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Algae Testbed
Public-Private Partnership

BIO ENERGY
U.S. DEPARTMENT OF ENERGY
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National Algal Biofuels Roadmap Review: Chapter 4

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A team of algae biologists with over 37 years large scale algae production experience

Dr. Philip Lee

Mission: To accelerate the development of the microalgae industry in every potential market via proven, reliable and cost effective manufacturing technologies.

“Bridging Gaps in Algae Technology Development”


Algae in DOE's
Billion-Ton Report

Why algae?

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- High productivity per acre
- Fast crop turn around time
- Avoid competition for agricultural land and water
- Carbon dioxide mitigation

Crop	Oil Yield (gal/acre/yr)
Soybean	48.0
Camelina	59.8
Sunflower	101.9
Jatropha	201.7
Oil palm	634.0
Algae*	1,500 (FY14) 2,500 (FY 18) 3,700 (FY20) 5,000 (FY22)

Source: Adapted from Darzins et al. (2010). *Note:* *Algae targets are set in the Bioenergy Technologies Office Multi-Year Program Plan (DOE 2016a) for intermediates.

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Roadmap Review: Cultivation Systems

Open vs Closed, Indoor vs Outdoor, Photoautotrophic vs Heterotrophic

Accomplishments in Cultivation: What do we know?

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- Strain matters – robust, productive, lipid content
  - DOE has funded multiple high throughput strain screening programs to identify promising strains for biofuel production
  - Nannochloropsis, Desmodesmus (marine strain focus) – now looking at crop rotation for sites with high environmental variation (winter vs summer strains)
- Production system matters – economics
  - DOE has funded research in all types of production systems
  - Low capital investment of open ponds attractive
  - High density of heterotrophic and closed production systems attractive – lower dewatering costs

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Accomplishments in Cultivation: What do we know?

- Translation from lab to cultivation at scale challenging – value in research at scale
- Ultimately strain and production system will be optimized for location – most likely co-location with carbon dioxide source and adequate water supply
  - TEA/LCA will provide cultivation strategies suitable for various locations
- Testbed facilities ready to support facilitation of industry development! Decreasing risk and encouraging investment – thanks to DOE

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Constraints in Cultivation

- Standardization of metrics: productivity, yield, reliability
- Resource management: where facilities can be located for sustainable production of microalgae =TEA, LCA with testbed data
- Scalable system designs
- **Unreliable cultivation methods due to lack of understanding of what drives reliability and pond ecology**
  - **Crop protection and weed/pest management**

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Cultivation System Reliability

