

***Artemia* individual and population level
acclimation to salinity increases in the Great
Salt Lake, Utah, USA**

Artemia resiliency to changing environmental conditions

Current Drought Conditions in Utah

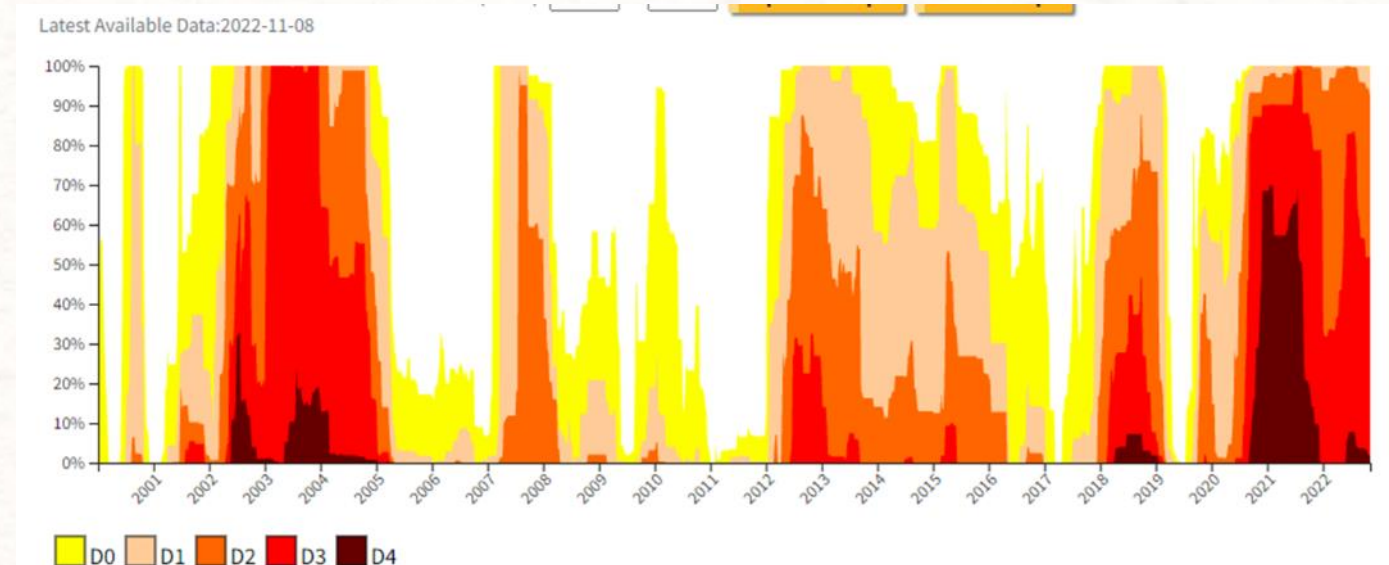
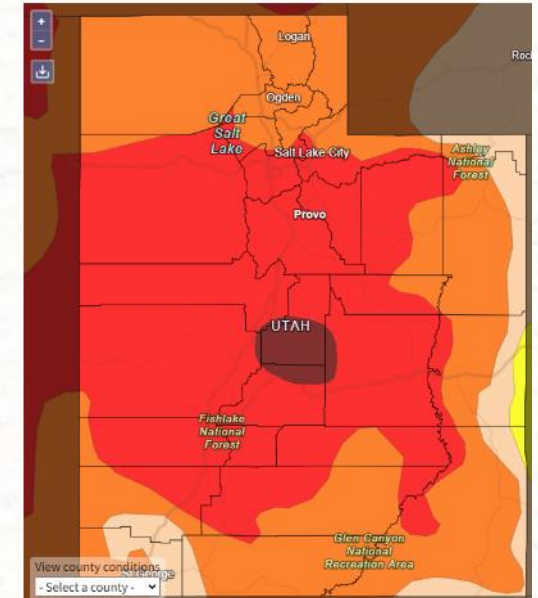
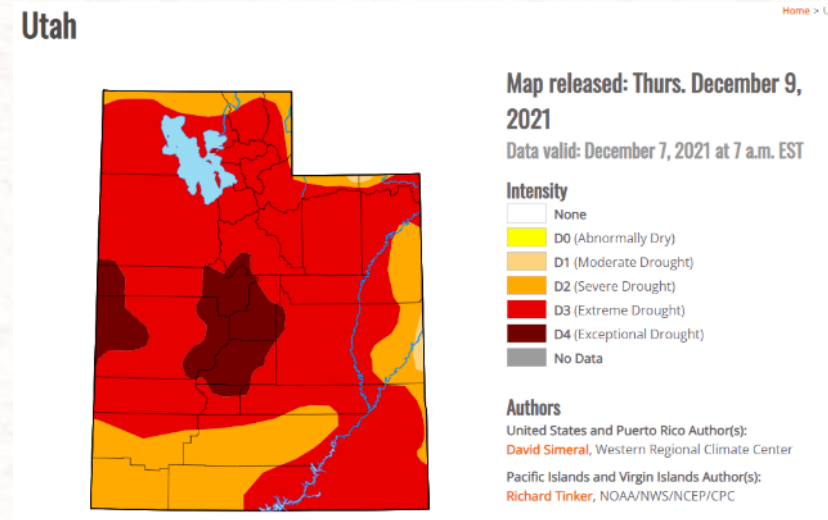
- Entire State of Utah is in Drought Condition

	D2 - Severe Drought - Pasture and water is inadequate for cattle; ranching management practices change - Air quality is poor; dust is a problem - Streams and ponds are dry	92.3% of UT (D2-D4)
	D3 - Extreme Drought - Fire danger increases; fire bans on public land are implemented - Native vegetation is stressed - Streamflow is low	51.7% of UT (D3-D4)
	D4 - Exceptional Drought - Fire restrictions increase - Irrigation water allotments are cut	1.9% of UT (D4)

WAS / GSL / Artemia Resiliency / Dec 2022

Previous year: December 2021

Current year: November 2022



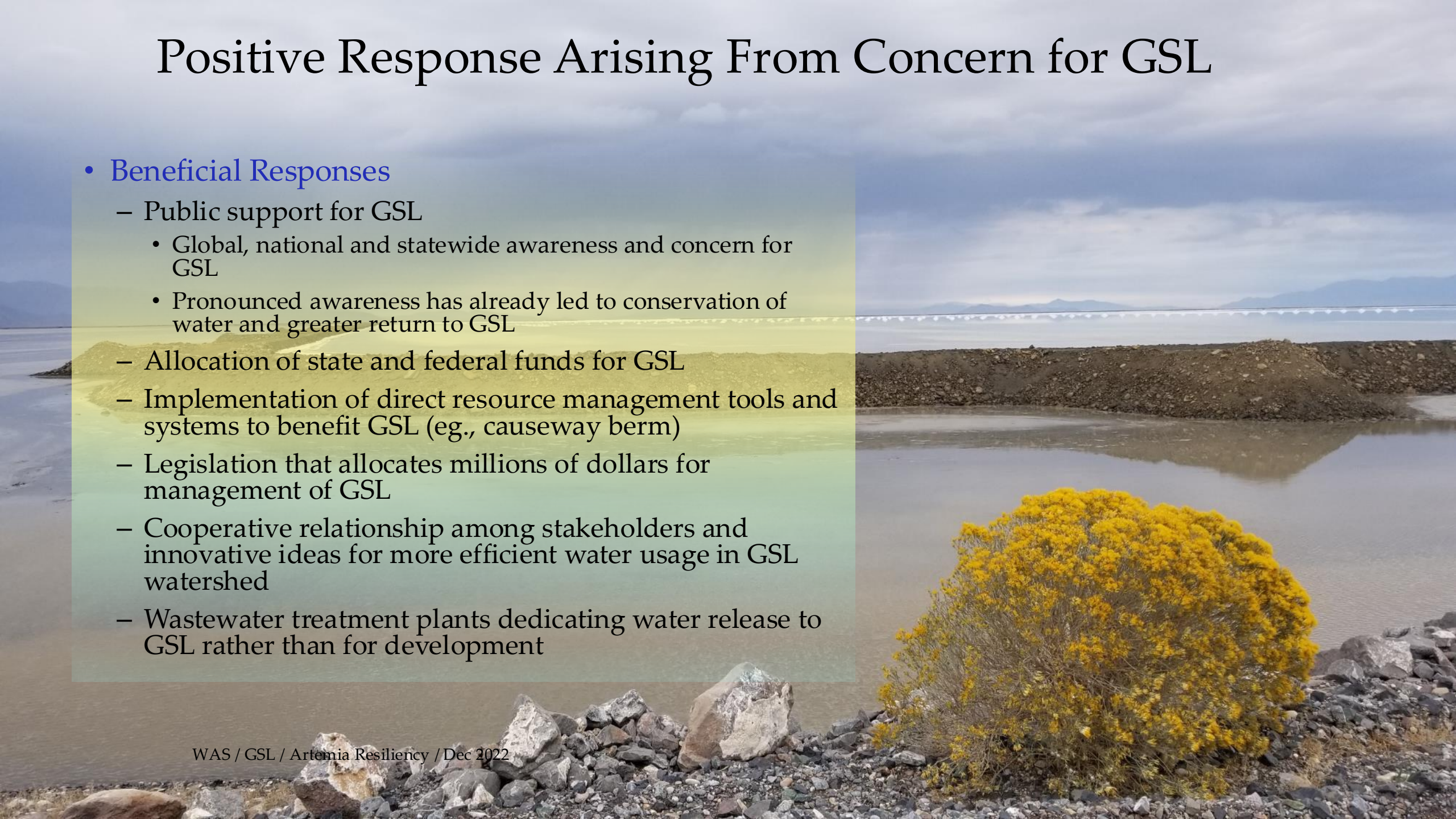
Great Salt Lake Volume: 1986 & 2022



Positive Response Arising From Concern for GSL

- Beneficial Responses

- Public support for GSL
 - Global, national and statewide awareness and concern for GSL
 - Pronounced awareness has already led to conservation of water and greater return to GSL
- Allocation of state and federal funds for GSL
- Implementation of direct resource management tools and systems to benefit GSL (eg., causeway berm)
- Legislation that allocates millions of dollars for management of GSL
- Cooperative relationship among stakeholders and innovative ideas for more efficient water usage in GSL watershed
- Wastewater treatment plants dedicating water release to GSL rather than for development



