THE IMPORTANCE OF SUSTAINABLE MANAGEMENT OF NATURAL *ARTEMIA* RESOURCES: A THIRTY-YEAR RETROSPECTIVE OF SUSTAINABLE MANAGEMENT PRACTICES IMPLEMENTED ON GREAT SALT LAKE AND A REVIEW OF WORLD-WIDE *ARTEMIA* CYST PRODUCTION

THOMAS BOSTEELS*, PHIL D BROWN, BRAD MARDEN, TIMOTHY HAWKES

*VICE CHAIRMAN, GREAT SALT LAKE BRINE SHRIMP COOPERATIVE, INC.

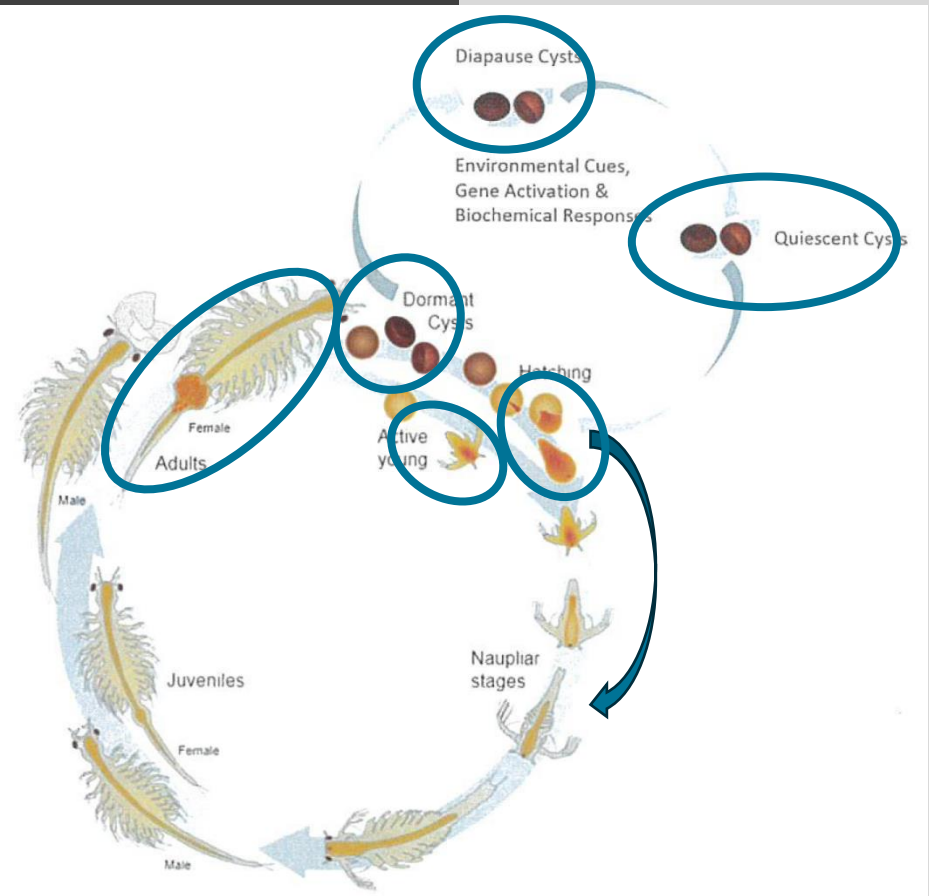
(DBA GREAT SALT LAKE ARTEMIA)

COMMITTED TO SUSTAINABILITY

GREAT SALT LAKE ARTEMIA

AGENDA SLIDE

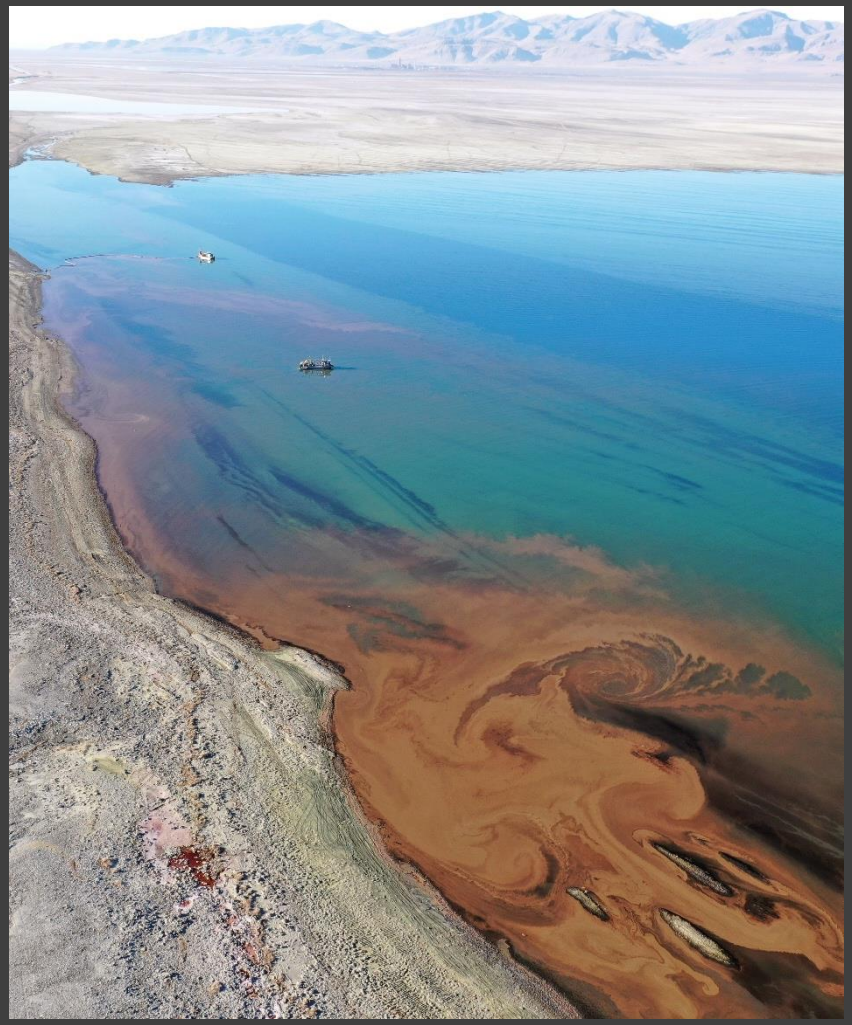
- *Artemia* life cycle and habitat
- Importance of *Artemia* in support of marine Aquaculture
- Managing Great Salt Lake: a 30-year effort in support of the Great Salt Lake biota
- A deeper dive into Salinity management on Great Salt Lake
- Worldwide *Artemia* cyst production – a historic review



ARTEMIA

LIFECYCLE

- Gravid females produce offspring via two pathways: ovoviviparous (live free swimming nauplii) or oviparous (dormant gastrula stage embryos)
- Cysts are initially in a dormant state referred to as diapause
  - Survival mechanism for drought and extreme cold conditions (240 micron)
- Following diapause environmental conditions and endogenous changes cause the dormant embryos to enter into a quiescent state which is then primed for hatching given suitable conditions
- Upon hatching nauplii proceed through multiple instar stages until reaching mature adult stages



