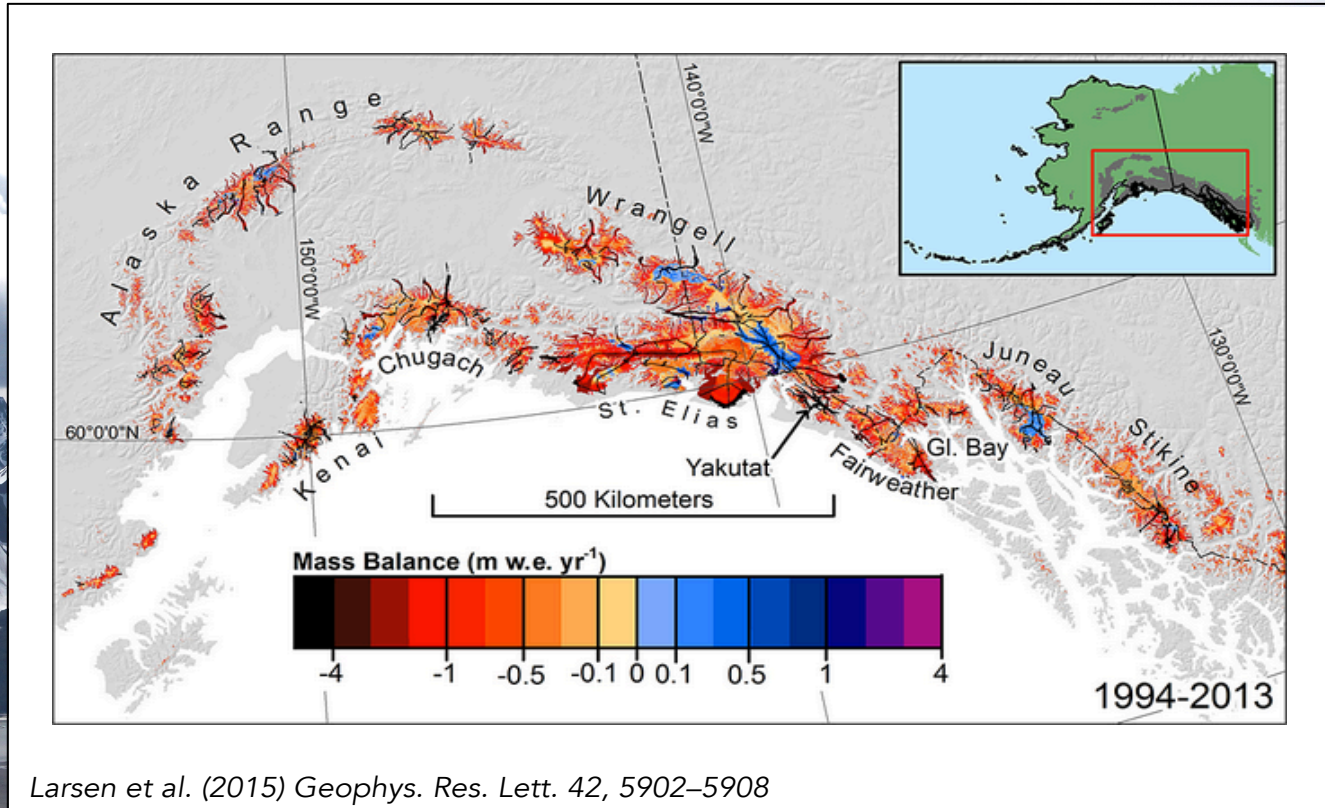
High Latitude Marine Ecosystems are Changing
Gulf of Alaska