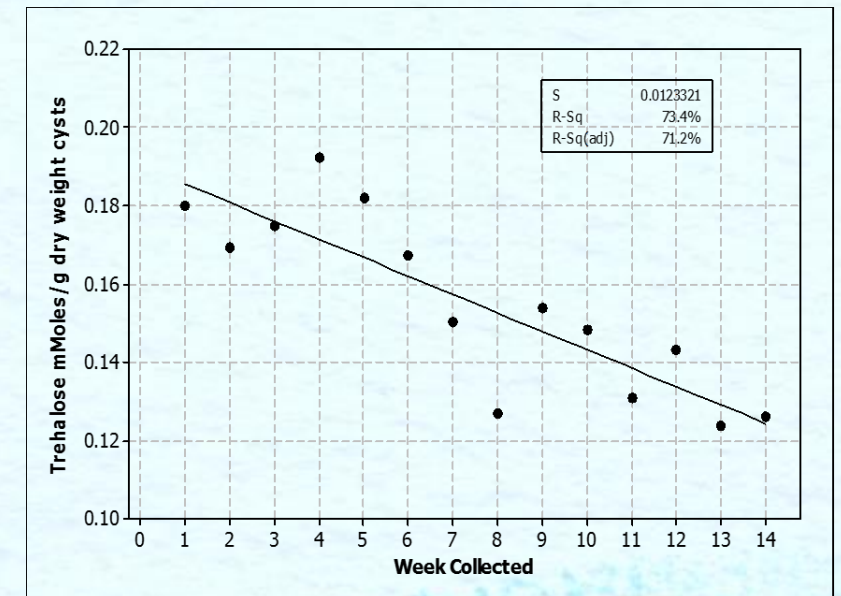
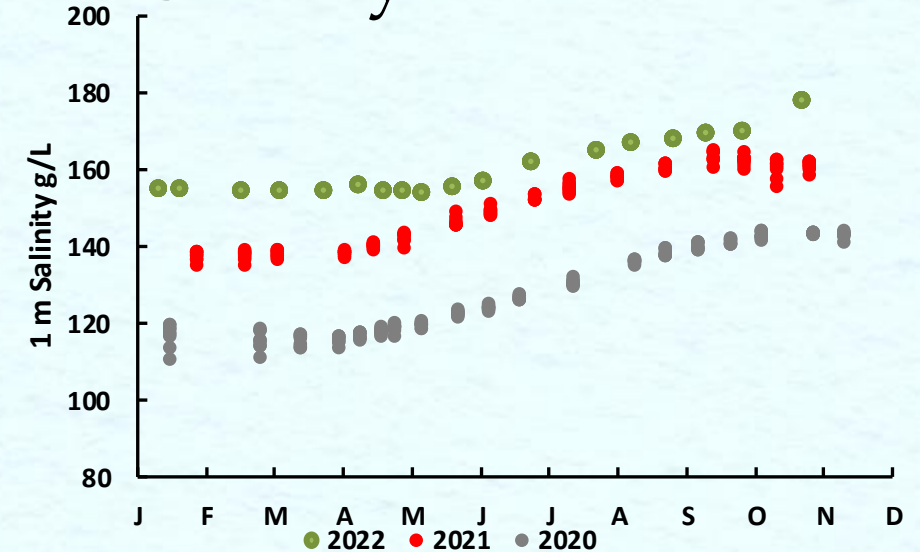
Potential Impacts on Artemia from Elevated Salinity

• CONCERNS

- Multiple stressors were accumulating that could impact Artemia reproduction, growth, development, and survival.
- According to scientific literature salinity is approaching the putative threshold (180 g/L to 220 g/L) for multiple adverse impacts on Artemia.
- The pattern of cyst deposition, diapause termination and emergence from quiescence may be altered by the high salinity.
- Insufficient influx of fresh water may fail to synchronously trigger hatching among quiescent cysts.
- Elevated salinity may impose greater energy demands for emergence.

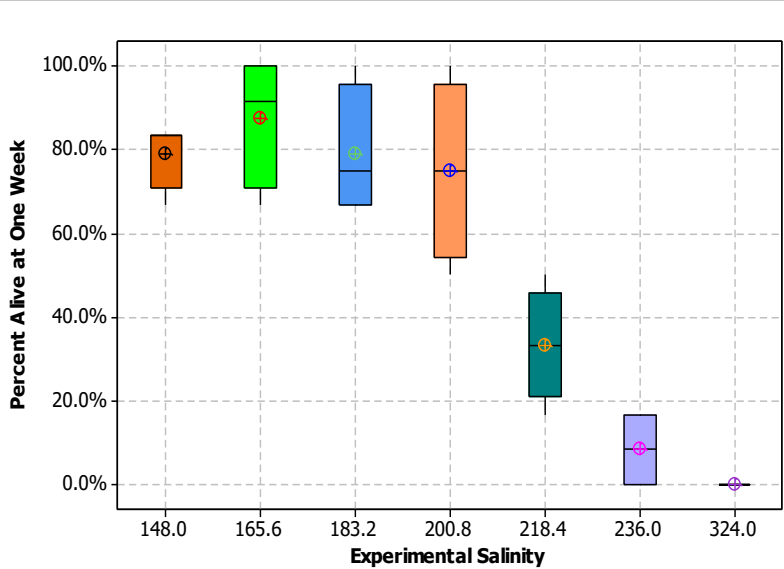
• LAB EXPERIMENTS AND OBSERVATIONS OF THE GSL POPULATION

- Lab experiments confirmed some of our concerns regarding adverse impacts of increased salinity.
- However, laboratory studies and literature assessments did not coincide with observed response of the GSL population. The Artemia population was more robust than anticipated.