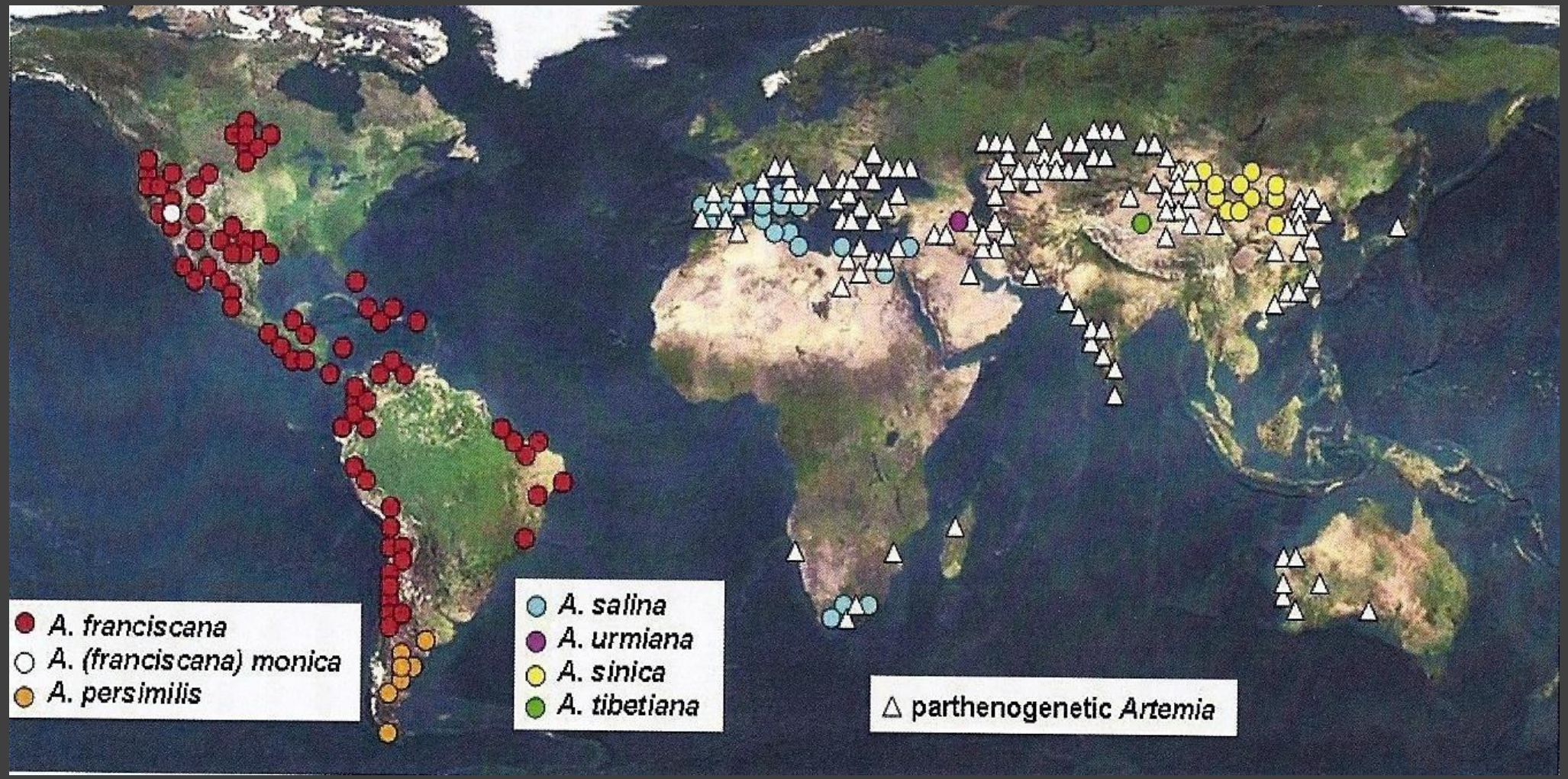
ARTEMIA HABITAT-HYPERSALINE LAKES

Why hypersaline lakes?

- The defense mechanism against predators is adaptation to high salinity
- Large monocultures where food competitors and predators can't survive
- Example of the Great Salt Lake strain of *Artemia Franciscana*, the optimal range is between 90 and 160 ppt

GREAT SALT LAKE ARTEMIA

Geographic occurrence



PhD dissertation Professor Gilbert Van Stappen (Belgium)

A. amati (Kazakhstan) 2023
A. sorgeloosi (Tibet) 2023

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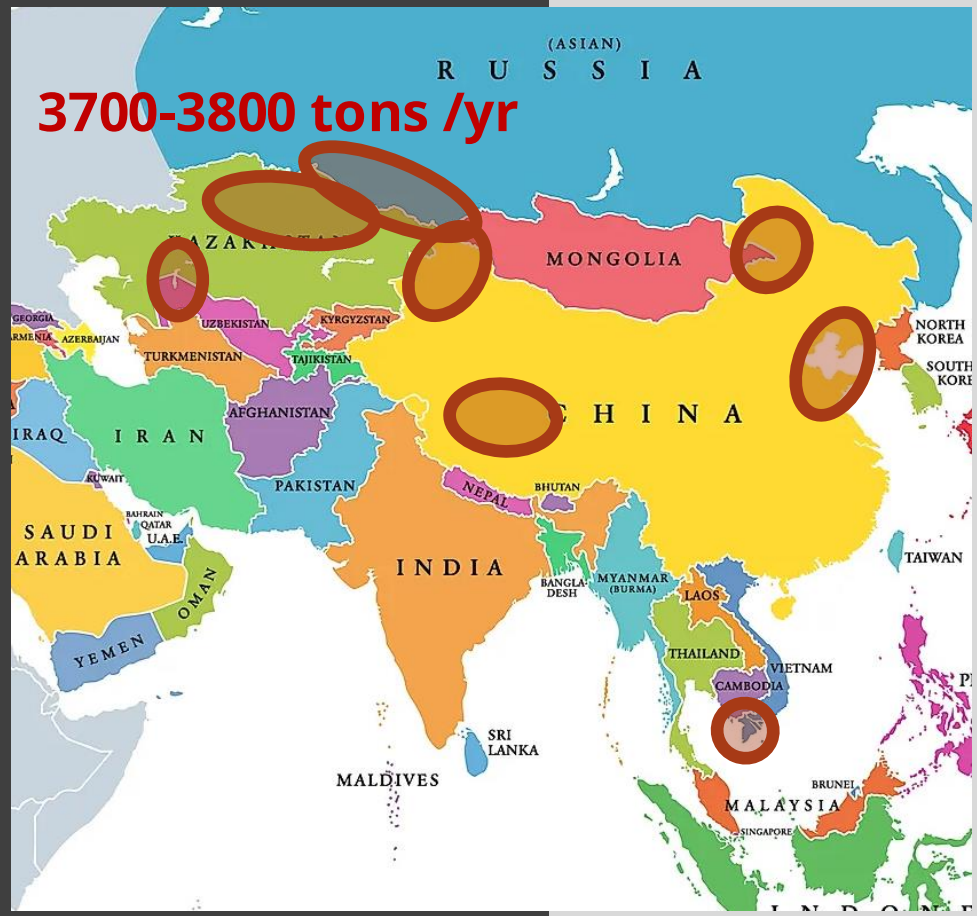


SIGNIFICANT COMMERCIAL SOURCES

- Great Salt Lake (44%)
- Southwestern Siberia
  - Multiple smaller lakes
- North Kazakhstan
  - Multiple smaller lakes
- China
  - Multiple smaller lakes
    - Western China
    - Tibetan plateau
    - Inner Mongolia
  - Manmade saltworks – Bohai Bay
- Vietnam's manmade salt works of the Mekong Delta
- Uzbekistan – Kazakhstan "Aral sea"