Reduction in Body Size of Copper River Sockeye

Data courtesy S. Moffitt, S. Haught, & J. Morella
ADF&G Cordova
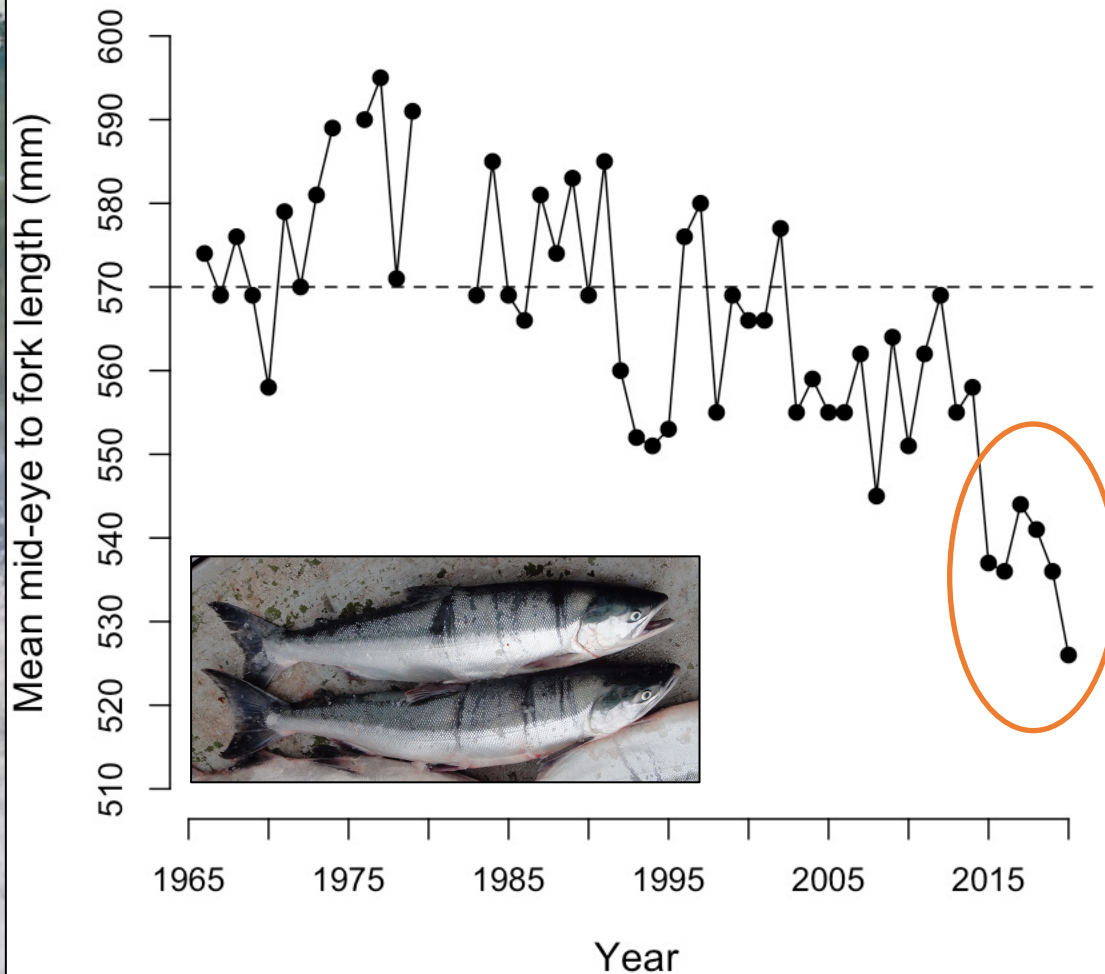
Image: NASA