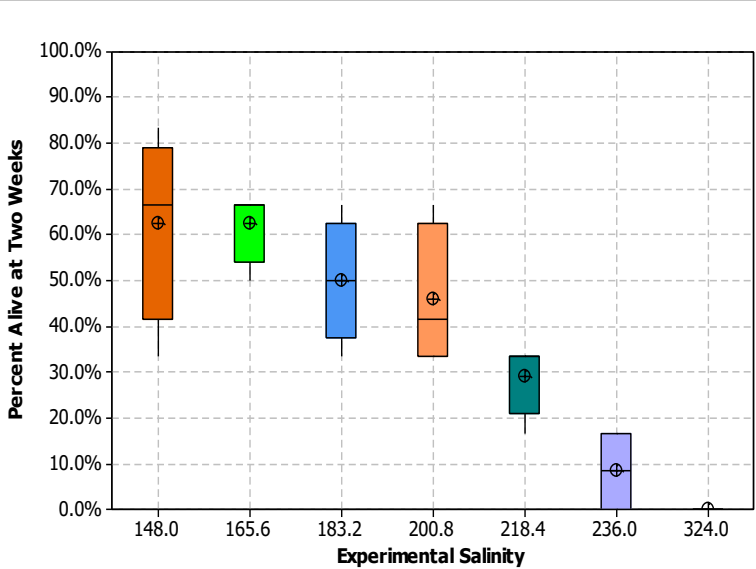


Salinity Stress: Weekly Survival Under Laboratory Conditions

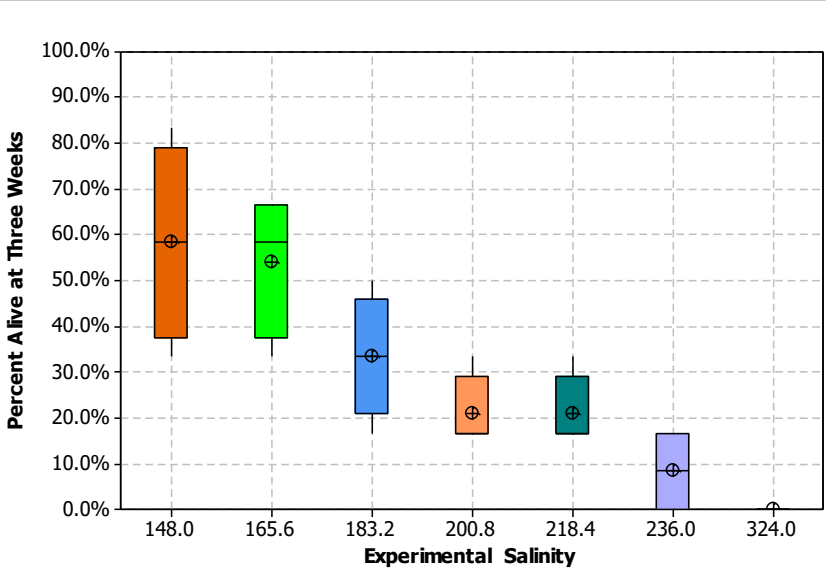
One Week



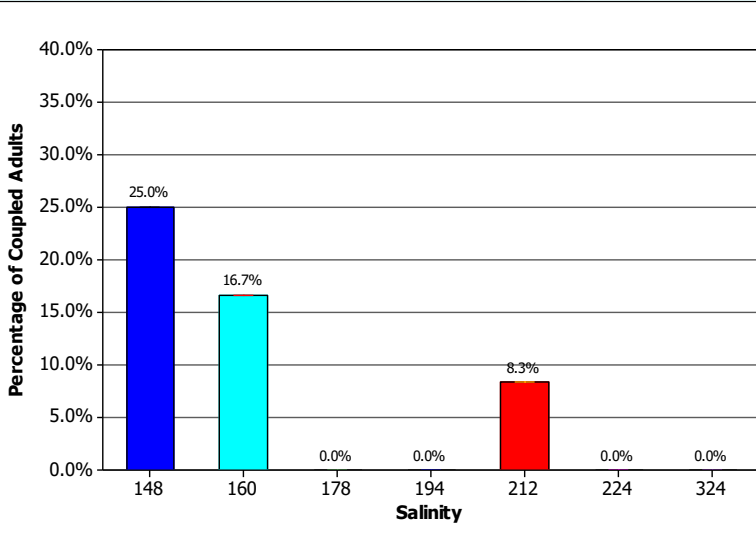
Two Weeks



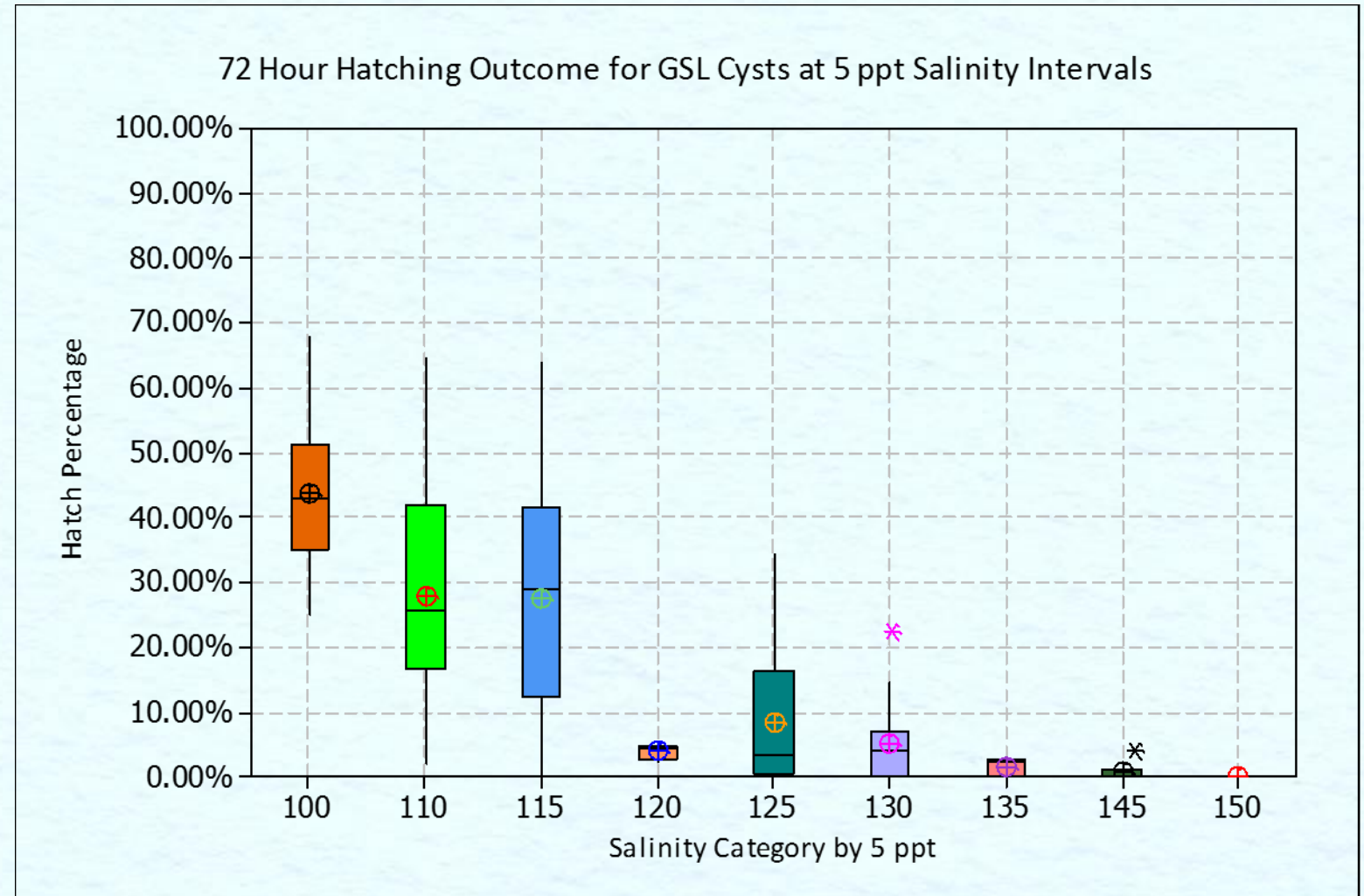
Three Weeks



Salinity effect on coupling of adults



Influence of Salinity Change on Hatching and Emergence Under Laboratory Conditions





Research Program on GSL

Since 1999 to present (13 years of research)

Weekly, biweekly to monthly year-round

9 to 27 sites in Gilbert Bay per survey

Routine surveys completed: 446

Water samples collected: 5,352

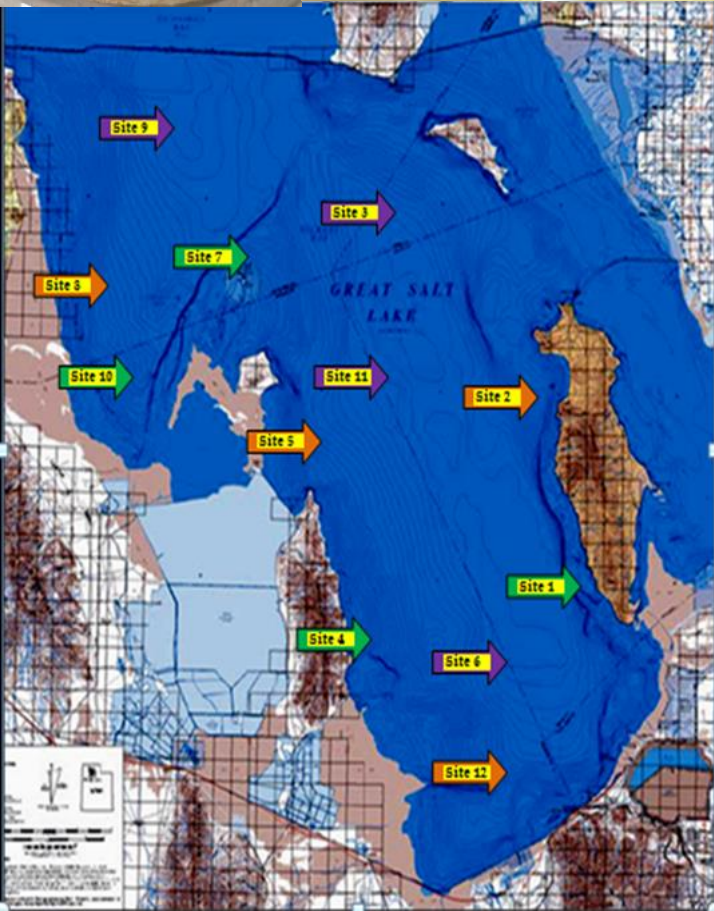
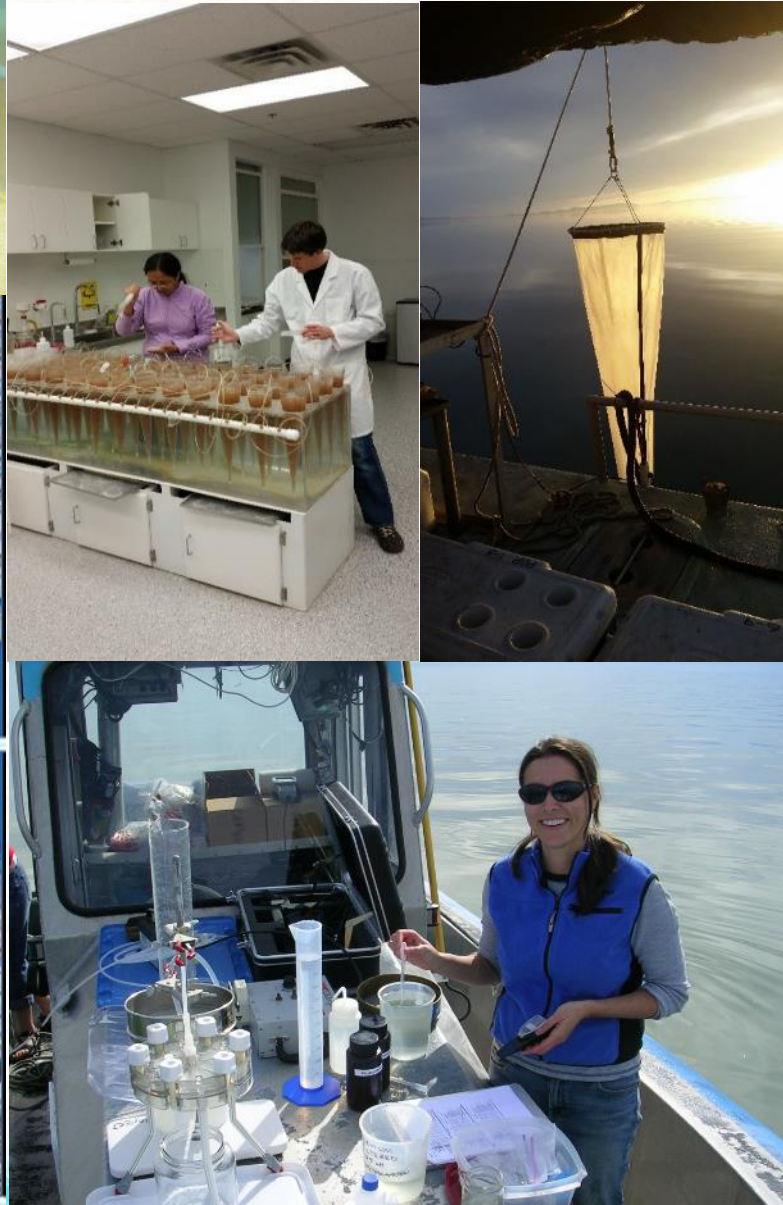
Abiotic measurements: 16,056