IMPORTANCE OF *ARTEMIA* TO MARINE AQUACULTURE

THE BRANDS YOU CAN TRUST

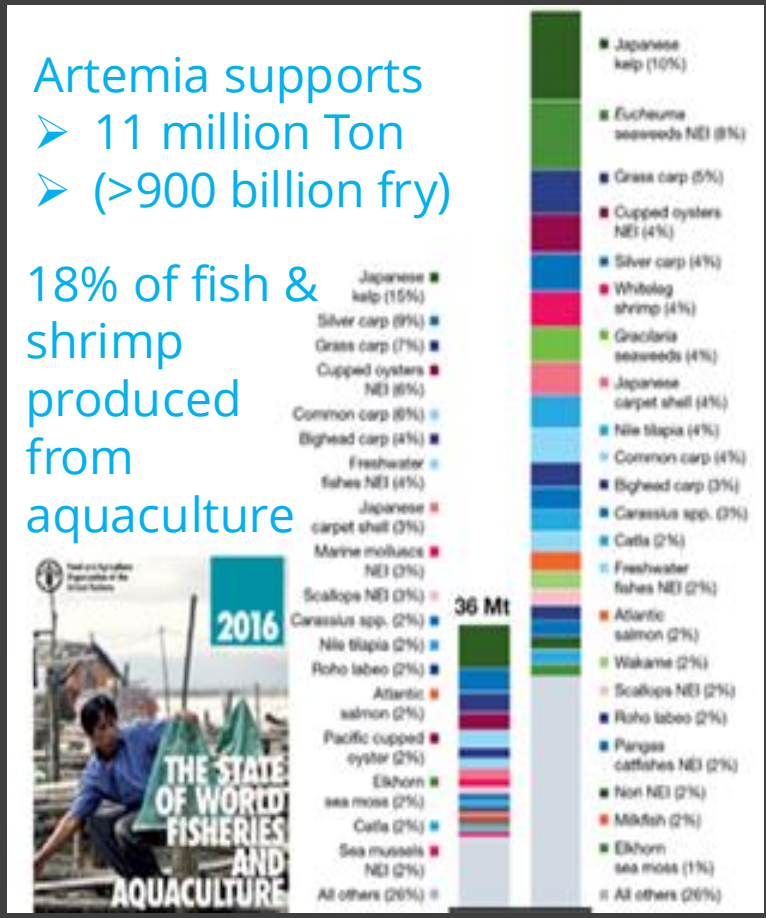
GREAT SALT LAKE ARTEMIA

WHY LIVE FEEDS, WHY ARTEMIA?

- ➔ *Artemia* supports more than **11 million tons/yr** of marine Aquaculture production
- ➔ Beyond nutrition "***ARTEMIA* (live feed) FACTOR"**
- ➔ **Legacy effect**: using optimal *Artemia* ratios in the hatchery/nursery increases production in the grow-out
- ➔ Current aquaculture practices do not apply optimal feeding ratios of live *Artemia* in hatchery and nursery culture

Artemia supports
- ➢ 11 million Ton
- ➢ (>900 billion fry)

18% of fish & shrimp produced from aquaculture

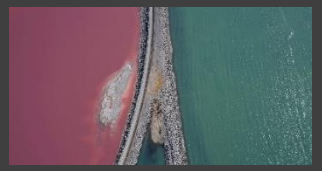


MANAGING GREAT SALT LAKE

A 30-YEAR EFFORT IN SUPPORT OF THE GREAT SALT LAKE BIOTA

THE BRANDS YOU CAN TRUST

GREAT SALT LAKE ARTEMIA



1951
Brine shrimp harvesting originates on GSL

1959
Causeway filled in, dividing lake into North and South arms

1994
Great Salt Lake Ecosystem Program established

2023
MSC certification GSL

Technical Solutions

Policy responses

1993
Utah Artemia Association established

2010
Great Salt Lake Advisory Council established HB 343

2023
Great Salt Lake Commissioner

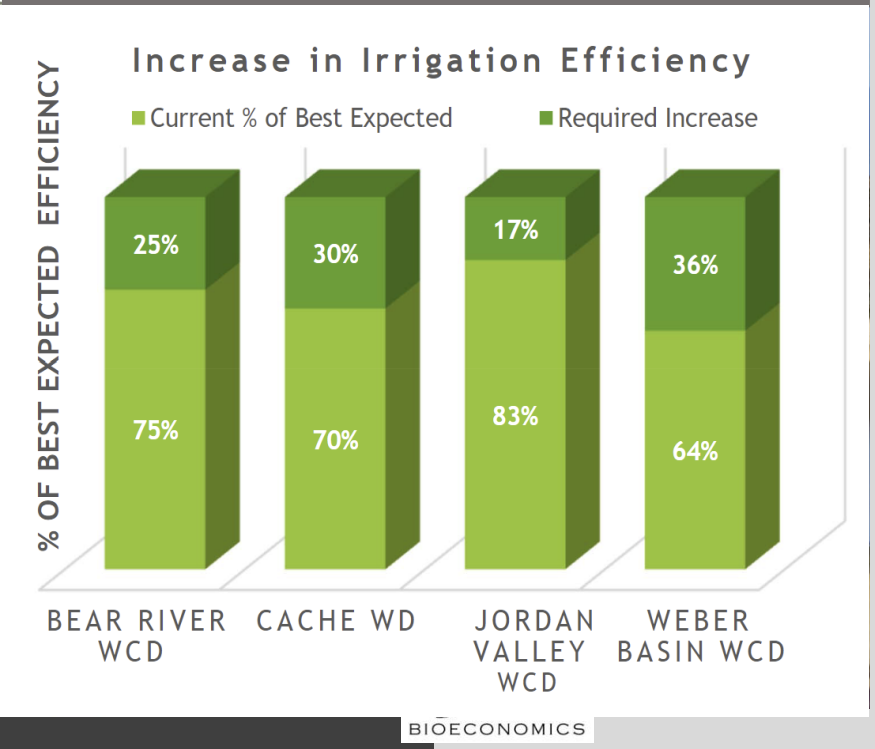
KEY HISTORIC EVENTS

SHAPING TECHNICAL SOLUTIONS

- Long-term Study of the *Artemia* Population in support of the Adaptive Sustainable Harvest Management Model
- Long-term Studies of the Nutrient Inflows, Nutrient Cycling and the Phytoplankton Population informing future nutrient management decisions
- Long-term Studies of Abiotic Factors such as salinity, laying the groundwork for future Salinity Management decisions
- Microcosm Studies of Temperature – Salinity – Phytoplankton and *Artemia* Interactions to model future conditions and support management actions
- Long-term Studies of the Avian Population understand the importance of *Artemia* to support avian species

GREAT SALT LAKE ADVISORY COUNCIL

GSLAC



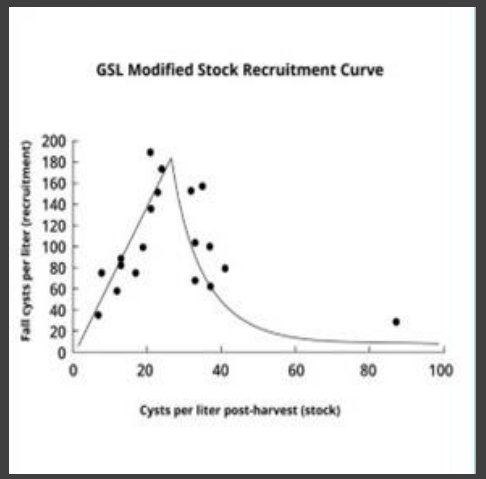
BIOECONOMICS

SHAPING POLICY

The Great Salt Lake Advisory council commissioned multiple (12) studies to support future policy actions:

- Economic value of Great Salt Lake (1.3 billion $ / year)
- Assessment of great salt lake health
- Cost of declining lake levels (2.2 billion $ / year)
- Great Salt Lake Integrated Model
- Water strategies for Great Salt Lake
- Conservation impact study
- ……

GREAT SALT LAKE ARTEMIA



HARVEST MANAGEMENT

➢ START 1996

- ➢ Escapement stock of 21 cysts/liter
- ➢ Studied and refined for 29 years
- ➢ Results published in Belovski et al. 2011 and Belovski and Perchon 2019

UTAH DEPARTMENT OF ENVIRONMENTAL QUALITY
WATER QUALITY

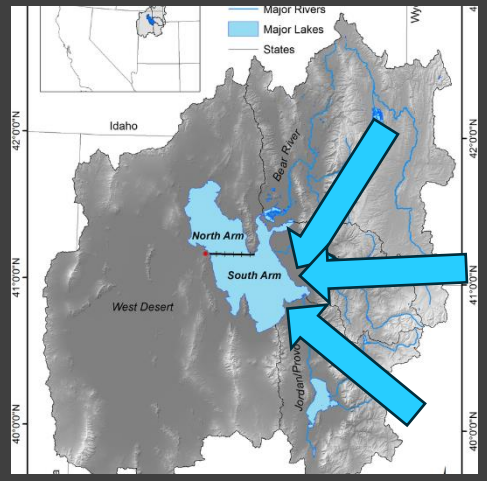
NUTRIENTS MANAGEMENT

START 2012

2019 Novel nutrient criteria

2024: Re-directing nutrient rich water to hypersaline portion of Great Salt Lake

Protect fresh-water resources while Maintaining nutrient inflow



WATER MANAGEMENT

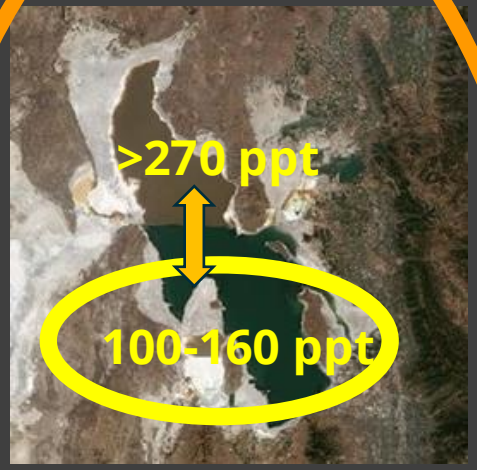
Start 2012

Great Salt Lake Advisory Council

2020 changes to Utah water law

2020 to 2022: $750 million for water conservation

Going forward, 10's of millions yearly to lease conserved water as



SALINITY MANAGEMENT

START 2017

North >270 ppt

South 100-160 ppt ideal for artemia

Move water North to South and South to North

Used in 2022 and 2023

OPTIMIZING ARTEMIA RESOURCES THROUGH SUSTAINABLE RESOURCE MANAGEMENT

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COMMITTED TO SUSTAINABILITY

GREAT SALT LAKE

ACTIVE MANAGEMENT OF SALINITY

GREAT SALT LAKE ARTEMIA

SAFE SALINITY RANGE FOR BRINE SHRIMP *ARTEMIA FRANCISCANA*

WHAT IS THE

SOLUTION?

Active Salinity Management

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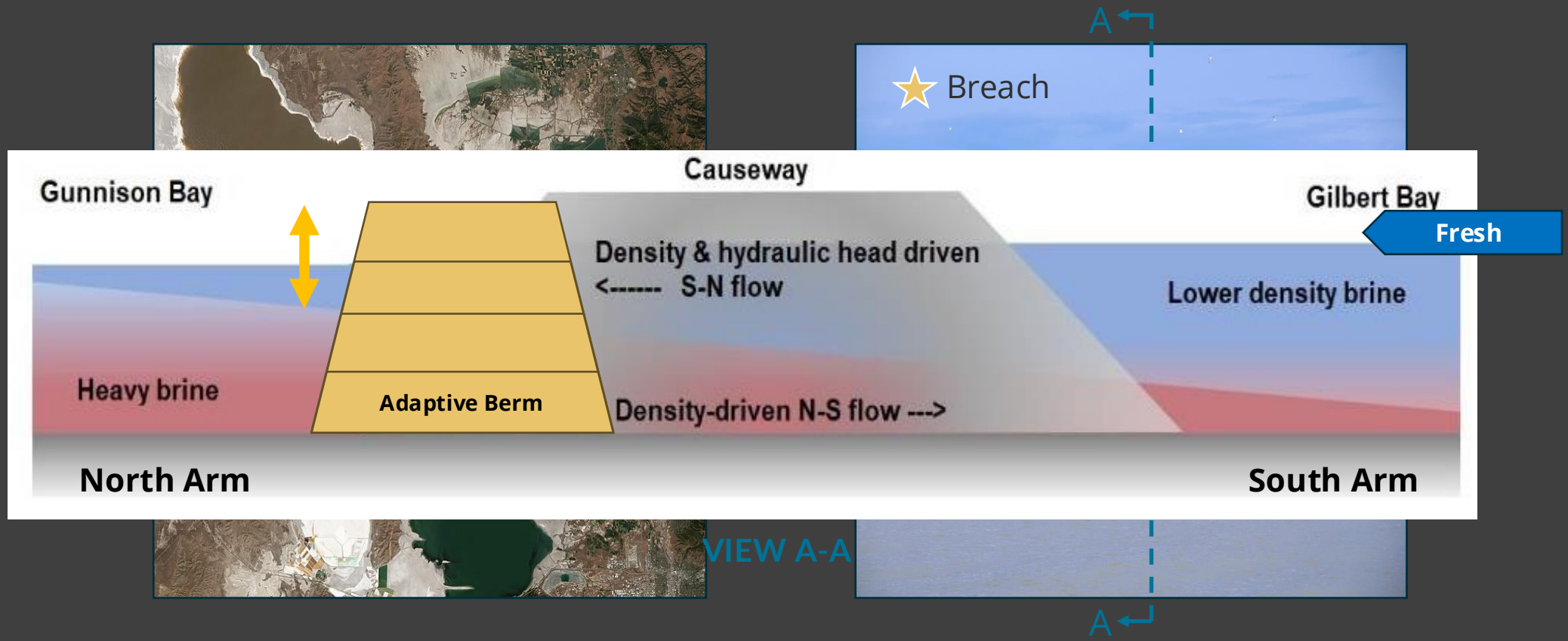
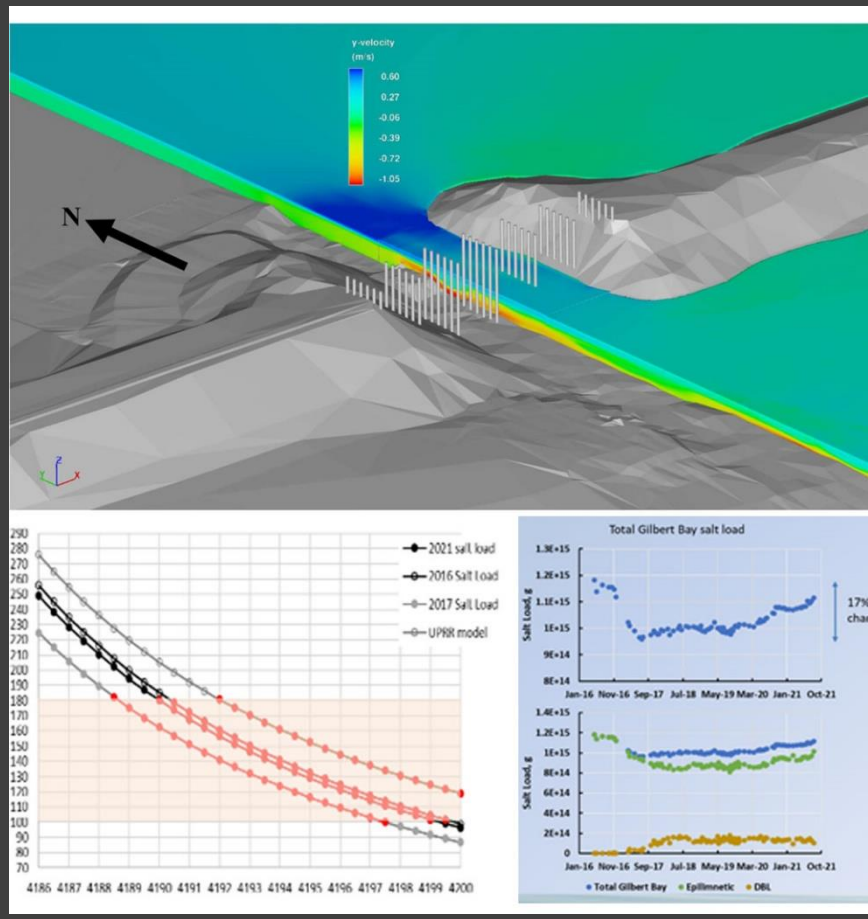
ACTIVE SALINITY MANAGEMENT