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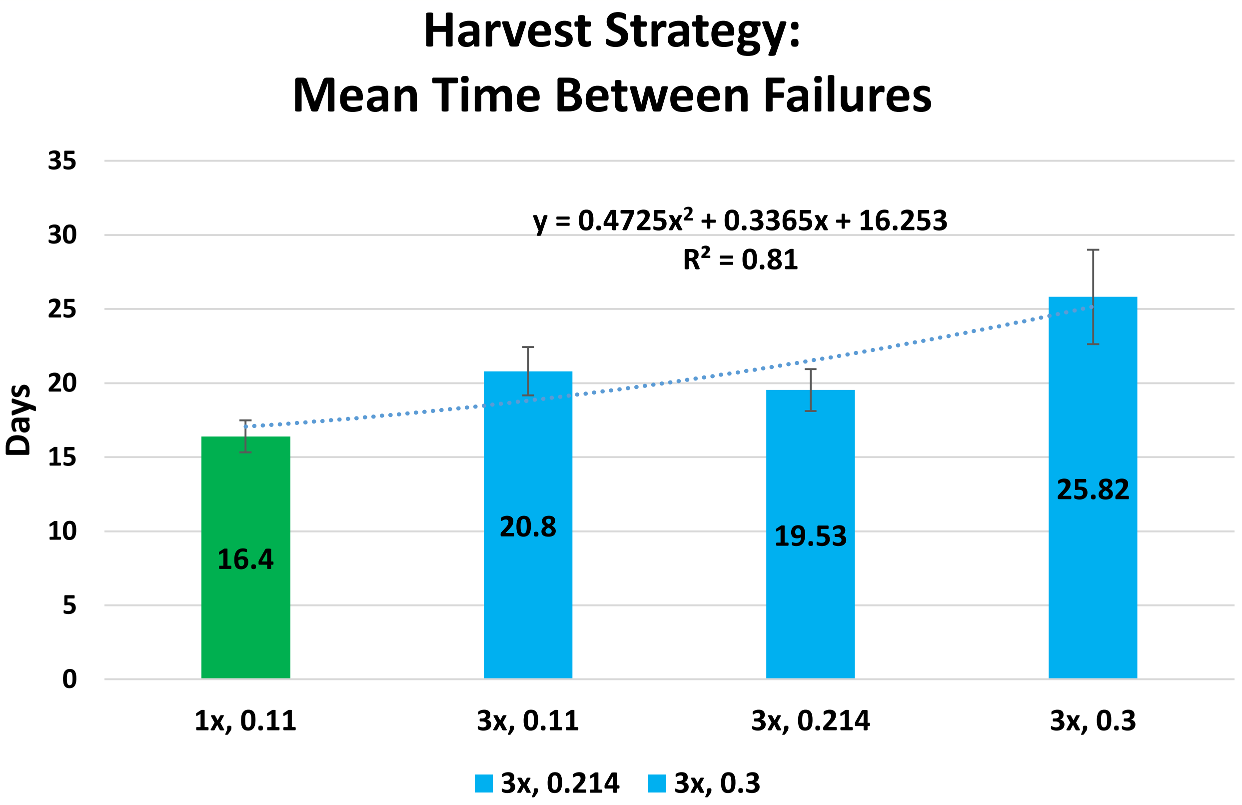
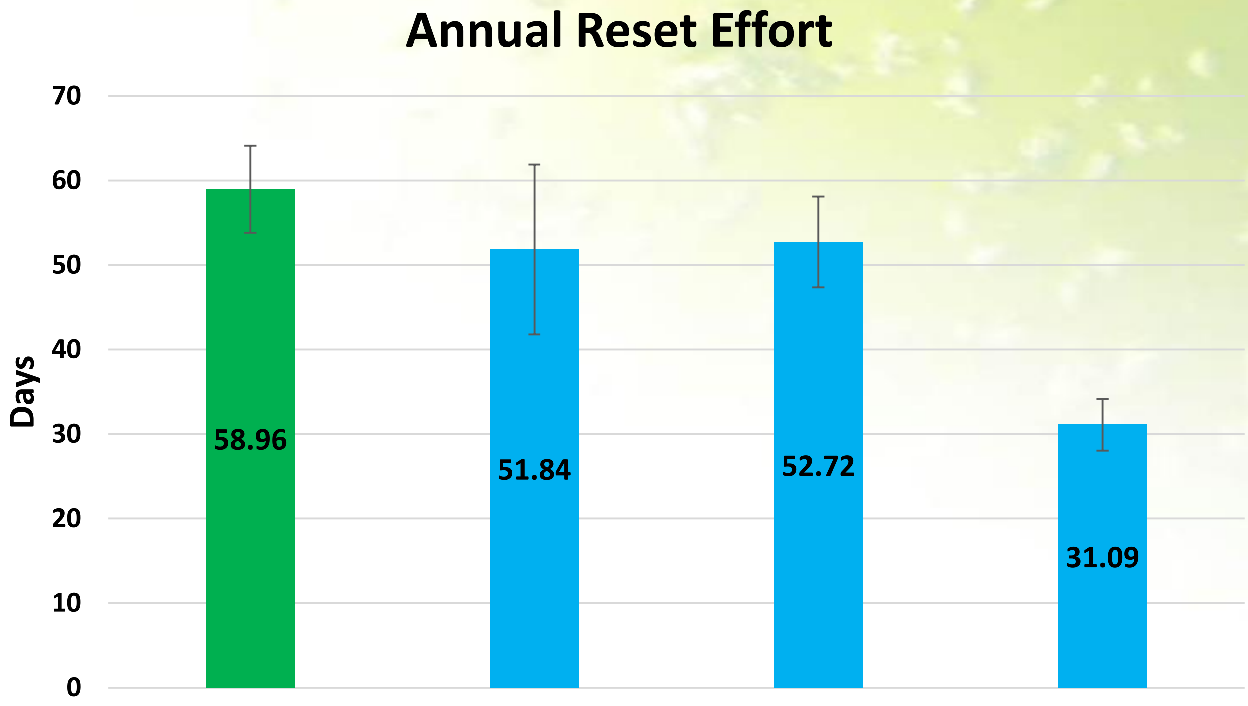
Reliability Metrics