Nutrient analyses of water samples:
16,474

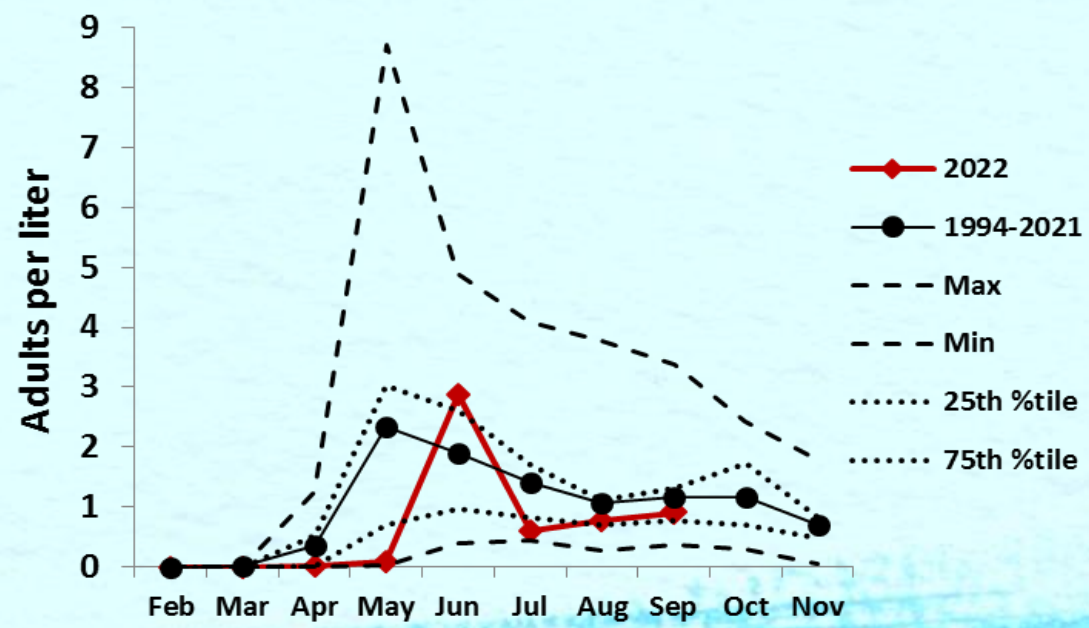
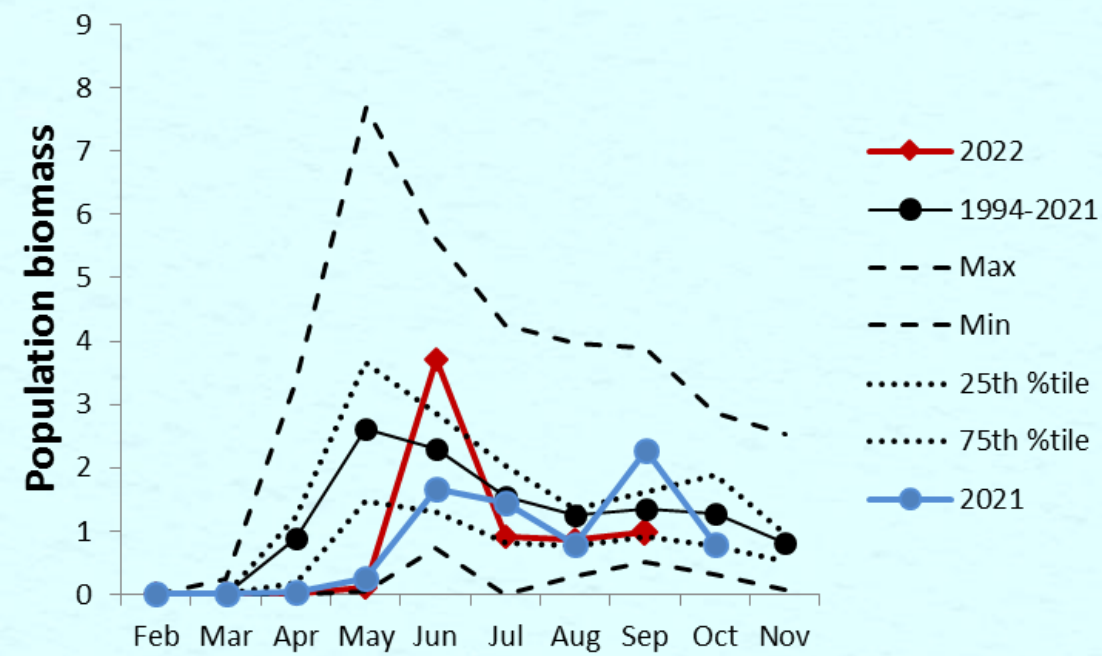
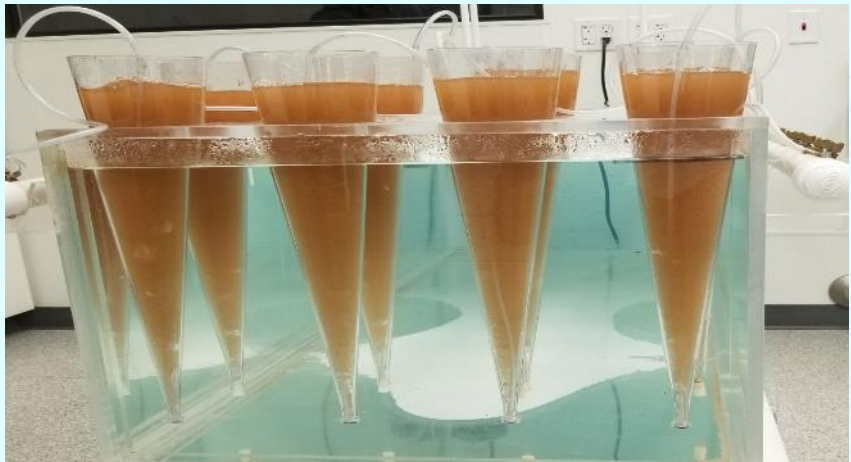
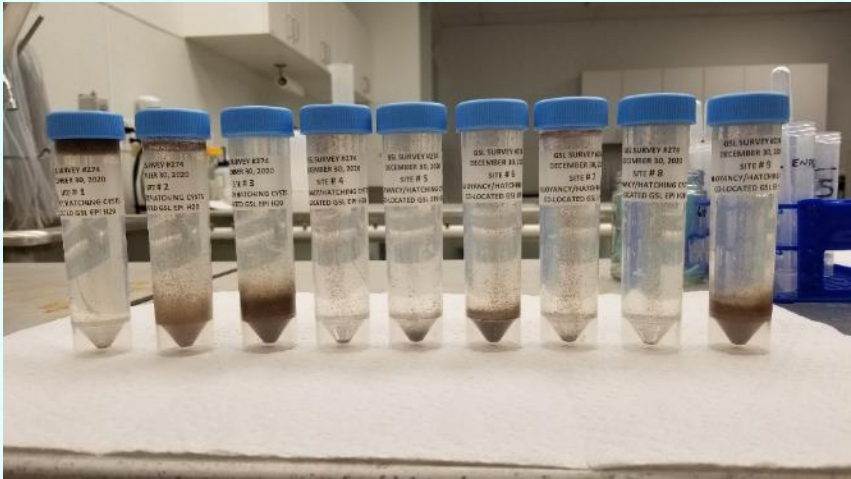
Artemia reproduction counts: 11,150

