

Nutrition and Feeding: How to Keep Your Mussels Happy

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Propagation goal

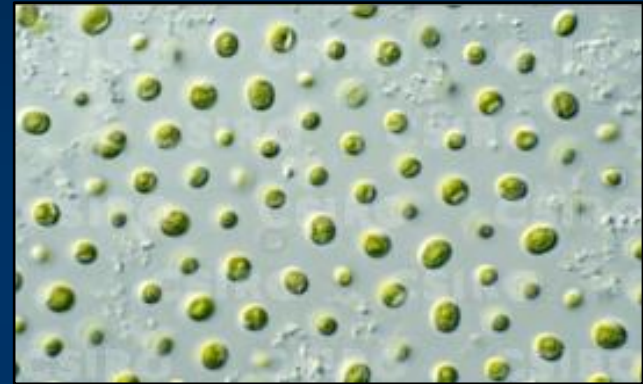


FOOD



Traditional feeding techniques

- Batch fed
- Feeding single species of algae
- Little monitoring of food quantity
- Used mainly recirculating methods



**Diet is usually the limiting factor
in growth and survival!**

What do we know?

- Large information gaps on food quality and diet
- How mussels feed
- Mussels grow well outside
- Marine and zebra literature



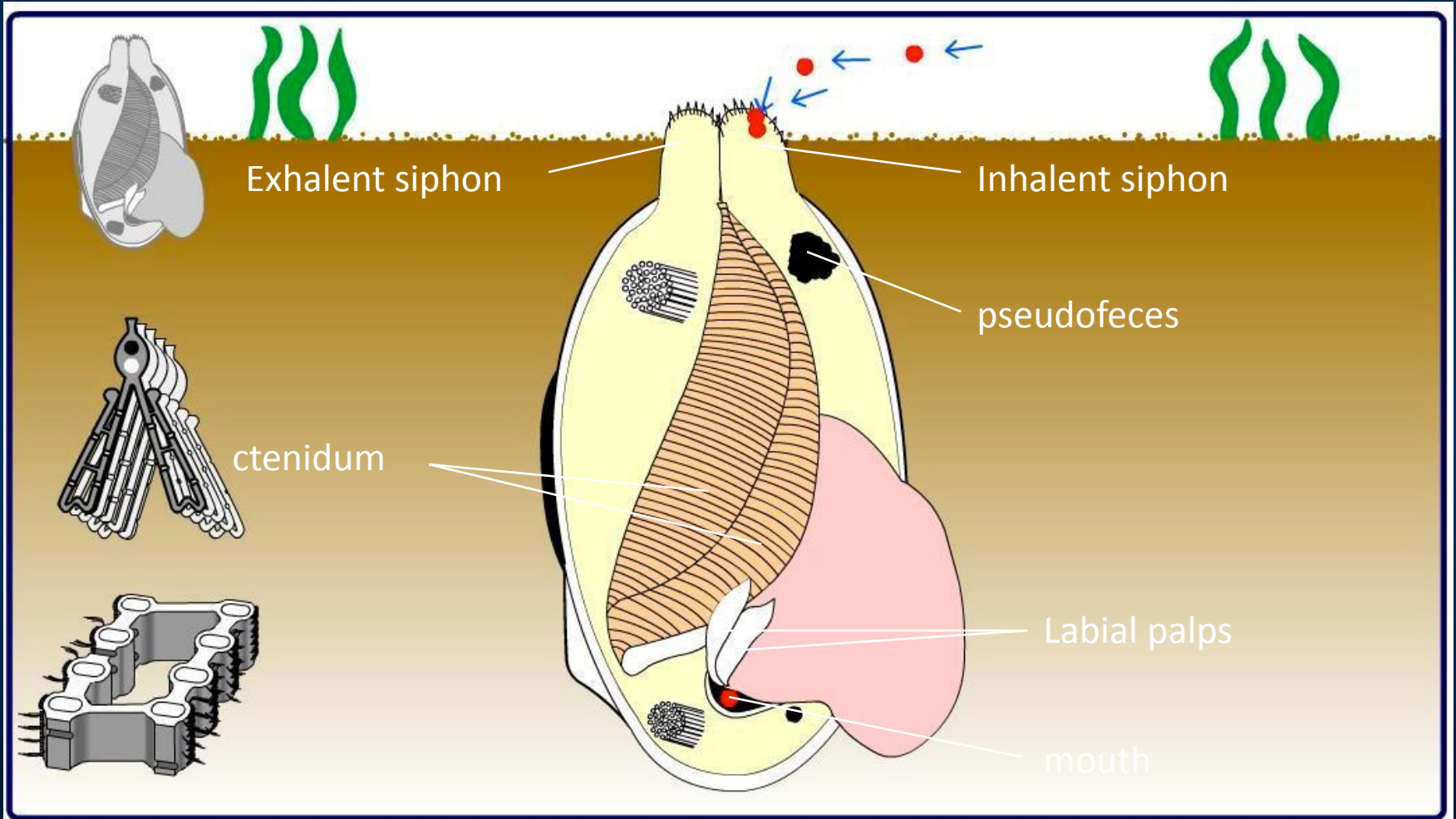
How do mussels feed

- Suspension feeders
- Extend siphons to bring in water
- Water flows in one siphon and out the other
- Fine particles are filtered by the gills
- Cilia move particles to the labial palps
- Labial palps sort particles



Photo courtesy of Jayne Brim-Box, CTUIR Freshwater Mussel Project

Suspension feeding



What do you look for in a diet?

- Biochemical composition of food
- Multiple species/water sources
- Appropriate cell size
- Easily stored and obtained