Salinity Management under different conditions of precipitation and inflow

2022 - 2023
ADAPTIVE MANAGEMENT BERM
MODIFICATIONS

- Principles are simple
- Historic salinity and bathymetric data were the basis for developing these principles
- In reality is very complex -- > Computational Fluid Mechanical modeling
- changed the berm structure in 2022 and 2023



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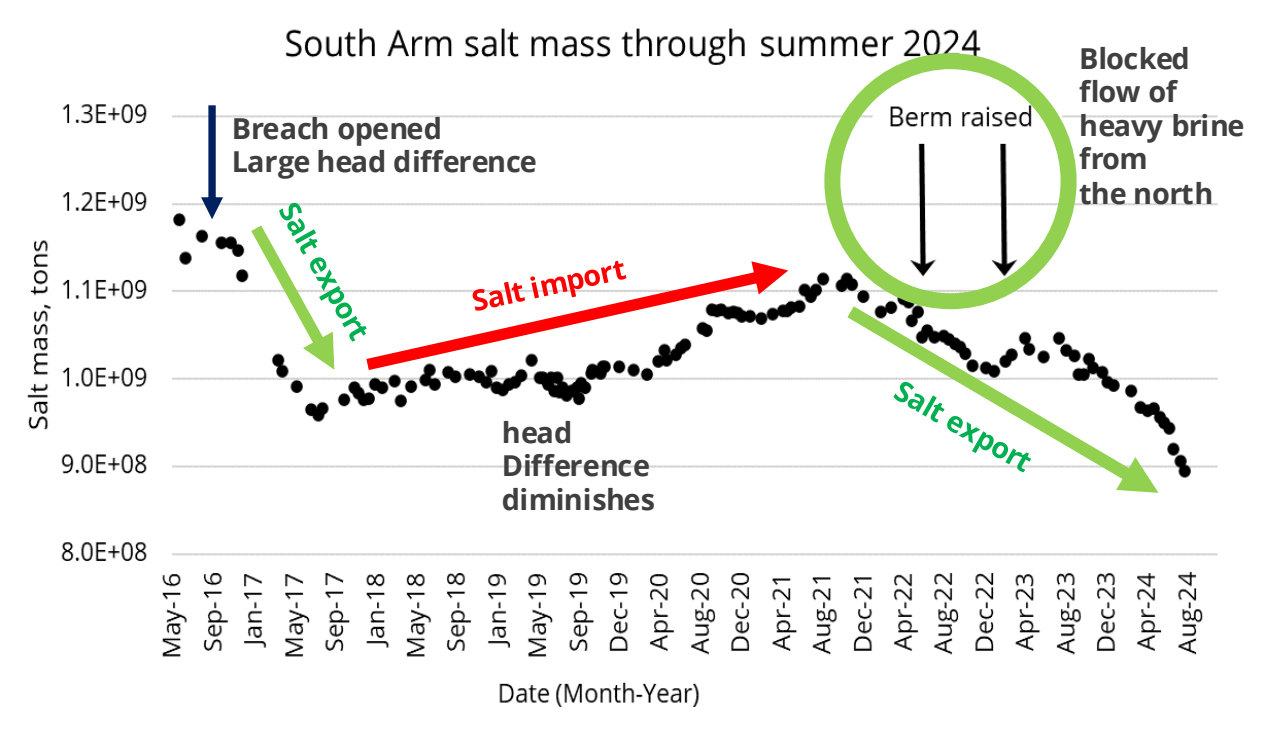
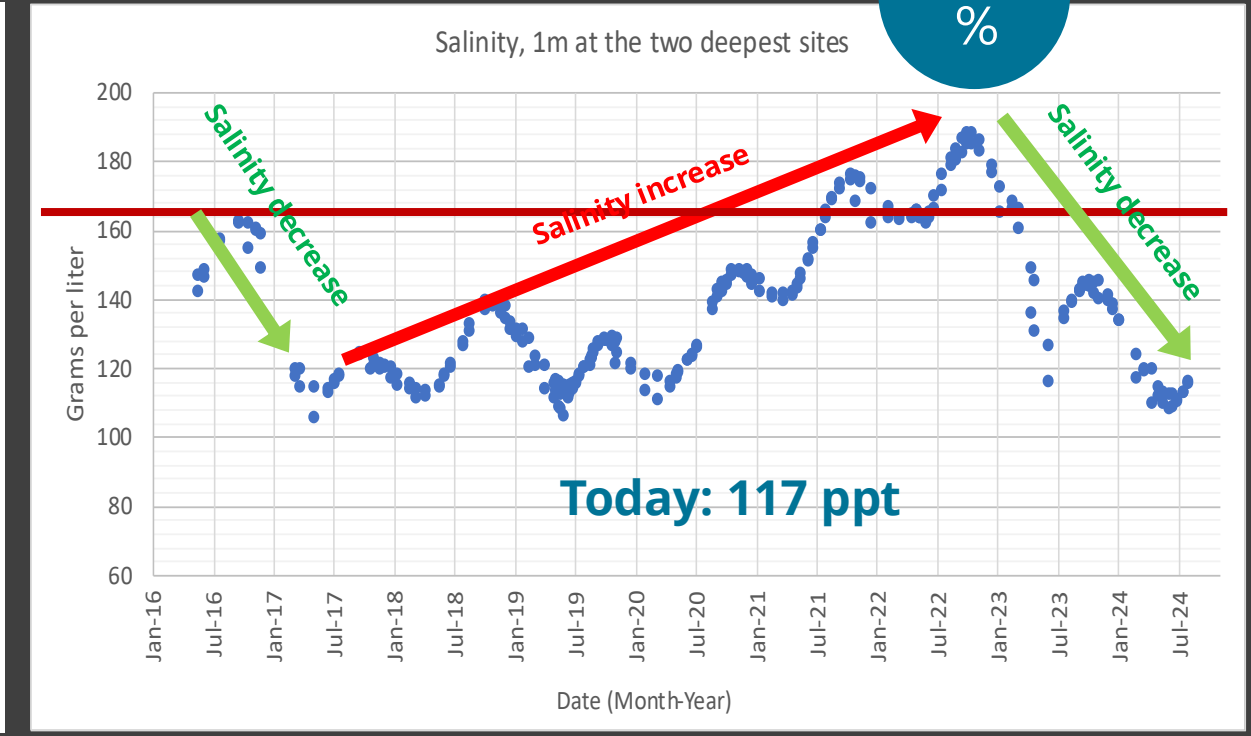
GREAT SALT LAKE SOUTH ARM SALINITY MANAGEMENT