Detailed monimolimnion evaluations:
4,014

Contaminant analyses: 558



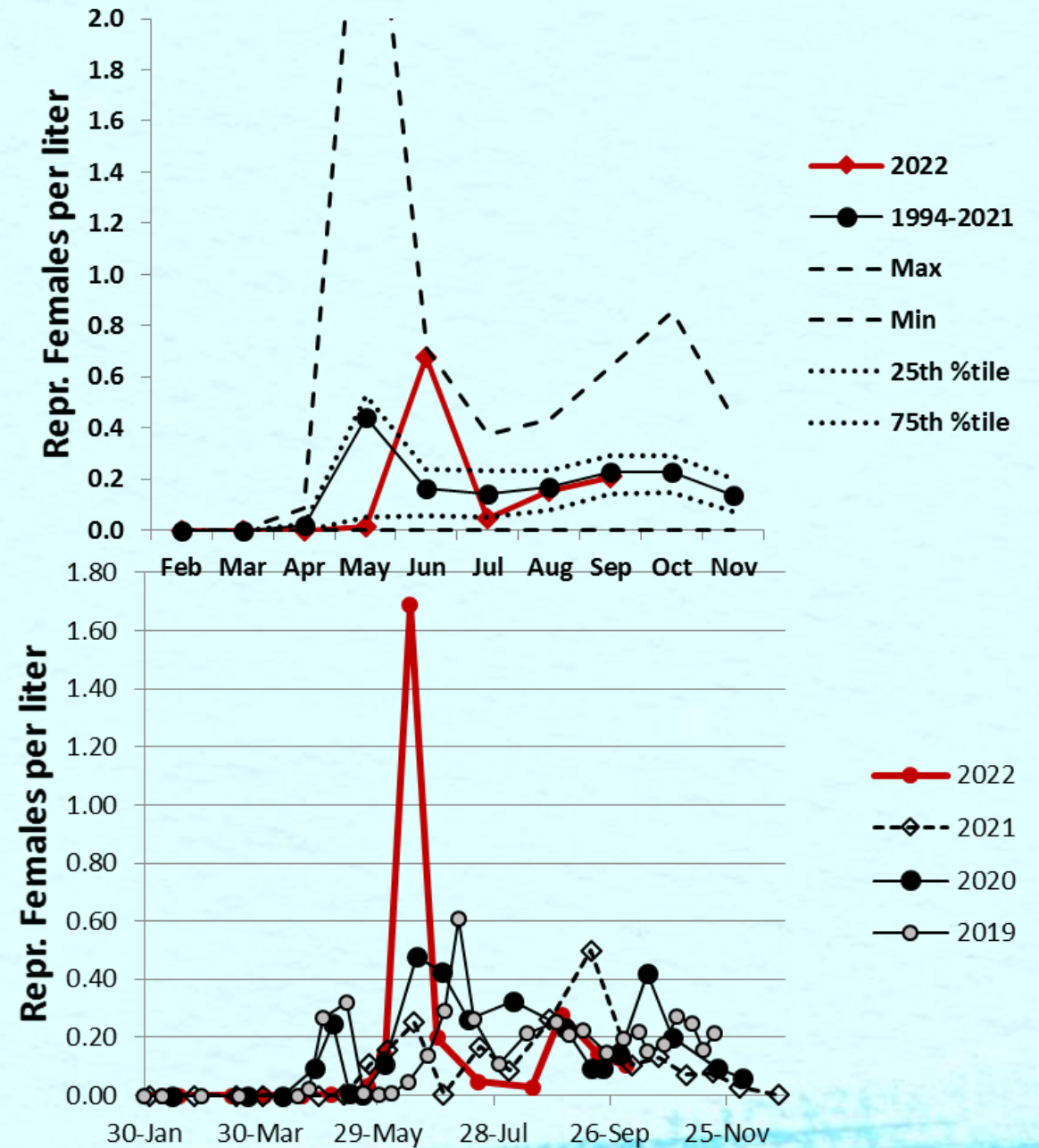
Comparing laboratory studies with actual population dynamics



Artemia Reproduction

- GRAVID FEMALES

- Current Average = 0.21 Females / Liter



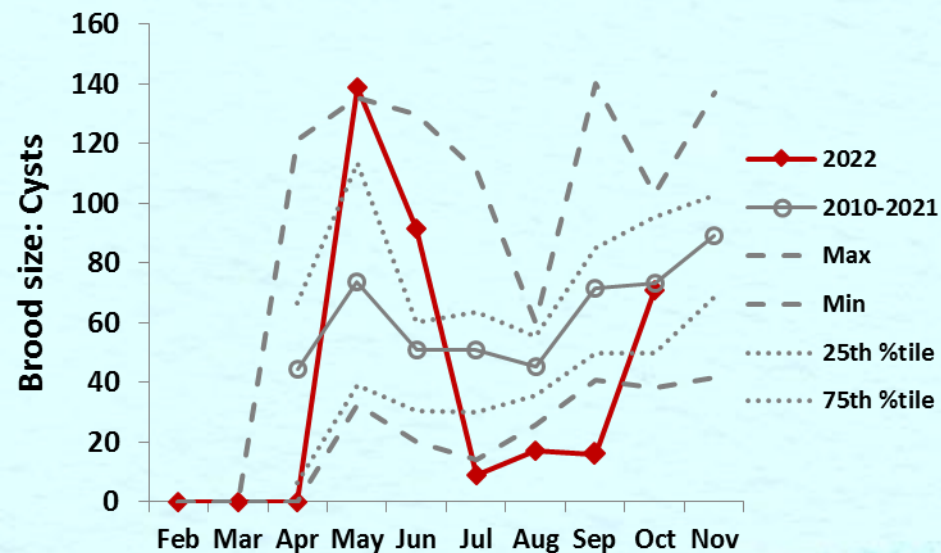
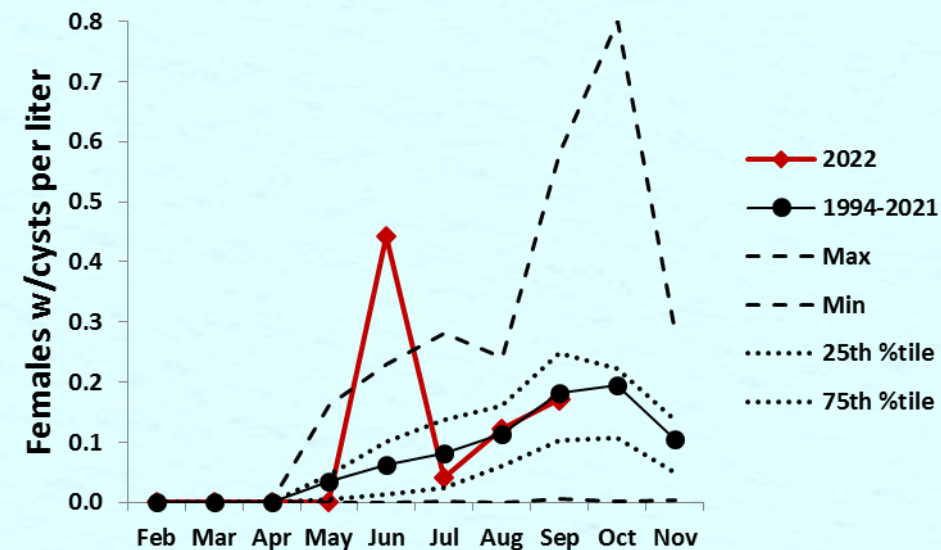
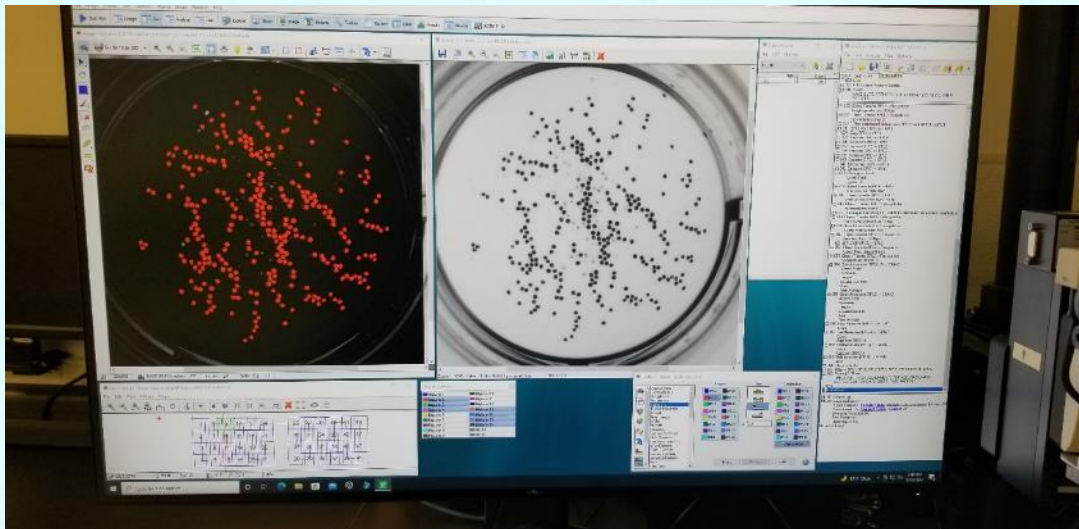
Artemia Cyst Production

- OVIPAROUS FEMALES

- 2022 Max: 0.46 Oviparous Females/L
- Current Average = 0.17 Oviparous Females / Liter