High Latitude Freshwater Ecosystems are Changing
Copper River, Alaska

Larsen et al. (2015) Geophys. Res. Lett. 42, 5902–5908

Image: M.& D Roberts

High Latitude Freshwater Ecosystems are Changing
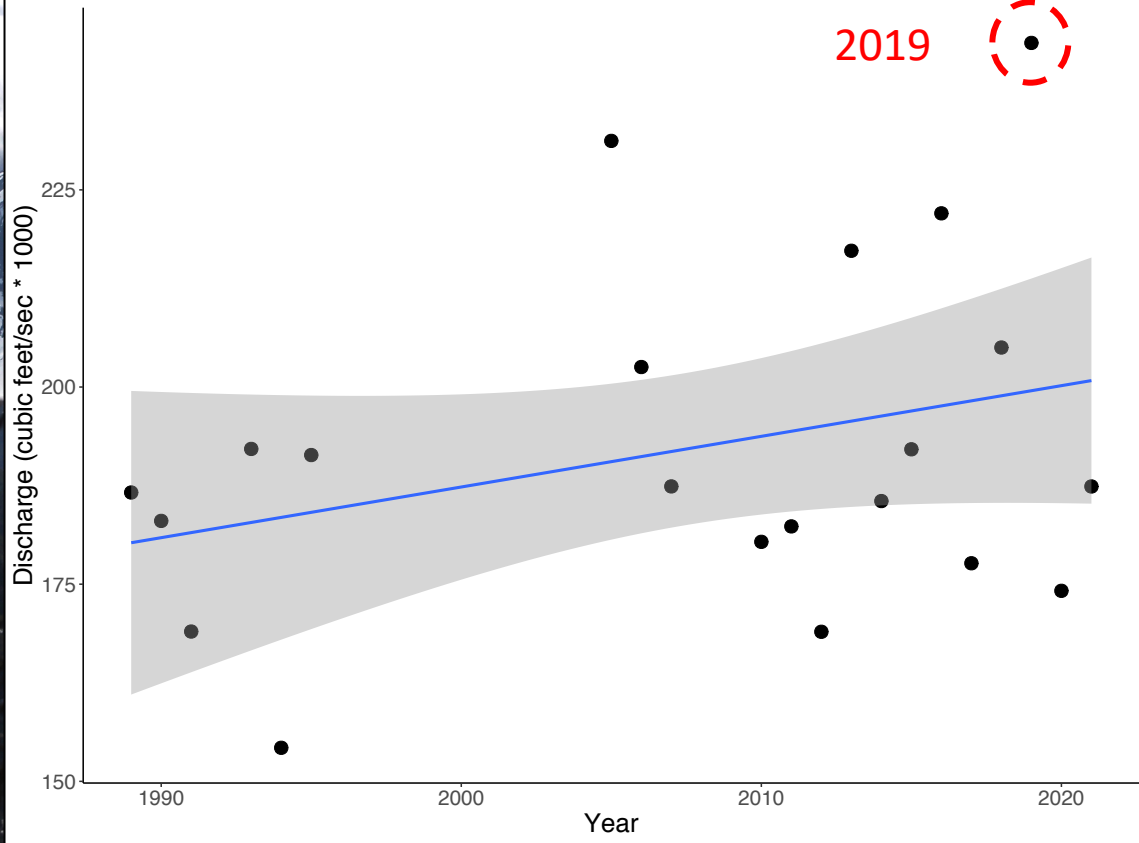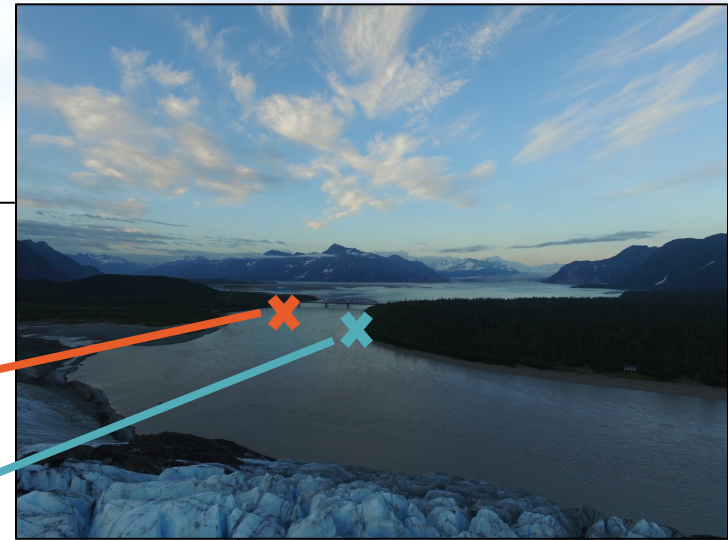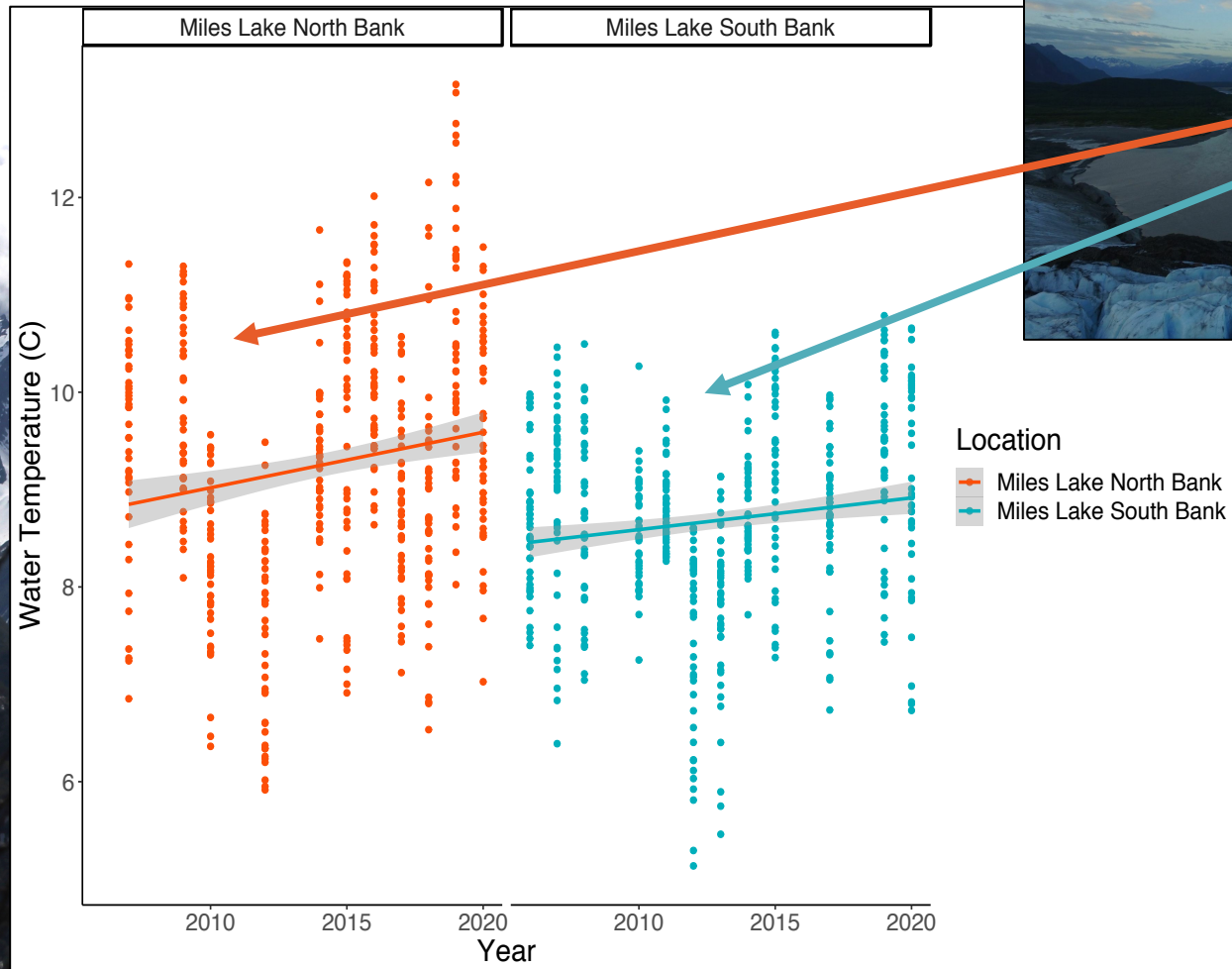## Copper River, Alaska

