Shrimp culture in inland low salinity water of west Alabama: Water remediation strategies to improve ionic balance and maximize production

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U.S. Shrimp Production - 2015

U.S. mainland: 3,789,835 lbs from 1,274 acres

- **Alabama: 376,700 lbs (142 acres)**
- Florida: 423,410 lbs (112 acres)
- Texas: 2,989,725 lbs (1,020 acres)

Does not include biofloc facilities in the midwest or eastern U.S., Hawaii, or Saipan.

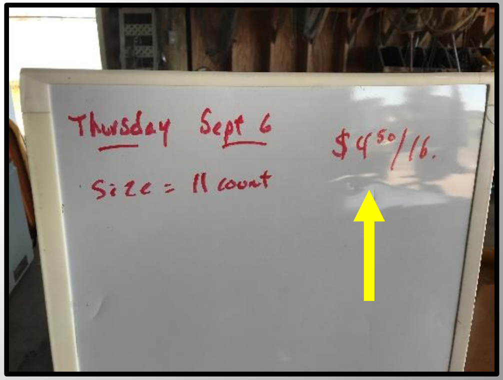
Source: Granvil Treece, Treece & Associates, Lampasas, Texas

Low salinity aquaculture in the US

- West Alabama has an abundance of low salinity (2 – 11 ppt) artesian ground water not suitable for traditional aquaculture
- Several other states also have access to low salinity water sources (Texas, Florida, Arizona, Mississippi)
- Since 1999, this water source has been utilized by a handful of west Alabama farmers to culture Pacific white shrimp (*L. vannamei*) due to their tolerance to low salinity water.

Alabama Shrimp Industry

- Semi-intensive pond production (3 farms stocked in 2018, 125 water acres)
  - ➢ Small compared to catfish (77 farms, 17,450 water acres)
- ➢ Cost of production: <**$3.00/lb** (fixed and variable costs)
- Farmers sell shrimp to the public for **~$4.50-$5.75/lb**, typically 10-20 count shrimp
- One farmer is having his shrimp processed by a seafood processor and is selling his product throughout the U.S. and Canada (grocery stores, including Whole Foods)



Alabama shrimp & catfish farm

Advantages of Pond Production

- Availability of inland saline water not suitable for agriculture
- Availability of ponds and technical expertise
- Natural productivity
- Some diseases are less likely to occur
- Local market
- Lower cost of production

Disadvantages of Pond Production

- Salinization of fresh water resources (drain harvesting)
- Problematic algae (blue green algae, golden algae)
  - Off flavor, toxins
- Ionic composition of the water
  - Expensive to fertilize with potassium and magnesium
- Predators (waterbirds, etc)
- Long distance from hatcheries
- **All of the product is harvested in 4-6 weeks of the year! (must sell immediately or freeze)**