- **Reliability**: The ability of an asset (in this case a pond) to perform its intended function without failure for a specified period of time under specified conditions.
- **Primary Metrics**
  - **# of Failures**
    - Pond Failure can be system/human failure or biological contamination or stress causing the pond productivity to drop below acceptable levels
    - When ponds failed, they were typically re-inoculated from a healthy pond in the same treatment, or from seed produced indoors when available
  - **Mean Time Between Failure (MTBF) in Days**
    - A harmonized metric as per the *Society for Maintenance and Reliability Professionals*
    - Average length of operating time between failures; error-free performance time
    - A measure of asset (in this case a pond) reliability
  - **Mean Time to Reset (MTTR) in Days**
    - Total amount of time spent performing a reset (in this case draining, cleaning/calibrating and re-inoculating a pond)/number of resets (in this case one pond); assumed that all sites are equally competent to re-set a pond requiring a consistent measure between sites
  - **Reliability Coefficient**
    - Error-free performance time (MTBF)/error-free performance time (MTBF) + time to reset (MTTR)
  - **Failure Rate (Probability of Failure)**
    - 1/MTBF
  - **Effort**
    - Annual # of resets (365/MTBF+MTTR) x MTTR

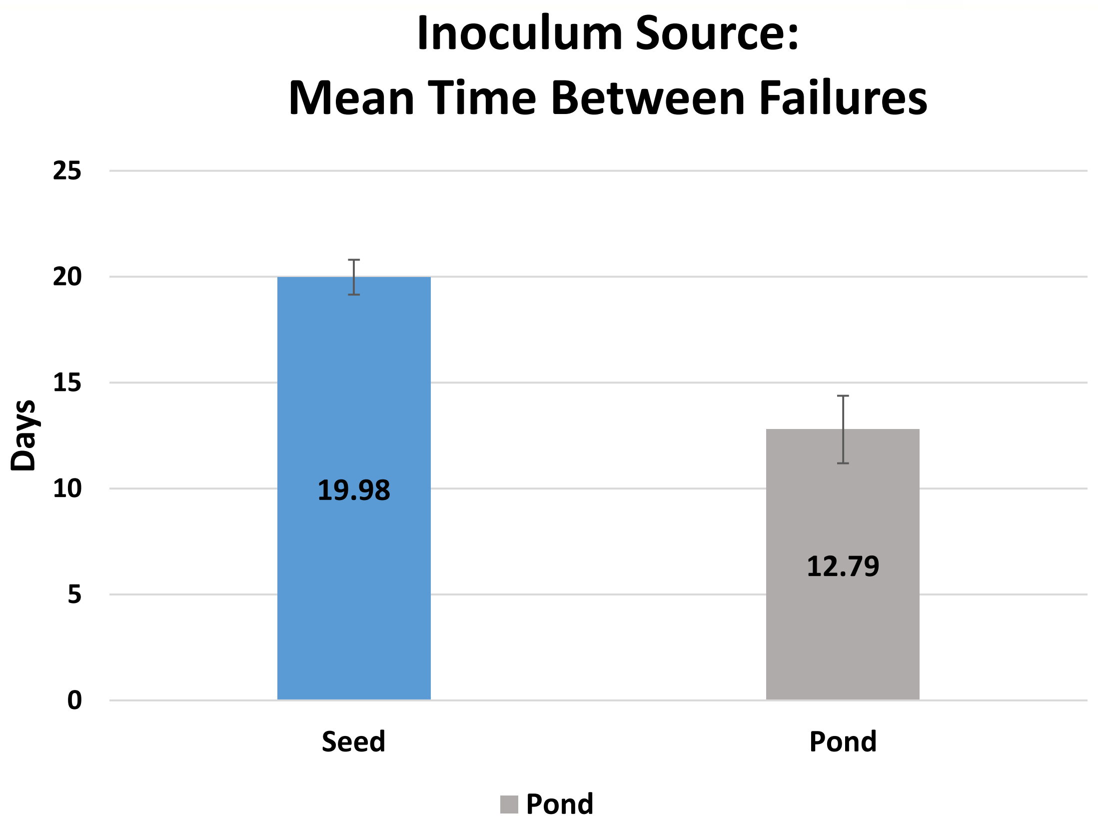
Harvest Strategy: Mean Time Between Failures, Reset Effort