- Decent shelf life
- Something that works at your facility



Biochemical composition

- Protein
 - Tissue production
 - Juvenile growth
- Lipids
 - Reproductive development
 - Major energy source for developing larvae (Berenberg and Patterson 1981).
 - Only from diet
- Carbohydrates (glycogen)
 - Primary energy source for bivalves.
 - Balance proteins and lipids for energy production (Whyte et al. 1989)

How much protein, lipids, carbs?

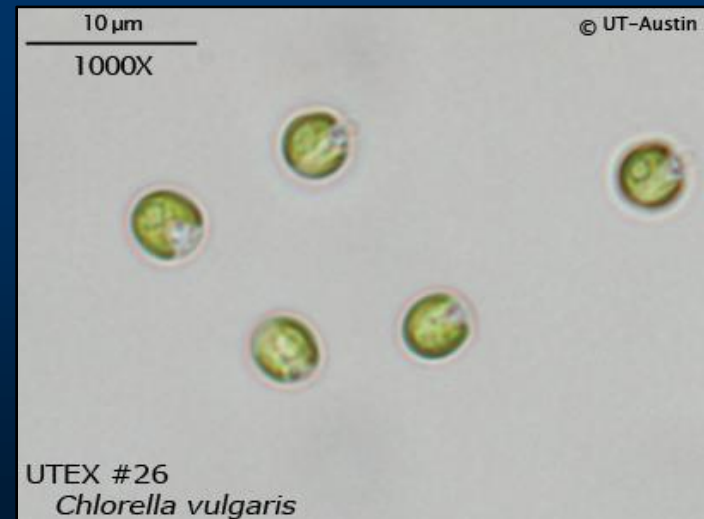
Diet	Protein (% dry wt.)	Carbohydrate (% dry wt.)	Lipid (% dry wt.)
Algae mix ¹	45.2-54.1	8-56	10.0-28.5
Shellfish Diet ²	46-54	18-24	14.3-19.6
Phytofeast ²	1.3	Not known	0.5%
<i>Nannochloropsis 3600</i> ²	58.6	20	14.5

1. Data from Gatenby et al. 2003 for *Neochloris oleoabundans*, *Bracteococcus grandis*, and *Phaeodactylum tricornutum*.

2. Data provided by Reed Mariculture/Reef Nutrition (Campbell, California)

Use multiple species

- Microalgae species differ in their biochemical components
- Provide a multispecies diet, provide a more balanced diet.