Image: M & D Roberts

High Latitude Freshwater Ecosystems are Changing
Copper River, Alaska

- 0.8 °C increase over period of record at North Bank
- 0.5 °C increase over period of record at South Bank

Image: M & D Roberts

Copper River Sockeye Spawning Migration Study Research Questions

What factors are related to mortality risk for river migrating sockeye salmon while enroute to the spawning grounds?

Potential factors include: Body size,
Energetic condition (bomb cal & fat meter),
Spawning stock (run timing group),
Gene expression (gill genomics),
Pathogen presence/load (gill genomics)

Also addressing more basic questions related to life history tradeoffs, specifically the relationship between the energetic costs of migration and investment in reproduction.

Two broad study components (2019-2021):
Body composition of adults at different stages of migration
Radio telemetry

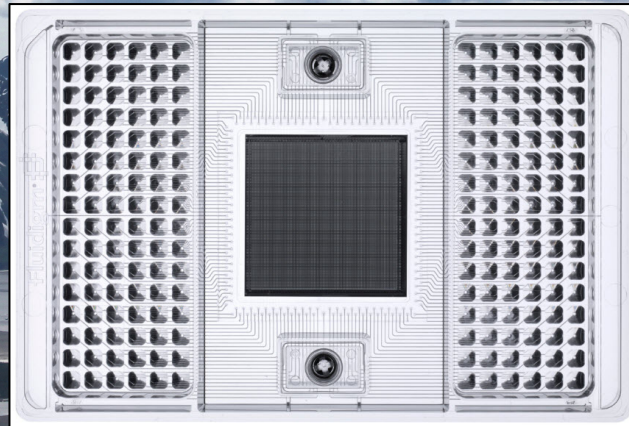*Image: Copper River Marketing Assoc.*

Field Campaign

- Radio-tag 100 fish in 3 different run timing groups (early, middle, and late season).
- 854 adult sockeye radio-tagged and tracked (2019-2021).
- Collected biological data on all fish radio tagged in study.
- A handheld sensor allows for reliable estimates of fat content. Measurements ranged from less than 1% up to 16%.
- Gill tissue collected for transcriptome and pathogen analysis.
- Assess attributes of unsuccessful versus successful sockeye migrants.
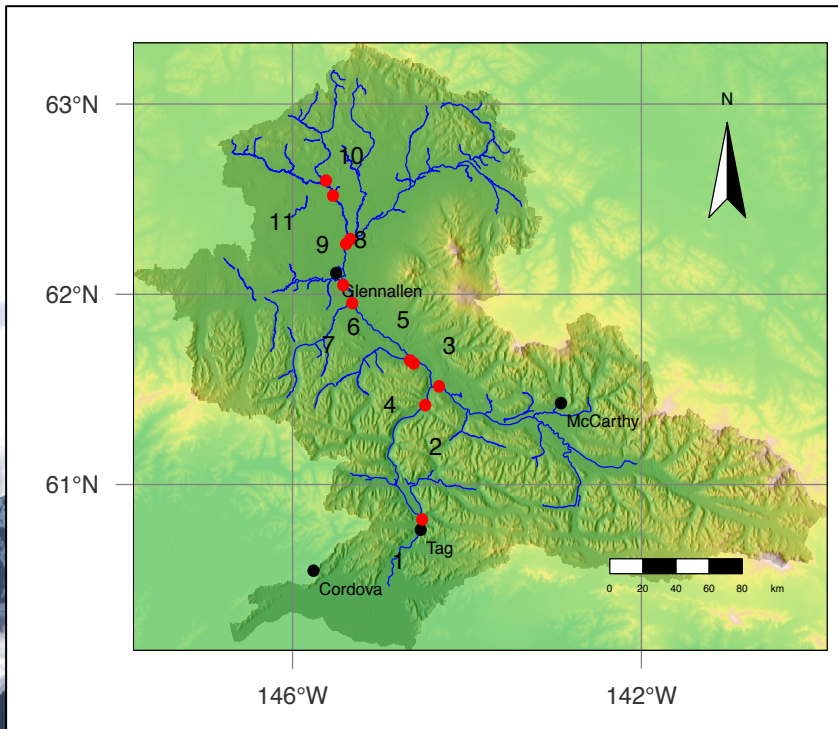
Image: M & D Roberts
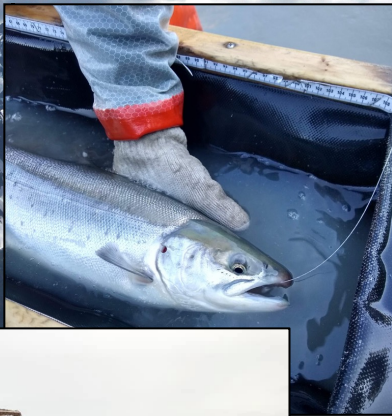
Lab Analysis