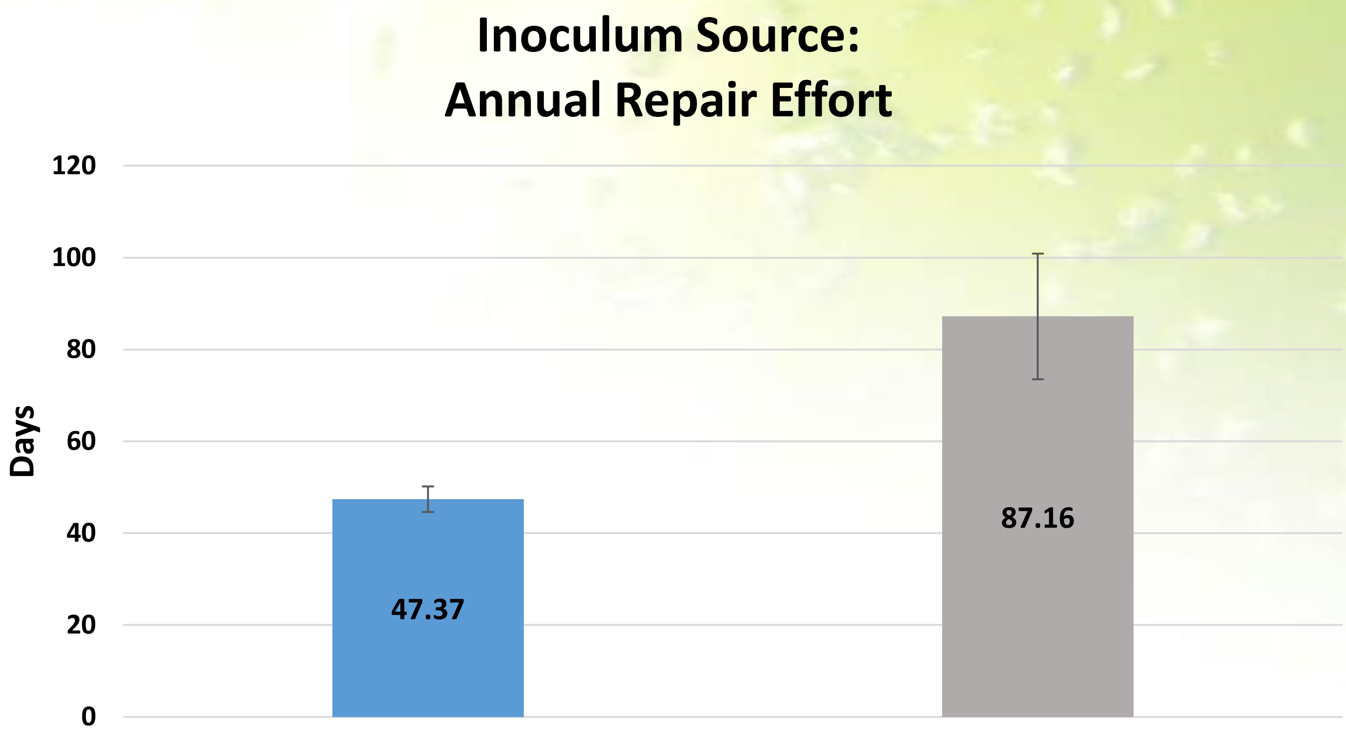




- As dilution rates and harvest frequencies increased a trend of improved reliability of ponds occurred
- Increased harvesting and higher dilution rate effort led to a reduction in pond re-set effort of 47%
- Is this justified by increased effort of harvest frequency and higher dilution rate?

Inoculum Source: Mean Time Between Failure, Reset Effort





- Inoculum from the lab (seed) provided a longer MTBF for a pond, than when a pond was used to start a pond
- Lab based inoculum can lead to a reduction in pond re-set effort of as much 46%

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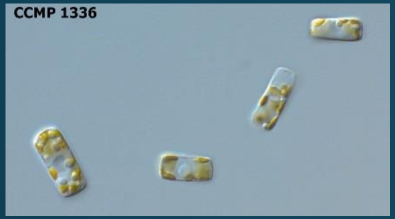
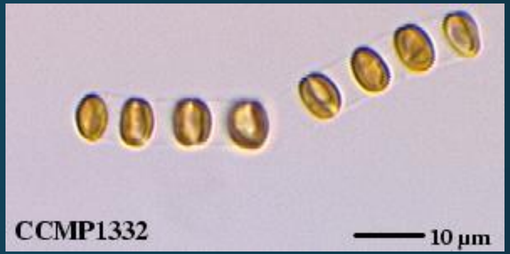


Conclusions



- Testbeds contribute to industry development
- With this preliminary foundation in reliability assessment, a concerted effort in improving cultivation system reliability (reducing failure) will reduce uncertainty of cultivation systems leading to improved strain performance and productivity.
- Cultivation reliability is uniquely affected by the interaction of the strain of interest, the inoculation and cultivation system, the fertilization regime (media), harvest timing and strategy, and crop protection.
- If reliability metrics are coupled with research to identify pest, system mitigation studies can identify ways to **improve reliability and economics** of biomass/biofuels from microalgae – the MOST PRODUCTIVE plants on our planet!!

Thank you!

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