www.wilsonlab.org/photos

Current Culture Paradigm: U.S. low salinity shrimp production in ponds

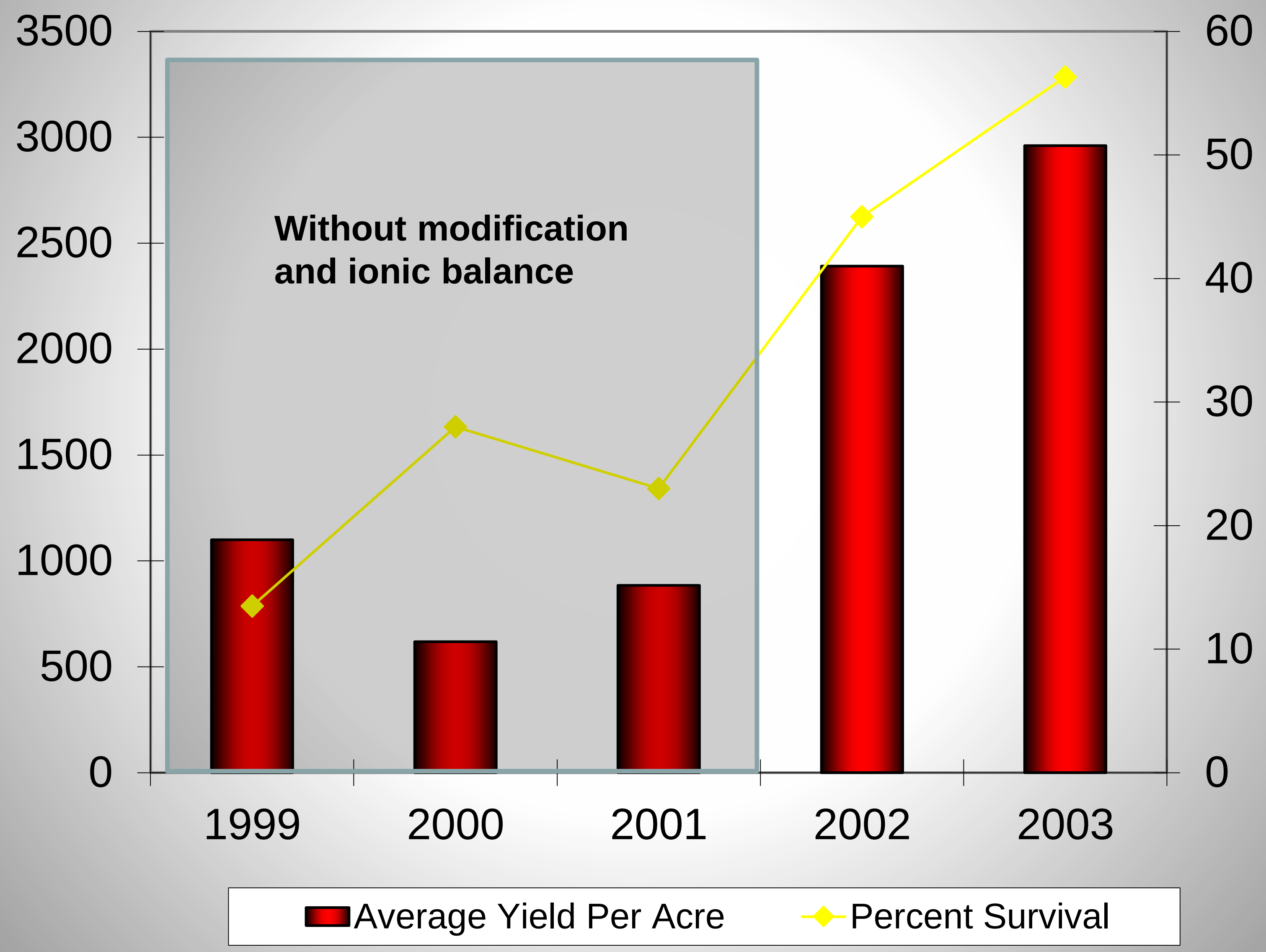
- **Mar - Apr**………...Prepare greenhouses, fertilize ponds
- **May - June**……...Obtain post-larvae from hatchery; acclimation of post-larvae to low salinity water; stocking
- **June - Oct**……….Growout
- **Sept - Oct**………..Harvest (before cold temperatures arrive)
- **Nov - Feb**………...Repair equipment; prepare for next year



Initial Problems (1999 – 2003)

- High and/or variable mortality
  - Poor survival at the end of the production cycle (<30%)
  - Those that survived grew!

Yield


3500
3000
2500
2000
1500
1000
500
0
60
50
40
30
20
10
0
Without modification
and ionic balance
1999
2000
2001
2002
2003
Average Yield Per Acre
Percent Survival

Current status – Low salinity culture

Remediation techniques have been developed for post-larval stages as well as for juvenile and adult stages of production. Average production 2,000 – 5,000 lbs/acre

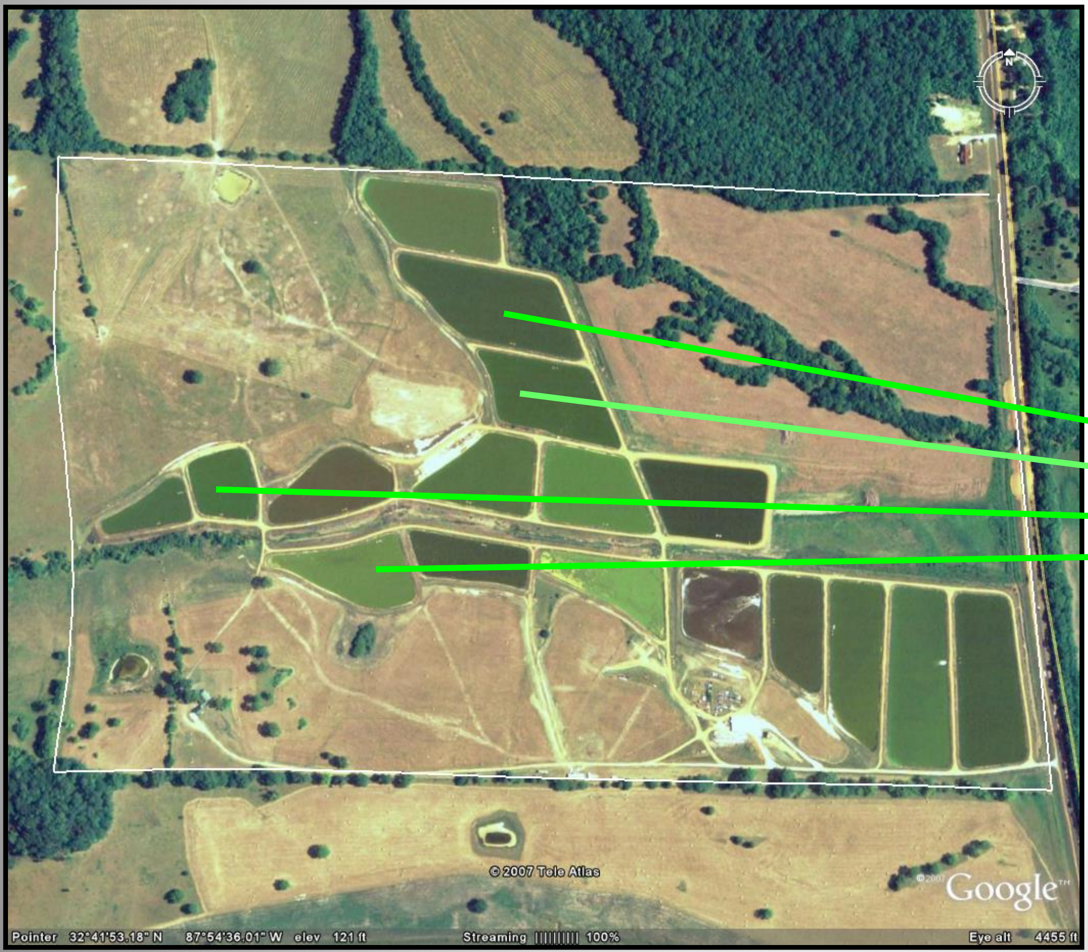
Two basic strategies have been investigated:

1. Modification of the pond water

   - **<u>Ionic Balance</u>**

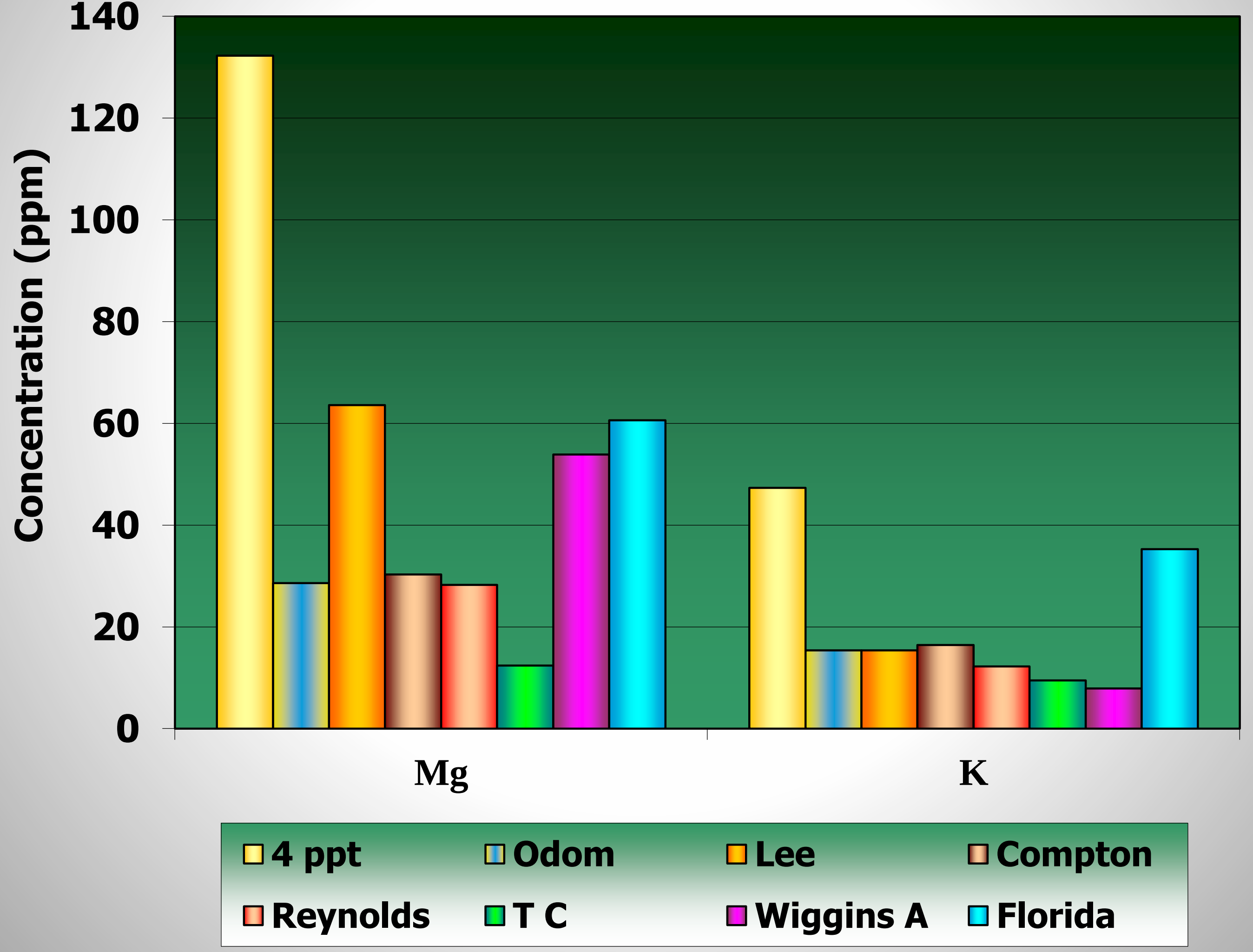
2. Modification of diets (dietary supplements) which was not very successful at the commercial level in Alabama