- Gill tissue transcriptome analysis at DFO Canada Nanaimo Genomics Lab (Kaukinen, Ming, Li, and Miller).
- Salmon Fit-Chip study used curated biomarker panels for thermal stress, hypoxia, viral disease, and imminent mortality.
- Random forest classifiers, based on sockeye and Chinook salmon of known stressor states, were applied to predict the probability that each stressor was present in wild-caught sockeye.
- High throughput molecular (qPCR) surveys of infectious agents using BioMark dynamic arrays were also conducted – data not presented here.

Image: M & D Roberts

Radio-Tagging Summary

Year/ Release Group	Total # Tags	# Successful	% Successful	
2019 - Middle	98	19	19.4 %	
2019 - Late	100	32	32.0 %	
2020 - Early	100	68	68 %	
2020 - Middle	106	54	50.9 %	
2020 - Late	30	2	0.1 %	*
2020 - August	53	30	56.6 %	*
2021 - Early	100	80	80 %	
2021 - Middle	105	65	61.9 %	
2021 - Late	117	70	59.5%	
2021 - August	17	10	58.8 %	*

10 ground receivers, managed by ADF&G

Success defined as passage through Wood Canyon, with the exception of August tagging near Chitina Airport (*)

Image: M & D Roberts

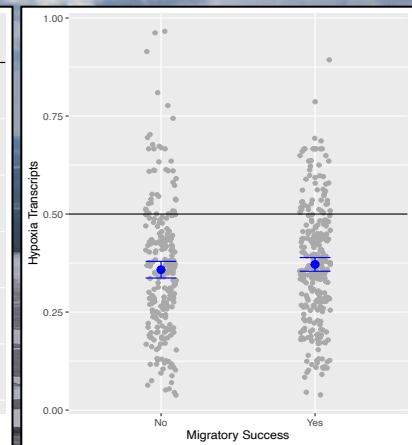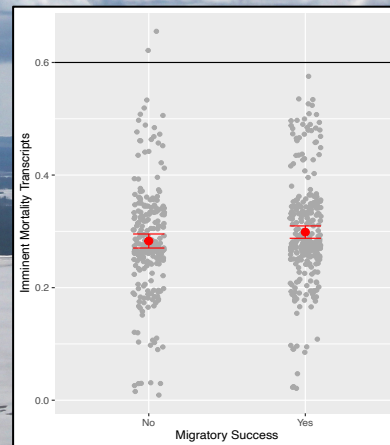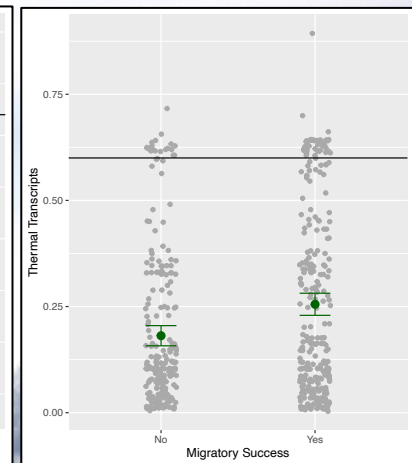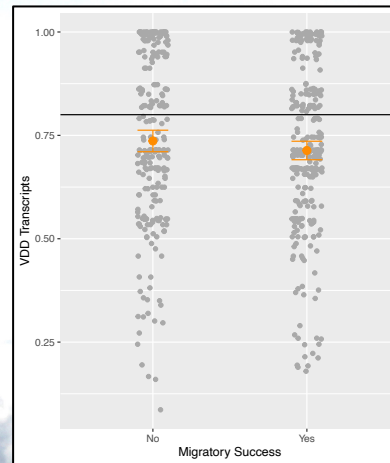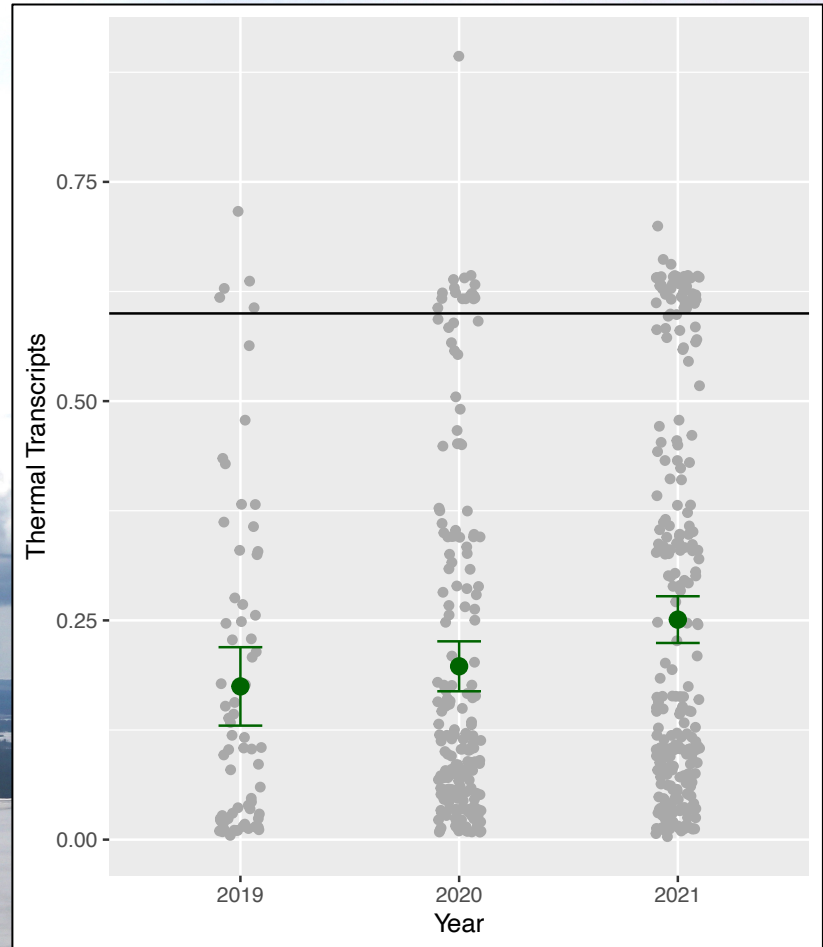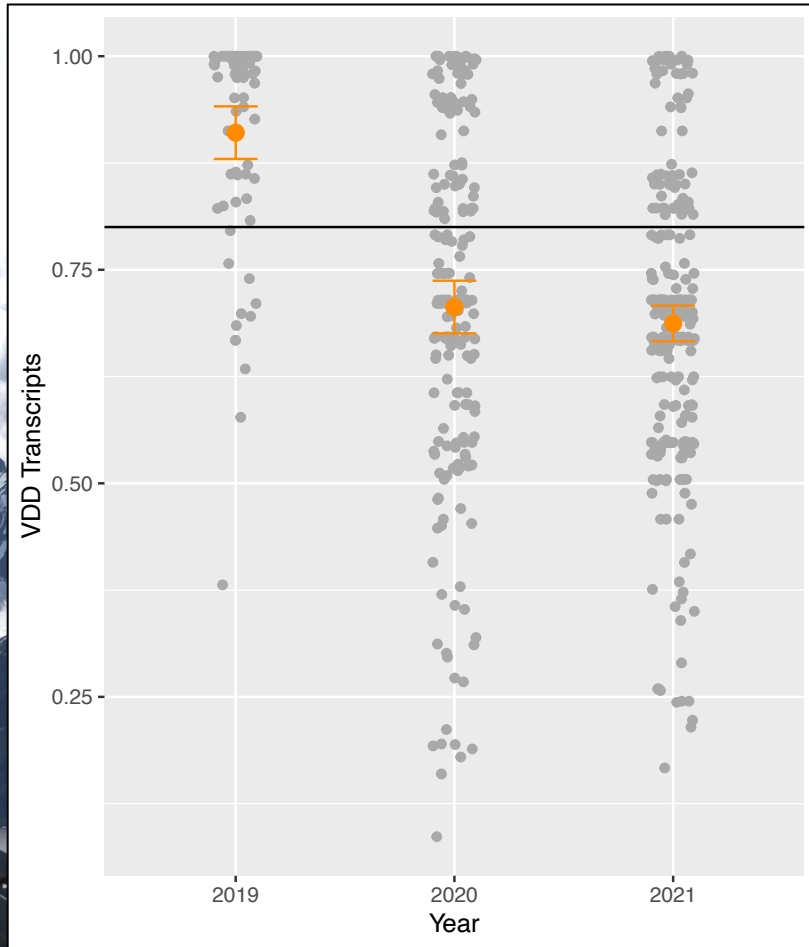# Characteristics of Sockeye Survivors – Body Size