- BROOD SIZE

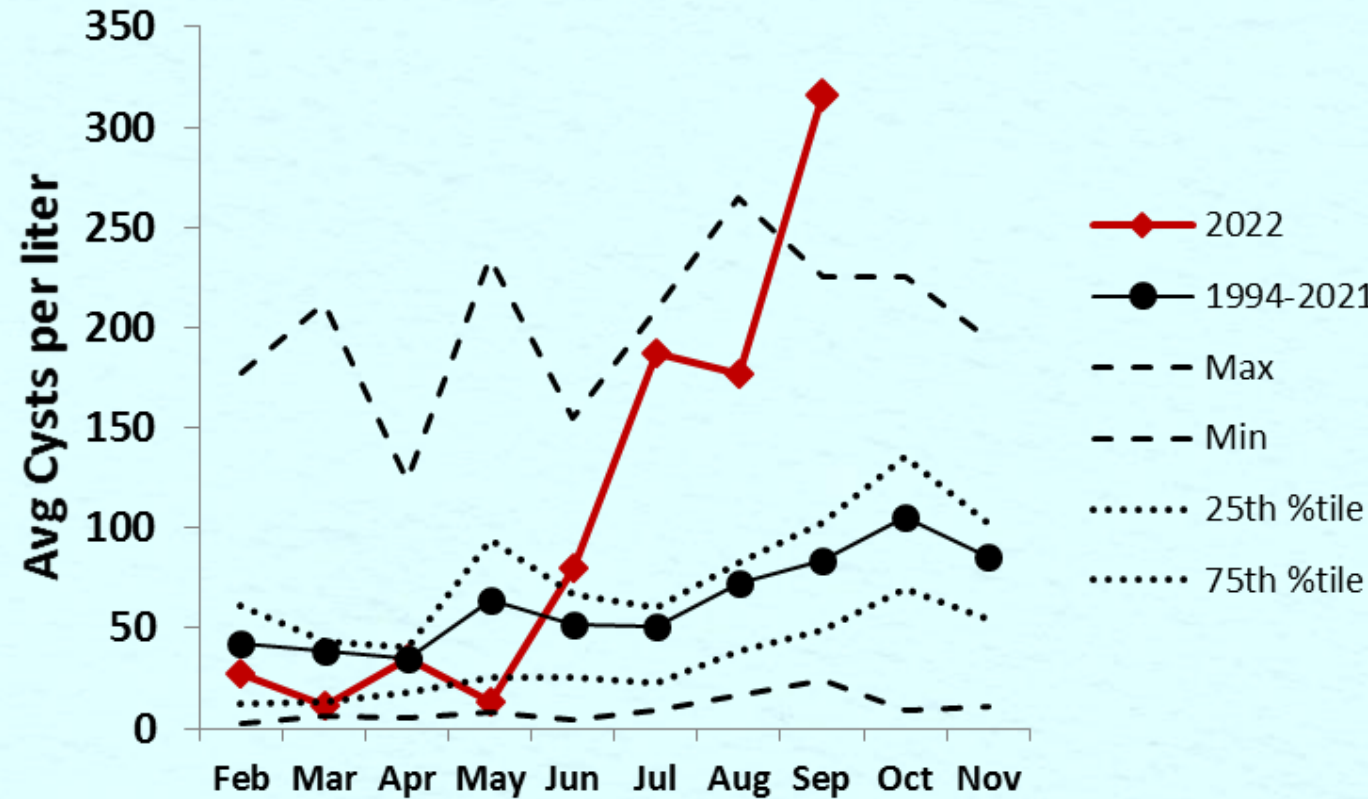
- 2022 Max: 146 cysts / brood
- Current Average = 71 cysts / brood



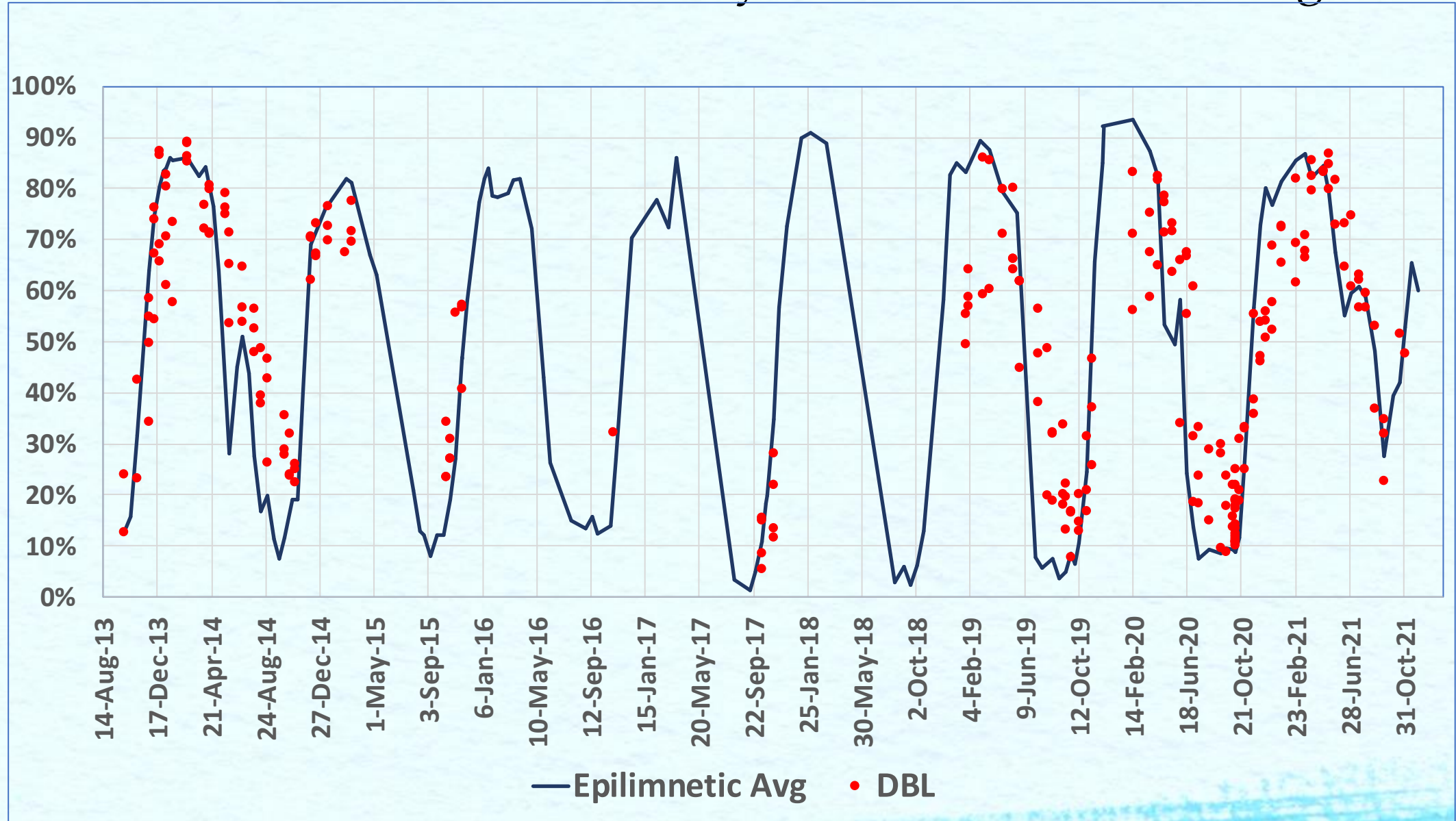
Cyst Abundance in GSL

- Fall Cyst Count

- October 2022 > 300 per liter
- Long-term average = 107 per liter



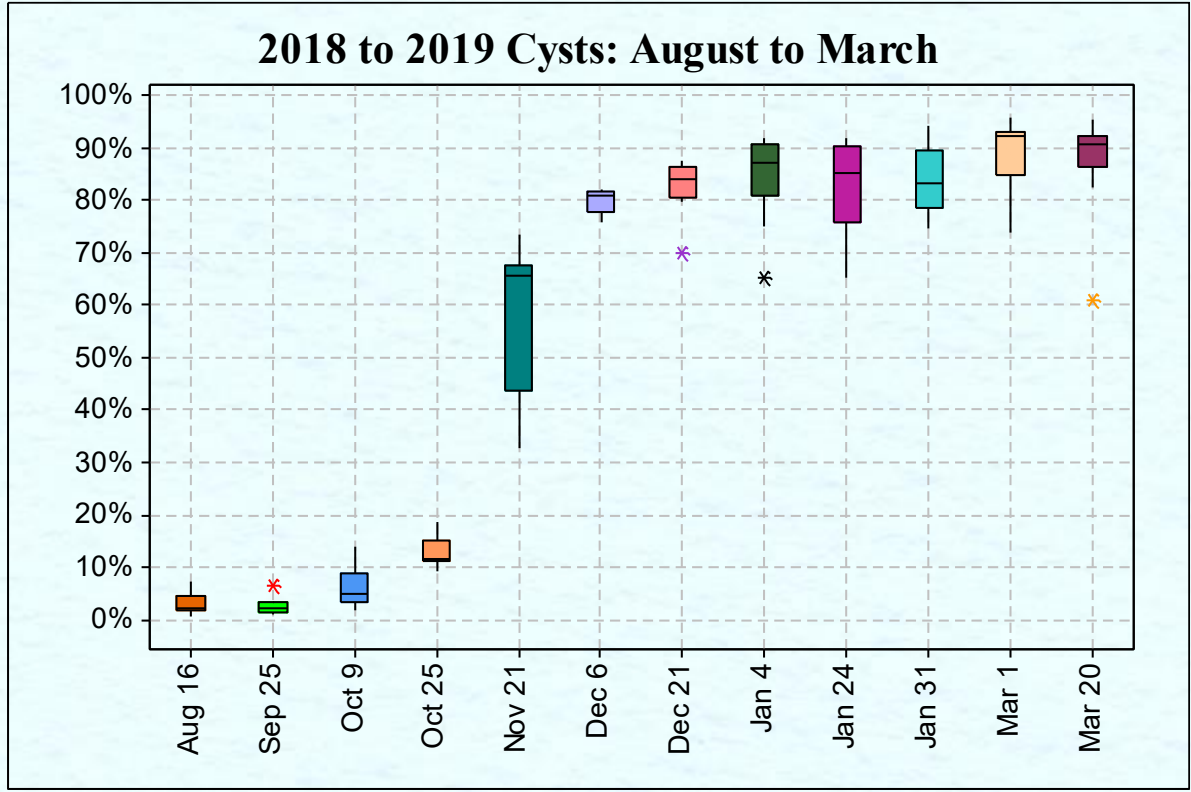
Multi-Year Pattern of Dormancy Deactivation and Emergence