South Arm Salt Mass



South Arm Salinity

18 %



Under the extreme drought of the past 10 years, the Adaptive Management Berm allows a salinity adjustment averaging about 5 to 10 ppt per year

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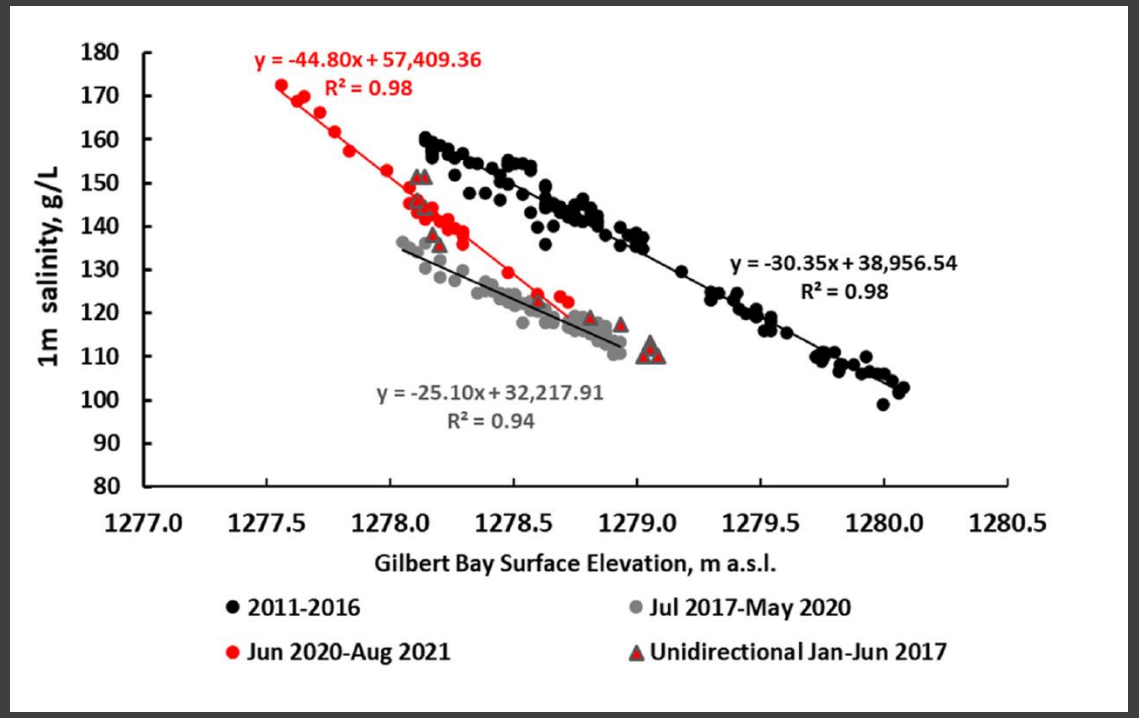
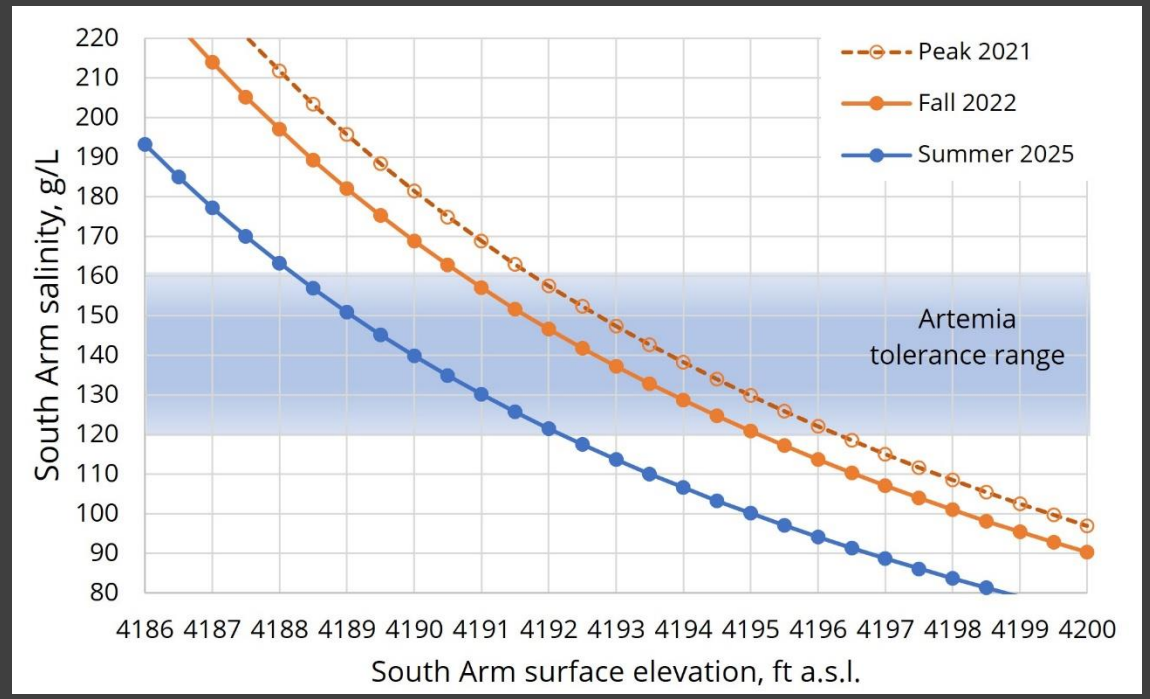
GREAT SALT LAKE SOUTH ARM SALINITY MANAGEMENT





Developing tools to manage salinity

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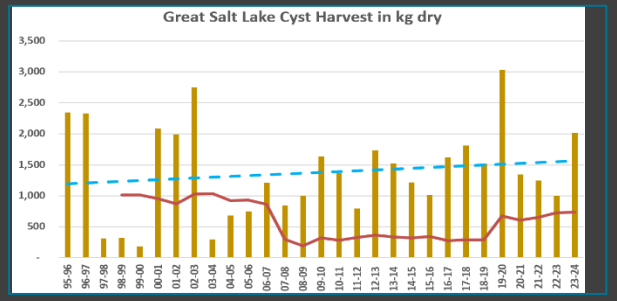
SUSTAINABLE HARVEST MANAGEMENT