Roberts
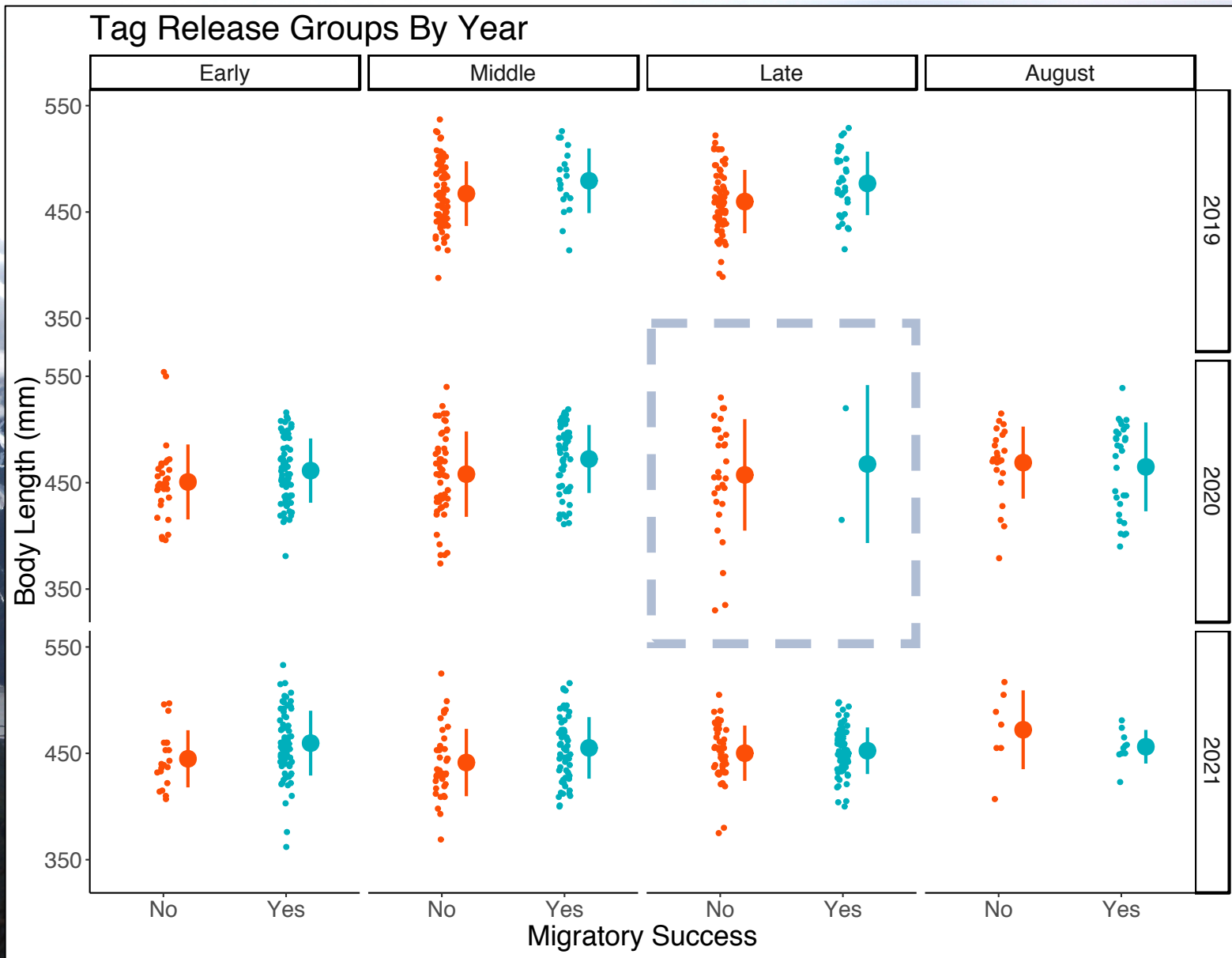
Characteristics of Sockeye Survivors - Fat

Roberts
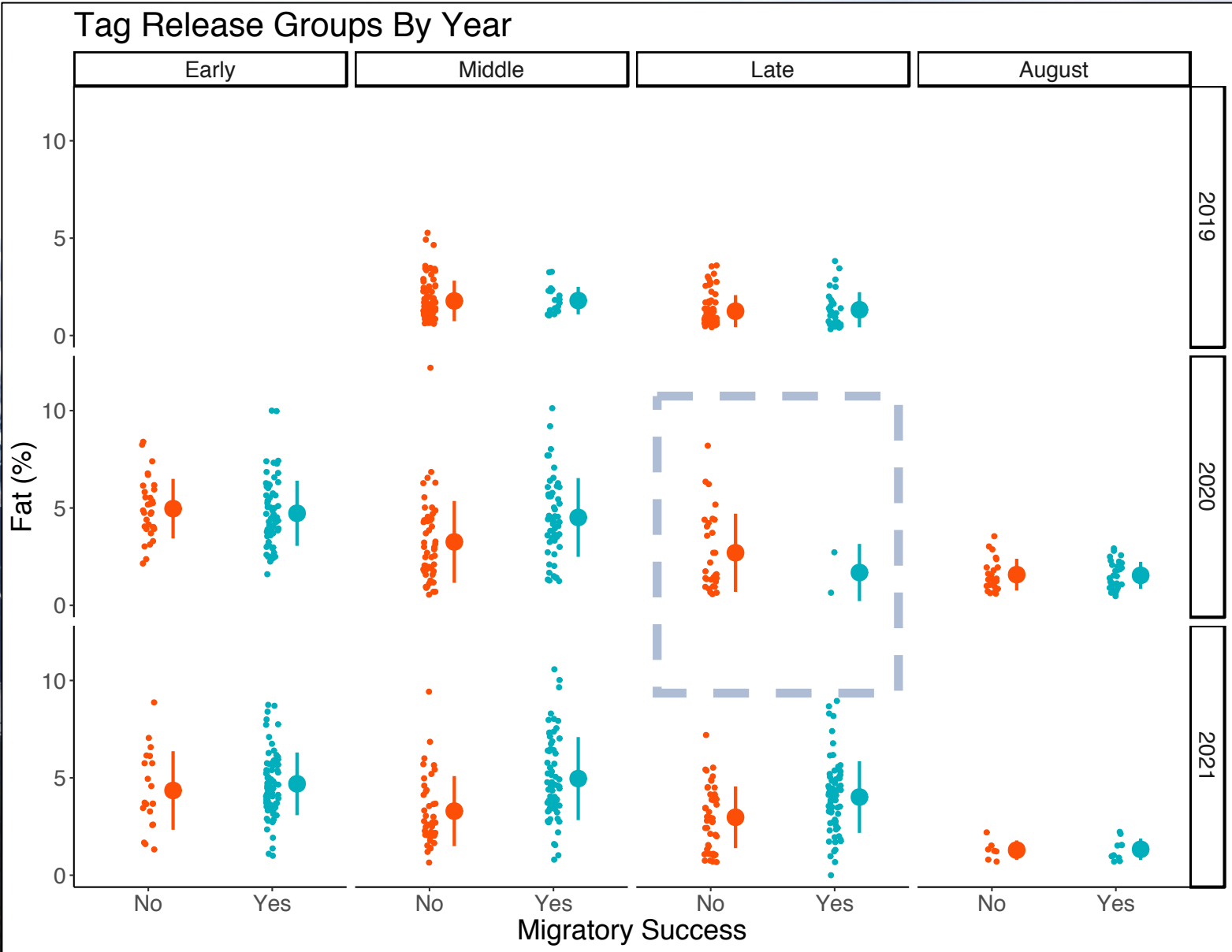
Characteristics of Sockeye Survivors - Transcriptomes