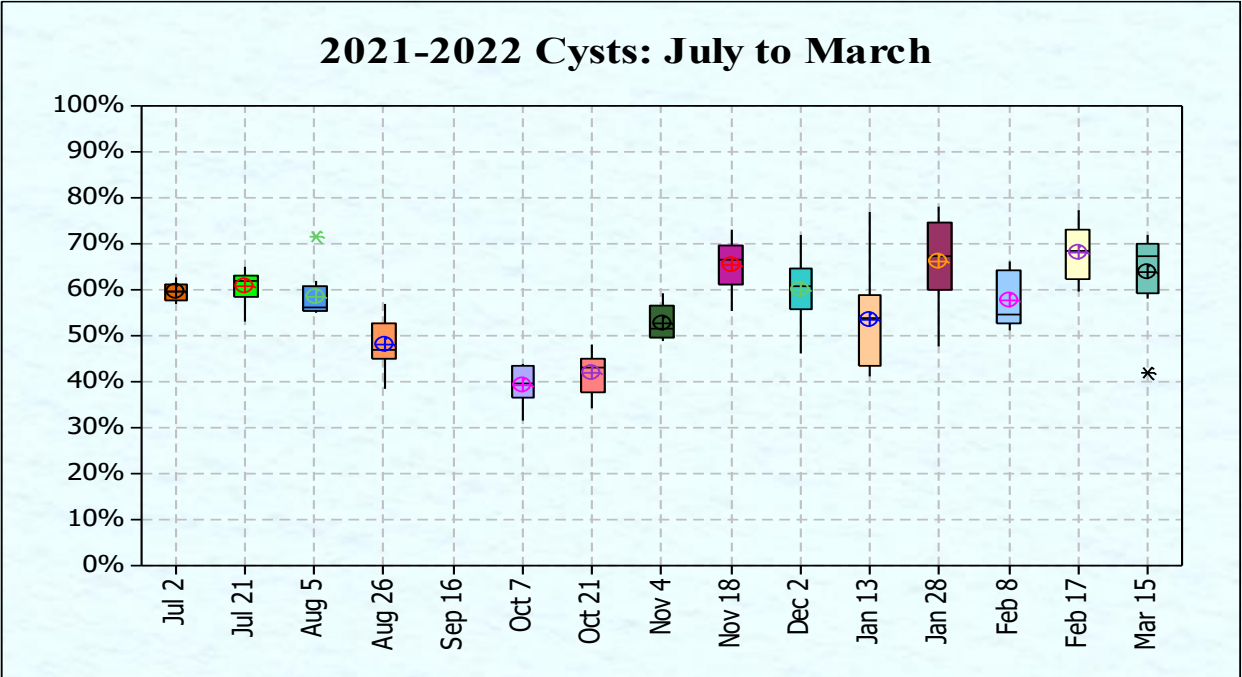
Comparative Pattern of Dormancy Termination and Emergence