NUTRIENT INFLOW MANAGEMENT

WATER MANAGEMENT

SALINITY MANAGEMENT



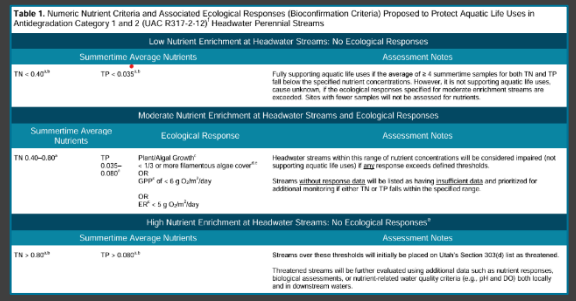


Table 1. Numeric Nutrient Criteria and Associated Ecological Responses (Bioconfirmation Criteria) Proposed to Protect Aquatic Life Uses in Antidegradation Category 1 and 2 (UAC R317-2-12)[1] Headwater Perennial Streams

Low Nutrient Enrichment at Headwater Streams: No Ecological Responses		
Summertime Average Nutrients		Assessment Notes
TN < 0.40[a,b]	TP < 0.035[a,b]	Fully supporting aquatic life uses if the average of ≥ 4 summertime samples for both TN and TP fall below the specified nutrient concentrations. However, it is not supporting aquatic life uses, cause unknown, if the ecological responses specified for moderate enrichment streams are exceeded. Sites with fewer samples will not be assessed for nutrients.
Moderate Nutrient Enrichment at Headwater Streams and Ecological Responses		
Summertime Average Nutrients	Ecological Response	Assessment Notes
TN 0.40–0.80[a]	TP 0.035–0.080[a]	Plant/Algal Growth[c] < 1/3 or more filamentous algae cover[d,e] OR GPP[f] of < 6 g O_2/m^2/day OR ER[g] < 5 g O_2/m^2/day Headwater streams within this range of nutrient concentrations will be considered impaired (not supporting aquatic life uses) if any response exceeds defined thresholds. Streams without response data will be listed as having insufficient data and prioritized for additional monitoring if either TN or TP falls within the specified range.
High Nutrient Enrichment at Headwater Streams: No Ecological Responses[a]		
Summertime Average Nutrients		Assessment Notes
TN > 0.80[a,b]	TP > 0.080[a,b]	Streams over these thresholds will initially be placed on Utah's Section 303(d) list as threatened. Threatened streams will be further evaluated using additional data such as nutrient responses, biological assessments, or nutrient-related water quality criteria (e.g., pH and DO) both locally and in downstream waters.

HAVE WE SUCCEEDED?

The combination technical solutions with policy efforts, will ensure a healthy Artemia population on Great Salt Lake for years to come

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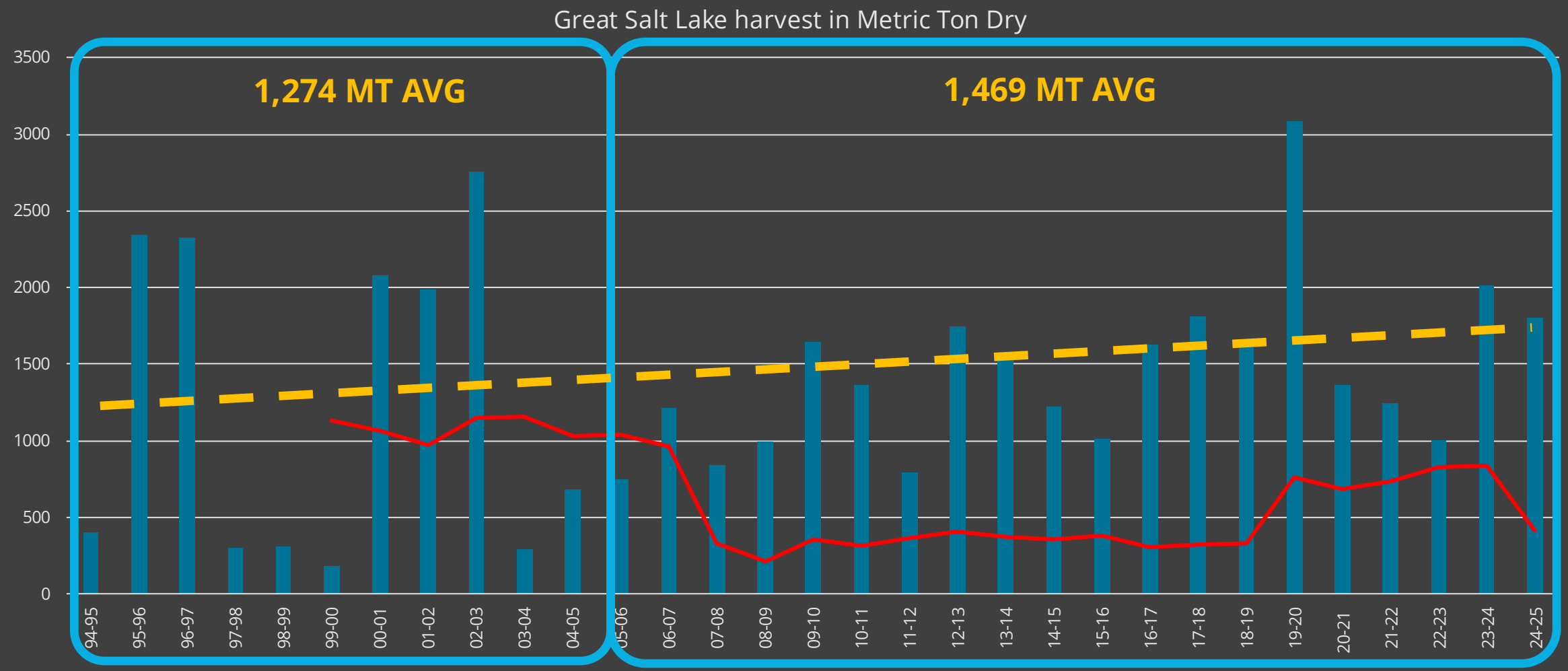
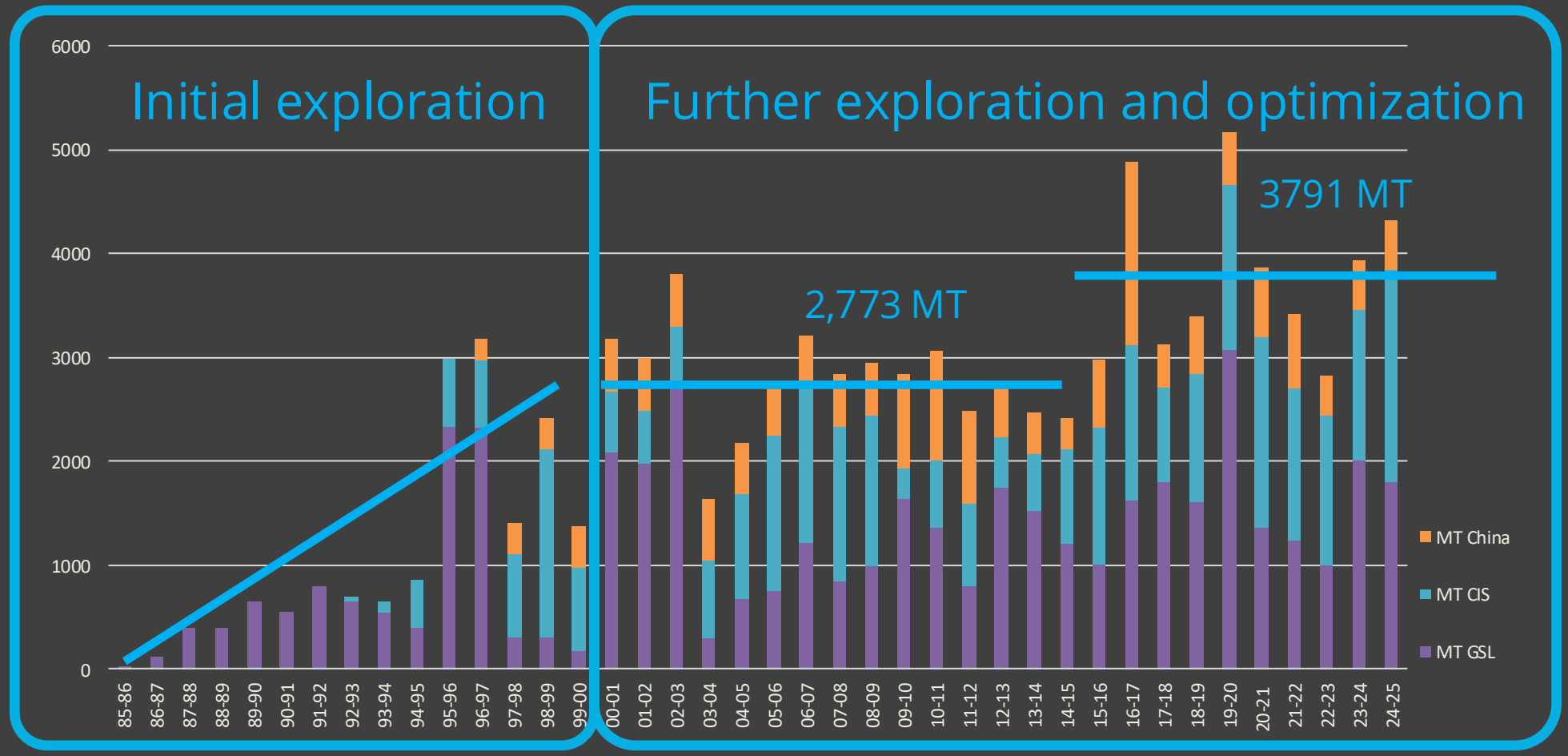
SUSTAINABLE MANAGEMENT OF GREAT SALT LAKE RESULTED IN INCREASED AND STABLE CYST PRODUCTION