Bioassays



Pond water was obtained from different ponds to conduct 24 and 48 hour survival bioassays of PLs and correlated to ionic profiles

Bioassays were conducted with various water sources



Summary

- Bioassays revealed that **deficiencies** in aqueous **potassium (K)** and **magnesium (Mg)** appeared to be the major problem
- Post-larvae survived the pond acclimation/stocking process better if stocked at an **age greater than PL_{15}**
- Determination of major cations needed to correct ionic imbalances in pond water is of utmost importance

Na:K ratios

- The ionic ratio of sodium (Na) to potassium (K) in the water appears to be more important than pond water salinity
- Potassium is required at the appropriate ratio for the proper function of the Na^+/K^+ ATPase, which is important for osmotic and ionic regulation in crustaceans
- Improper Na:K ratios lead to osmotic stress which has a subsequent effect on growth and survival of shrimp
  - If culture water has very low ionic Na:K ratios shrimp can be lethargic shrimp, swimming erratically

Take home: Be <u>extremely</u> careful if you try to make your own salt water!

Ionic vs Molar Na:K Ratios

<u>Ionic Na:K ratio calculation</u>

Na level in seawater: 10500 mg/L

K level in seawater: 380 mg/L

Na/K → 10500/380

= 27.6 Na:K ionic ratio

<u>Molar Na:K ratio calculation</u>

Na level in seawater: 10500 mg/L

K level in seawater: 380 mg/L

Na Atomic Weight: 22.99

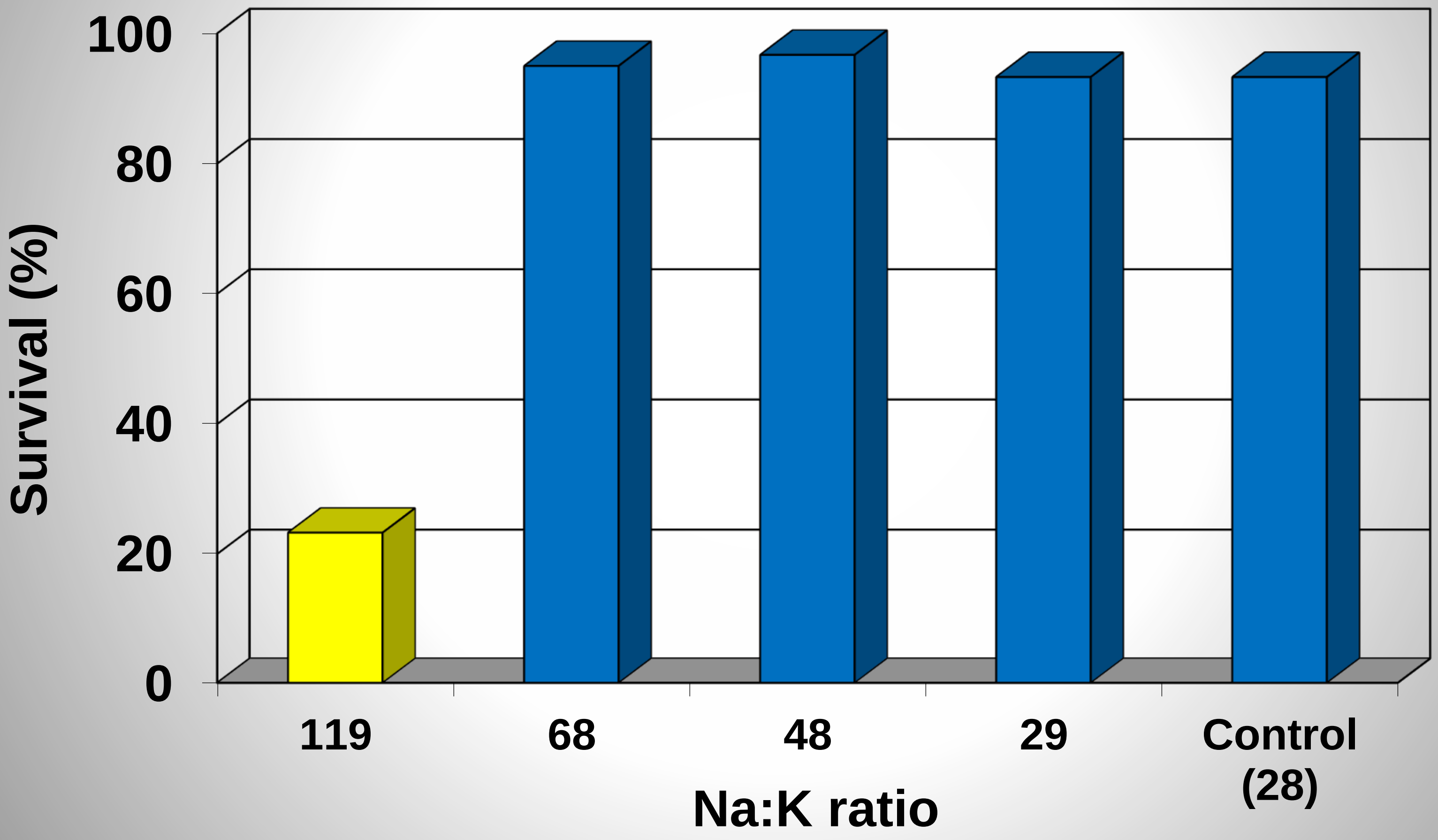
K Atomic Weight: 38.102

(Atomic Weights from the Periodic Table)