2018 to 2019 Cysts: August to March

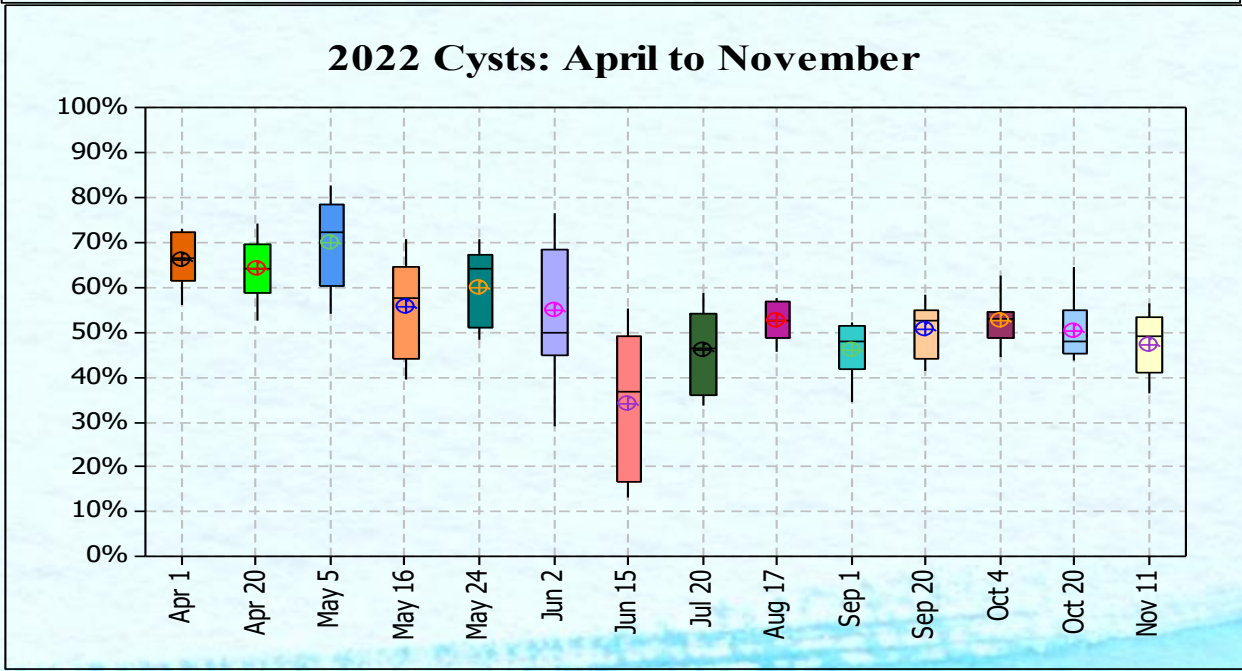
Hatching percentage



2021-2022 Cysts: July to March

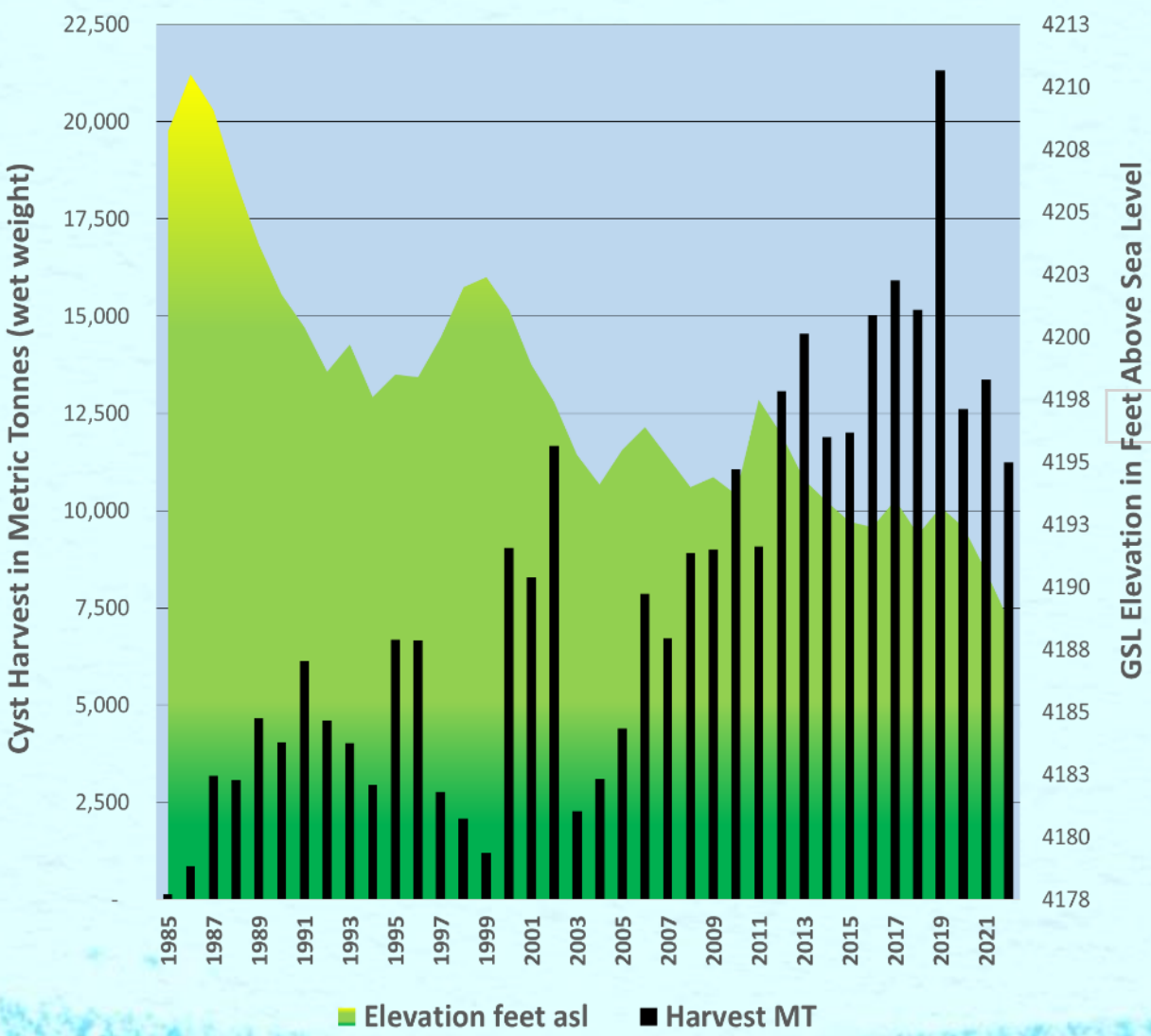


2022 Cysts: April to November

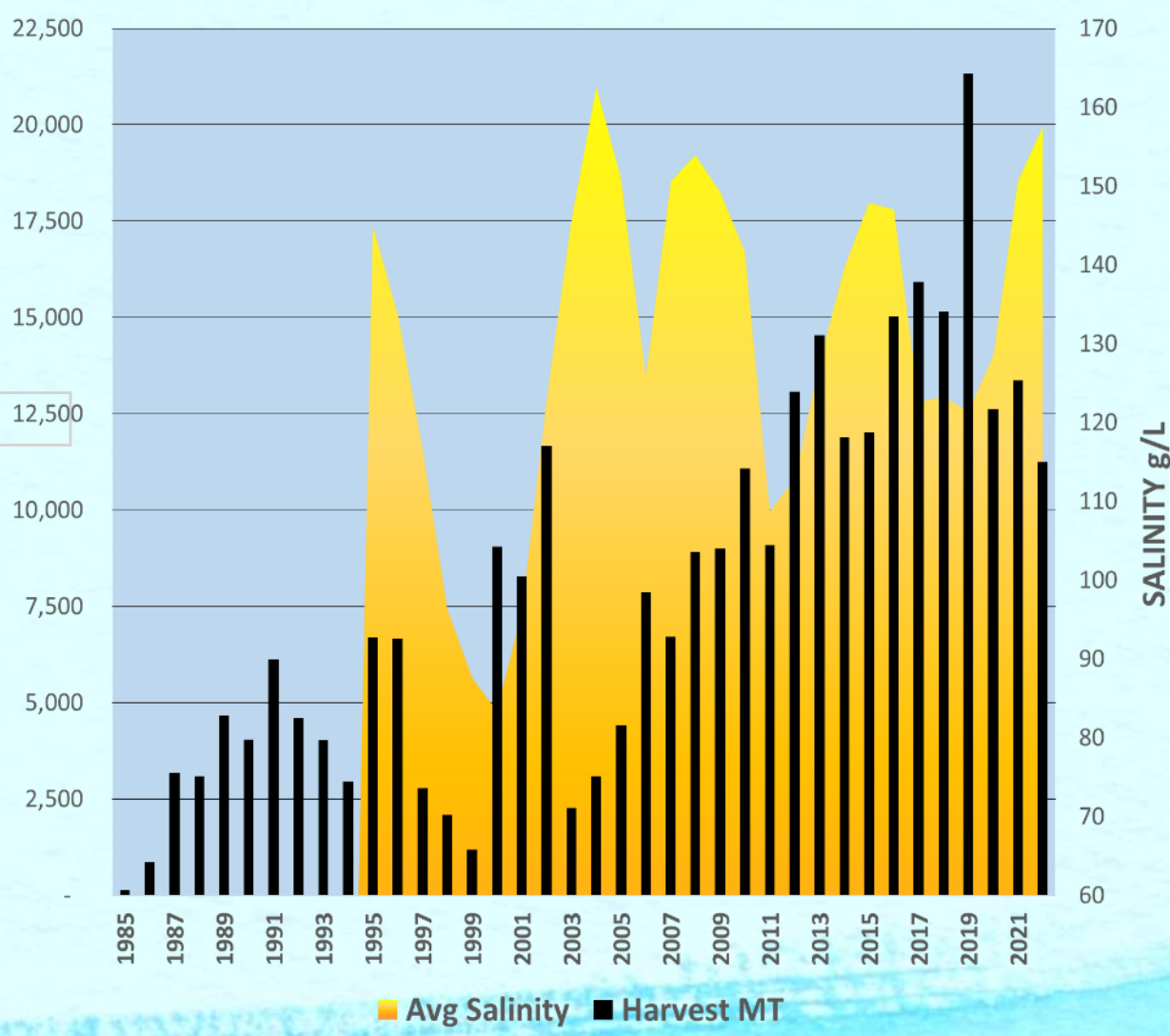


Artemia Resiliency During Variable GSL Conditions

Comparison of Cyst Harvest and GSL Elevation



Comparison of Cyst Harvest and Salinity



Summary Comments for GSL Artemia

- **GSL reduction in volume resulted in elevated salinity of concern for Artemia**
- **However...**
 - Artemia have exhibited an extraordinary ability to exploit transient favorable conditions.
 - Cyst production is not only maintaining, but is exceeding recent abundance levels.
 - One aspect of Artemia adaptability and resiliency is the change in the temporal pattern of dormancy and emergence, a change which is yet another strategy for survival.

QUESTIONS

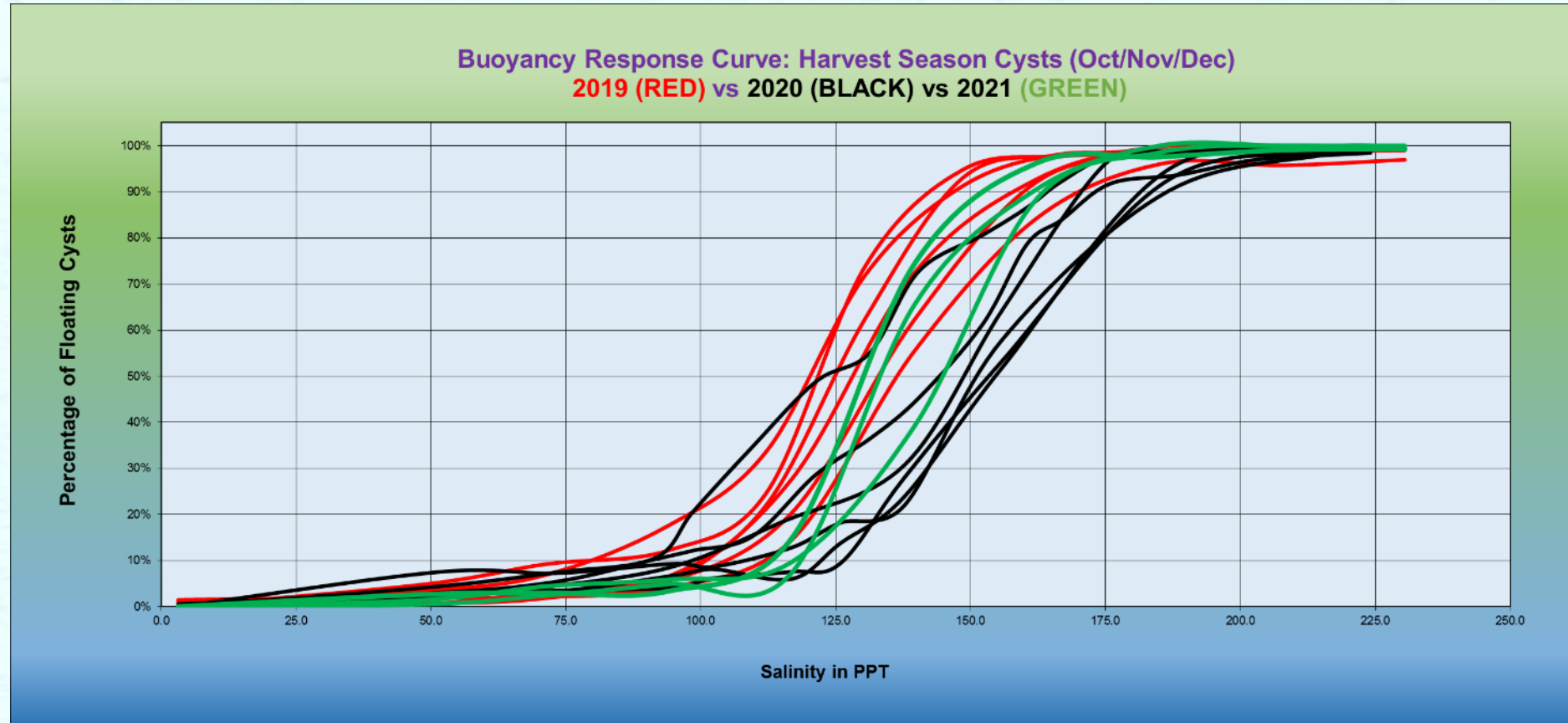
GSL Ecosystem under Drought Conditions

- **GSL Elevation / Volume** : Substantial decrease
 - Peak in 1986 4212 ft absl (1,283.7 m absl) to minimum of 4188 ft absl (1,277.1 m absl) in July 2022
 - Loss of 2.461 cubic kilometers of water in Gilbert Bay since 2017
- **GSL Salinity** : Increased to 180 g/L
- **Bird Populations** : No conclusive data, some indication of decline in specific populations. Reduction in optimal wetland habitat.
- **Algal Community** : Favorable phytoplankton remaining and limited current studies on benthic algae.
- **Microbialites** : Extensive regions no longer submerged.
- **Keystone Species**
 - Artemia : **Robust resiliency**
 - Ephydra : Indications of declining population but no thorough current studies.



Buoyancy Experiments

Comparison of Harvest Season Cysts from 2019, 2020, 2021



Outlook for GSL and Artemia Cyst Production

• PREDICTIONS FOR GSL

- Belovsky (2020) predicts higher than average precipitation in GSL watershed.
- Mohammed & Tarboton (2012) : Streamflow is most sensitive factor in lake level. A 25% reduction in streamflow = 66 cm reduction in lake level.
- Null and Wurtsbaugh (2020): “Climate change to date has not noticeably influenced lake level”. Targeting consumptive use is the most economical solution.

• PREDICTIONS FOR ARTEMIA POPULATION

- The ability to manage salinity coupled with hardiness and adaptability of Artemia suggests sustainable production of cysts if GSL remains at or below current salinity levels.
- If salinity exceeds 200 g/L then there are anticipated population level declines.