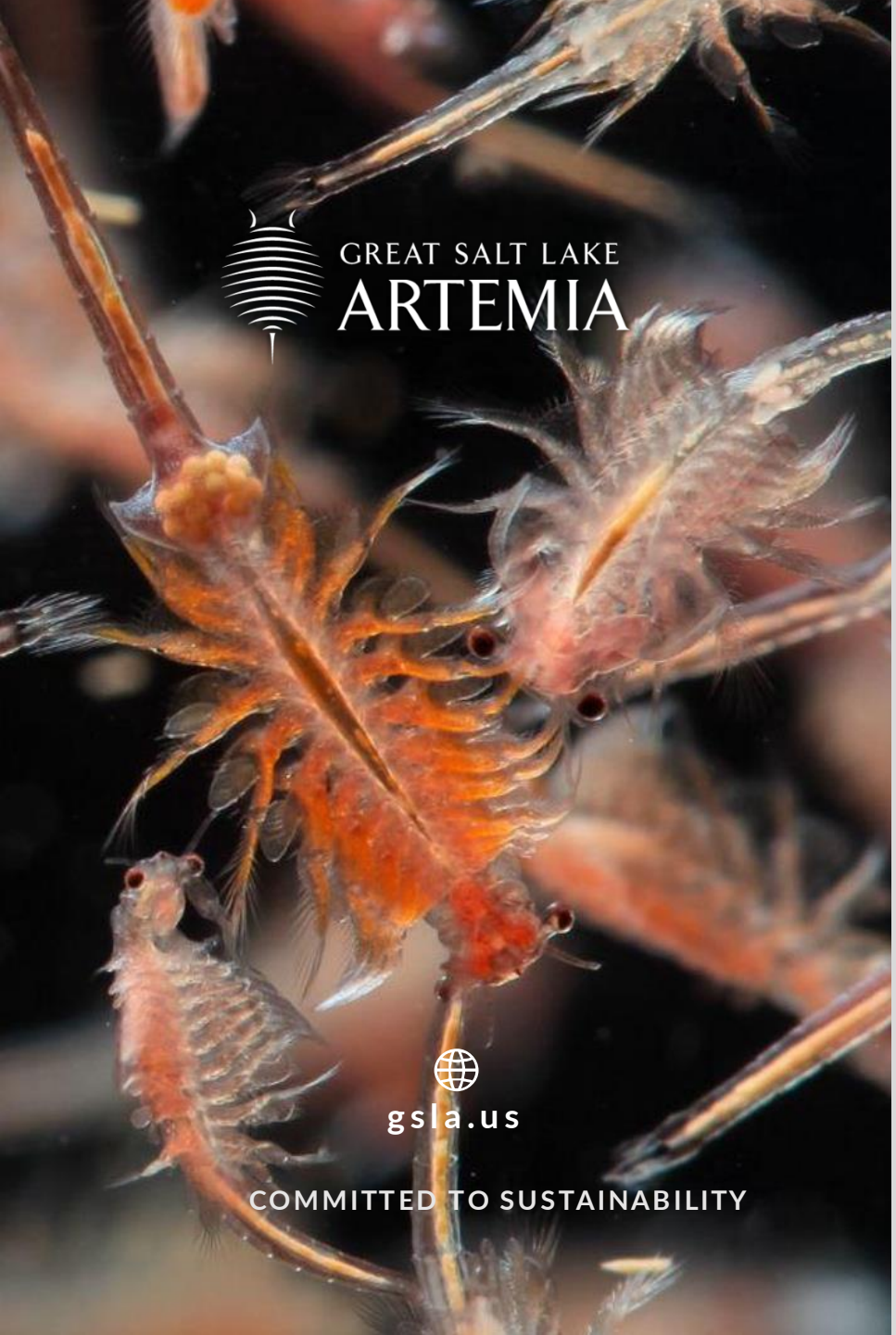


GREAT SALT LAKE ARTEMIA

WORLDWIDE ARTEMIA CYST PRODUCTION INCREASED AS A RESULT OF BOTH EXPLORATION AND IMPROVED MANAGEMENT

World Artemia Production by Source in metric ton Dry





FINAL THOUGHTS

- *Artemia* is essential to marine aquaculture
  - *> 11 million MT of marine species rely on Artemia*
  - *Beyond nutrition*
  - *Improved hatchery results*
  - *Legacy improvements in grow out from using optimal quantities of Artemia in the grow out*

- Marine Aquaculture continues to grow
  - *High-quality protein produced at low FCR*

- *Artemia* production in natural *Artemia* resources can be increased through sustainable management, as shown on Great Salt Lake

- History shows us that we have made progress in the management of natural *Artemia* resources, but more work needs to be done to protect all *Artemia* resources worldwide.