Na/K → (10500/22.99)/(380/39.102)

= **47 Na:K molar ratio**

Aqueous ionic Na:K ratio (4 ppt low salinity water)

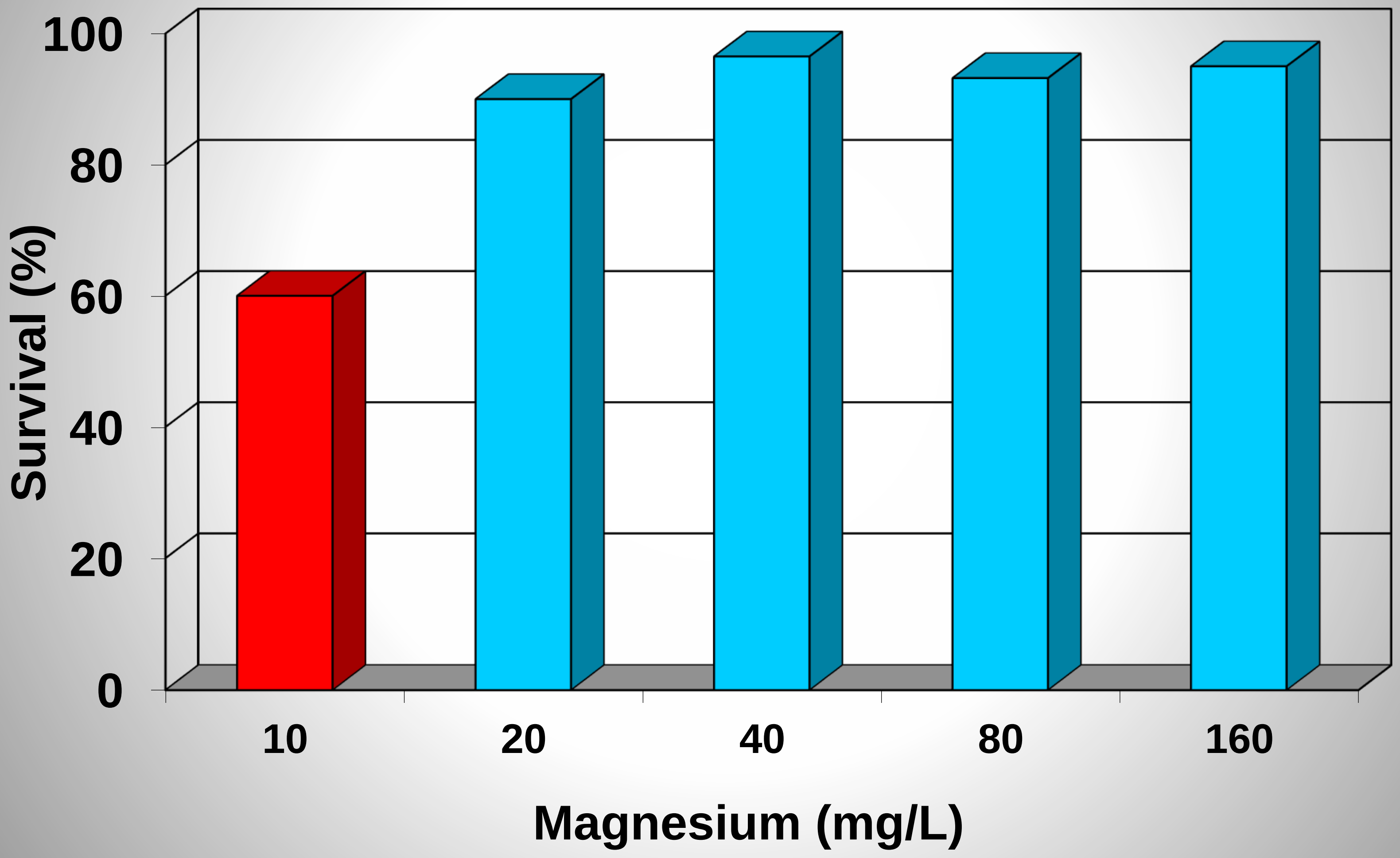


Note: control = diluted reconstituted seawater

Mg:Ca Ratios

- Shrimp farmers in Alabama typically do not have to worry about Mg:Ca ratios
- Optimal Mg:Ca ratios can be calculated using the previously described equations used for Na:K
  - Ionic Mg:Ca ratio in full strength seawater is 3.4
- With Alabama low salinity water, we recommend that producers keep Mg above 20 mg/L
  - This level of Mg is likely not suitable for all low salinity water sources
    - Wudtisin and Boyd (2011) reported that in Thailand maintaining aqueous Mg levels above 75 mg/L resulted in greater survival, size, and production of shrimp
  - Optimal levels of Mg will depend on salinity and Ca concentration in the water