Image: M & D Roberts
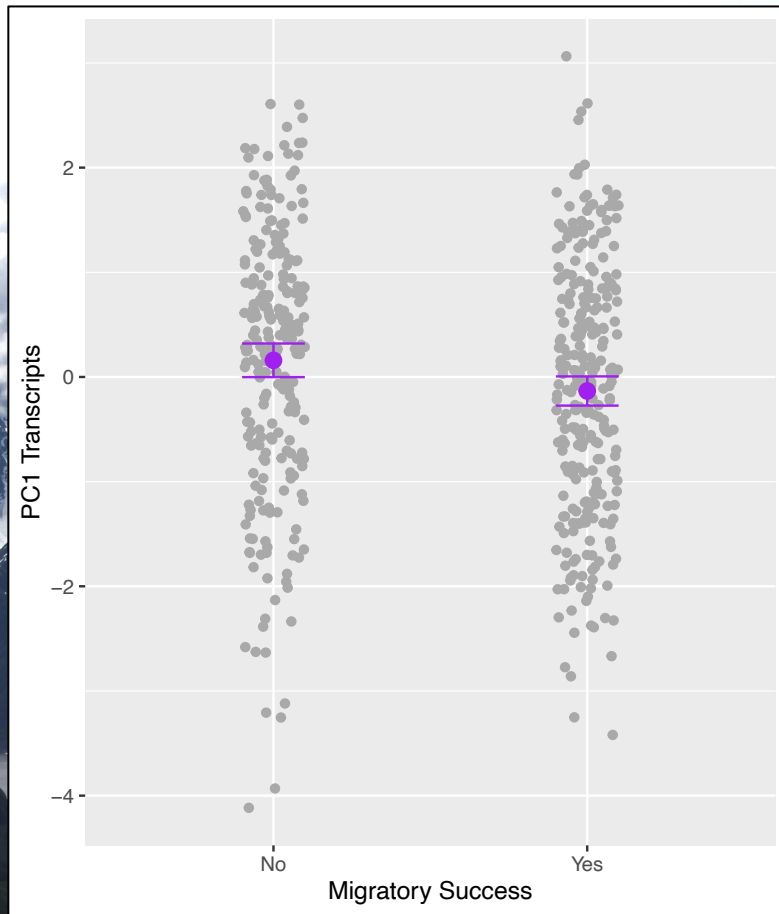
Annual Variation in Transcriptomes

Image: M & D Roberts

Copper River Sockeye Migration Study Summary

- General pattern: early run sockeye have greatest energy reserves, seasonal decline in energy reserves.

- Both body size and energy reserves explain migratory success, particularly for sockeye in the middle part of the run.

- Sockeye migration success is predicted by molecular transcripts – VDD and thermal markers. More analysis is needed to formalize these relationships. Include pathogen results in future analysis.

- Accelerated glacial melting can lead to higher flows that create a hydraulic barrier to passage at Wood Canyon, may create more physically demanding conditions for sockeye – 2019

- Future work (2023-2024) in collaboration with NPS (WRST)
  - Combining genetic stock identification with measures of energy and health of migrating adult sockeye salmon, and modeling efforts evaluating river temperature and flow on migration of Copper River sockeye salmon.

Image: M & D Roberts

Thanks to Field Crews & Collaborators

Image: M & D Roberts