Aqueous Magnesium
(4 ppt low salinity water)



Fertilizers

- Farmers must conduct an ion profile analysis for each pond every year to determine initial fertilization rates (K, Mg) as levels will vary from year to year due to leaching, soil adsorption, and other factors
  - Typically 3 times per year (prior to fertilizer application, 2-3 weeks after fertilizer application, and half-way through the production cycle)

Checking Pond Ion Levels

- Shrimp pond water is tested routinely by Auburn University personnel
- Typically farmers bring in water samples to determine levels of ions and ratios in their ponds
- Na and K tested by flame photometry
- Ca and Mg are measured utilizing titrations

Normal Seawater

Cation	Conc. in normal seawater (mg/L)	Factor
Sodium (Na)	10500	304.35
Magnesium (Mg)	1350	39.13
Calcium (Ca)	400	11.59
Potassium (K)	380	11.01

Note: Multiply the factor by salinity (ppt or g/L) to give seawater equivalent concentrations of cations. Normal strength seawater is typically 34.5 ppt

Source: Boyd CE. 2018. Revisiting ionic imbalance in low-salinity shrimp aquaculture. Global Aquaculture Advocate. March 19.

Checking Pond Ion Levels

- At the request of farmers, Auburn University personnel will perform the necessary calculations for commercial shrimp producers to determine optimal levels of ions in low salinity pond water
- Following calculation of optimal ion levels farmers then supplement fertilizers to their ponds

Common minerals used to counteract ionic imbalance

Name	Formula	K (%)	Mg (%)
Muriate of potash	KCl	50	0
K-Mag ®	K_2SO_4*$2MgSO_4$	17.8	10.5
Epsom salt	$MgSO_4$*$7H_2O$	0	9.86
Magnesium chloride	$MgCl_2$*$6H_2O$	0	12.0

Source: Boyd CE. 2018. Revisiting ionic imbalance in low-salinity shrimp aquaculture. Global Aquaculture Advocate. March 19.

Recommendation

- At present, shrimp farmers have been maintaining ionic **Na:K** ratios as close as possible to the ratio found in seawater (~28:1)
- AL farmers try to maintain **magnesium** at 20 mg/L or higher (Mg:Ca ratios are typically not taken into account in Alabama)
- Farmers in AL have been successful using these techniques culturing *L. vannamei* in low salinity waters with salinities down to 1 ppt (g/L)

Artificial Seawater

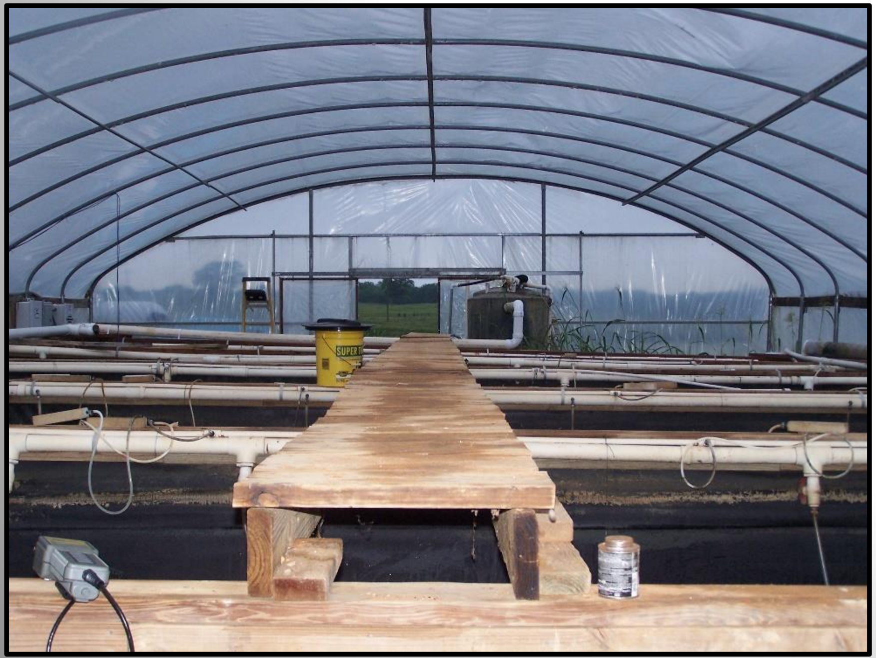
- During acclimation, farmers utilize reconstituted seawater (typically *Crystal Sea Salt* or *Instant Ocean*)
- To save money, in some instances farmers have made their own salt mixtures with limited success

Acclimation & Stocking

- Ponds fertilized 2-3 weeks in advance to ensure adequate levels of K and Mg
- Farmers in west Alabama have achieved the greatest success by obtaining $PL_{10\text{-}12}$ from the hatchery and holding them in nursery tanks located in greenhouses for 7-14 days prior to stocking (stocking a PL_{17}-PL_{22} shrimp)
- During this period salinity is reduced from 15 ppt (g/L) to the desired target salinity
- If possible, the target salinity should be reached at least 48 hours prior to stocking
- **Best results have been achieved when pond water temperatures are greater than 70°F**

Acclimation & Stocking

- Stocking rates: 100,000 – 150,000 shrimp/acre
  - The largest farm (79 water acres) typically stocks 10-11 million shrimp
  - Average pond size is 4 acres



Acclimation & Stocking

- It is necessary to acclimate shrimp to the target salinity and temperature at the pond bank for each individual pond
- It is best to be patient and take adequate time during this process
- Water is exchanged slowly between the tank and pond over the course of several hours

Growout

- Shrimp are sampled weekly by commercial producers to track growth
- Shrimp are offered a 32-35% protein feed at rates of 75 lbs/acre per day (fed twice daily)
  - FCRs average approximately 1.5 - 1.8
- Production season runs from May-October

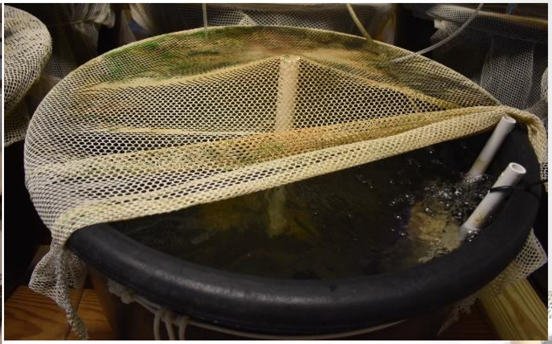
Harvest

Artificial Salt Mixtures

- Funding (USDA NIFA) has recently been secured by Kentucky State University, Auburn University, and Purdue University to explore "least cost" salt mixtures for production of shrimp in low salinity (2 - 8 ppt) and biofloc systems (15 ppt)
- The goal is to develop an artificial lower salinity salt mixture that is economical for farmers
- In the U.S., the high prices of artificial costs is a major financial constraint for farmers using semi-intensive pond production (large scale acclimation facilities) and biofloc systems

Recent growth trial at AU

- To test the efficacy of lower cost salt solutions to replace expensive crystalline sea salt



Low-Cost Salt Mixture

- A 15-g/L low-cost salt mixture (LCSM) solution consisted of,
  - sodium chloride (11.31 g/L)
  - magnesium chloride (0.855 g/L)
  - magnesium sulfate (1.83 g/L)
  - potassium chloride (0. 24 g/L)
  - calcium chloride (0.69 g/L) and
  - sodium bicarbonate (0.09 g/L) was prepared to yield sodium, calcium, potassium, and magnesium concentrations of 4474, 249, 126, and 588 mg/L, respectively which is comparable with the particular cation concentrations in 15g/L sea water.

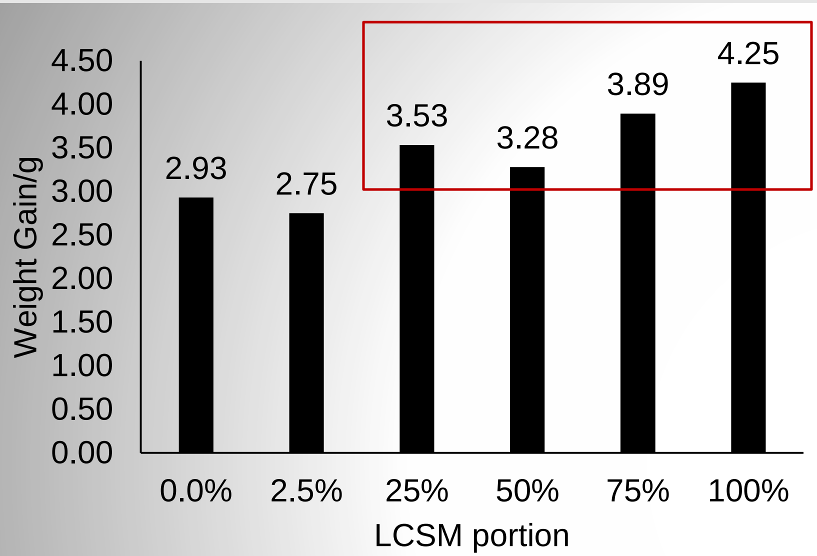
Growth Trial

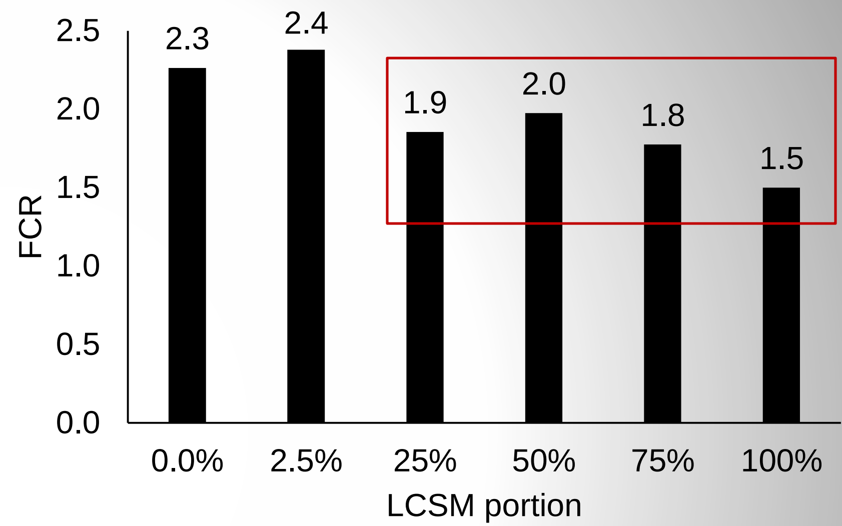
- The growth trial of Pacific white shrimp (initial weight = 0.17 ± 0.01g and stocking density = 20 shrimp/tank) was carried out in 150 L plastic tanks, each equipped with a miniature fluidized bed bio-filter.

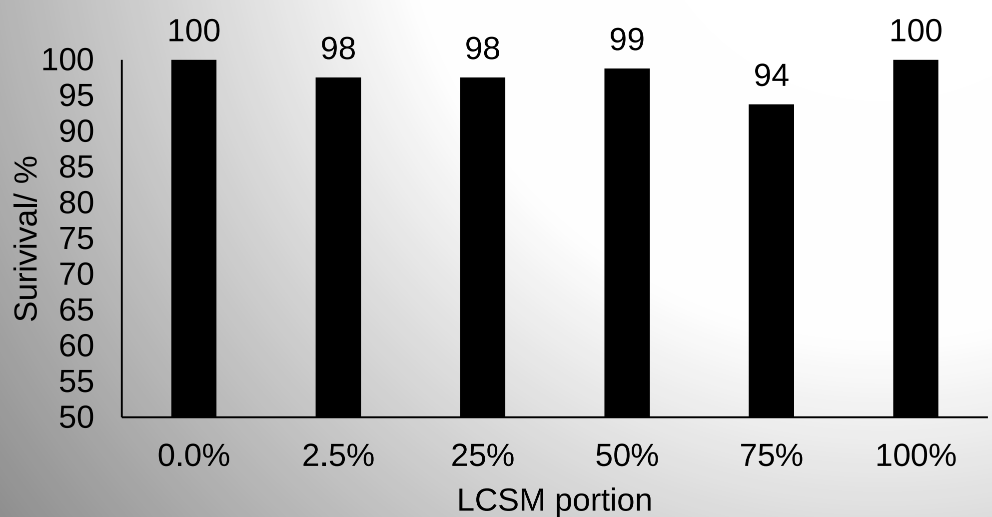
- CSS was incrementally replaced (2.5, 25, 50, 75 and 100 %) with LCSM at four replicates per treatment.

- Shrimp were fed four time/day using a standard ration over the 42-day growth trial.

Shrimp reared in treatment 3-6 (25, 50, 75 and 100% LCSM) had significantly higher growth performances and significantly lower FCR over treatment 1 and 2 (100 and 97.5% CSS)







No significant differences were observed in survival between the different ion solutions

Conclusions

- Semi-intensive shrimp production in inland low salinity ponds has excellent potential in the southern U.S.
- Failure to expand has been due to a number of factors including lack of reliable PL supply, risk, lack of technical expertise, high startup costs, variable survival, and a lack of market development
- Proper balance of ions in pond water is essential for inland low salinity shrimp production

Tips that may benefit biofloc producers

- Acclimation
  - Make sure to balance ionic profiles of culture water prior to receiving PLs
  - Use reconstituted seawater
    - If in doubt send a water sample to a commercial lab!
  - Be sure to take extreme care to acclimate shipments of shrimp to your facility’s culture water (temperature and salinity)
    - Our farmers typically wait 7-14 days prior to stocking received PLs in ponds
  - Wait until post-larvae are PL_{15} or older before acclimating to lower salinities
  - Reduce salinity slowly!

Final word of advice

AISPA (Alabama Inland Shrimp Producers Association)

- One key to success for Alabama shrimp farmers has been frequent communication, meetings, and free sharing of information
- Collectively have banded together and secured funding for research and development
- Have been involved politically
- Have actively sought to involve Alabama Cooperative Extension (Auburn University) in research and technology transfer

Working together to address challenges will increase the likelihood of success of your industry!

Acknowledgments

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