Don't just feed algae

- Mussels also eat detritus, FPOM and bacteria
- In nature, mussels consume very little algae
- Use pond or river water



Cell size

- Small cells (2.8 - 8.5 μm) preferred to large cells (23 - 45 μm) (Beck and Neves 2003)
- Juvenile esophagus 6 μm (Lasee 1991)
- Feed small cells to young juveniles
 - 1 - 10 microns in diameter



Storage

- Live or preserved algae has a shelf life
 - Optimal less than 4 wks for live
 - 12-14 wks for ‘instant algae’
 - Nannochloropsis can be frozen for 1 year
- Biochemical properties change over time
- Nutritional quality decreases over time



So.....what should I feed?

- Feed a diverse diet
 - Combine several microalgae and diatoms
 - Select species 1-10 μm
- Use commercial diets
 - Shellfish diet: *Isochrysis*, *Pavlova*, *Tetraselmis*, and *Thalassiosira pseudonana*
 - *Nannochloropsis oculata*
- Let 'mother nature' feed them



So....what should I feed?

- Depends on your situation
- What species are you culturing
- Drainage vs broodstock
- Facility space, staff time, budget



Feeding survey

- Surveyed 13 mussel facilities
- 12 responded
- Asked 17 food related questions
- What we are feeding?
- How much are we feeding?
- How often we are feeding?

Freshwater mussel feeding survey 2015	
Question	Answer
Facility name, contact person, and best way to contact you	
Do you grow mussels in recirculating systems, ponds/river, or other?	
If recirculating: Day old juveniles - What culture system are you using?	
What concentration of food do you try to maintain in your culture system? in cells/ml and/or volume. Please be sure to clarify what units you are using. Why are you feeding this amount? (ie: what paper, trial and error or other source lead you to feed this concentration).	
What algae are you feeding (ie: what species, commercial mix)?	
At what concentration? If you don't count algae cells, what is the water volume of your system	
How much are you feeding (in milliliters)? How often are you feeding (1x day, etc)?	
Are you using some sort of automatic feeder?	
Are you monitoring how much food is in the culture system? How?	
Is there a lot of variation in the food concentration over time?	
As mussels get older, do you increase the food? to what?	
Do you have different feeding rates for different mussel species?	
If flow through or pond/lake/river: What is your water source?	
Do you supplement with live/commercial algae if a flow through system?	
Do you know the concentration of available food in your 'culture water'?	
Do you monitor the food levels? How? How often?	
Please provide a brief description of how you feed your adult mussels? How long do you typically hold them?	

What are other mussel culturists feeding?

- Survey Results
 - 12 responses
 - 10 fed Shellfish Diet and *Nannochloropsis*
 - 4:1 to 2:1 ratio
 - 1 fed Shellfish only
 - 1 used filtered river water
 - Facilities (12) also used pond or river water or moved mussels to ponds/rivers

How much do you feed

- Studies show as food concentration increases filtration rate decreases
- Research suggests a low continuous supply of algae is best
- Do not overfeed young juveniles



So..... how much do you feed?

- Maintain 30,000-50,000 (5) cells mL⁻¹ < 1 mo
- Survey results:
 - Some (4) feed 50,000-70,000
 - Some (2) feed 300,000-500,000
- Feed juveniles regularly or incorporate an automatic feeder or use 'wild water'

Do you feed more as mussels age?

- Increase food to 30,000-150,000 cells mL⁻¹
- Watch for over production of pseudofeces
- Older (~1mm) out to pond/river (11)
- Larger juveniles may require more food at/over 1,000,000 cells mL⁻¹



How often do you feed?

- Use automatic feeders
 - Keeps food in suspension for indoor culture
 - Allows food distribution 24/7
- Main types: peristaltic pumps (4), dosing pumps (1), drip feeder (1) or timers/solenoids (3)



Fins,
Furs,
&
Feathers, Inc.



Automatic feeding

- Dosing and peristaltic pumps are programmable
- Both limit the number of systems
- Drip feeders can be finicky but are inexpensive
- Timers and solenoids not system limiting
 - Solenoids do clog often and need maintenance

Timers and solenoid valves

- Each solenoid is electronically connected to a timer that controls when the solenoid opens and distributes algae.
- The length of time the solenoid valve is open controls the amount of algae



Timer



Solenoid



How often do you feed?

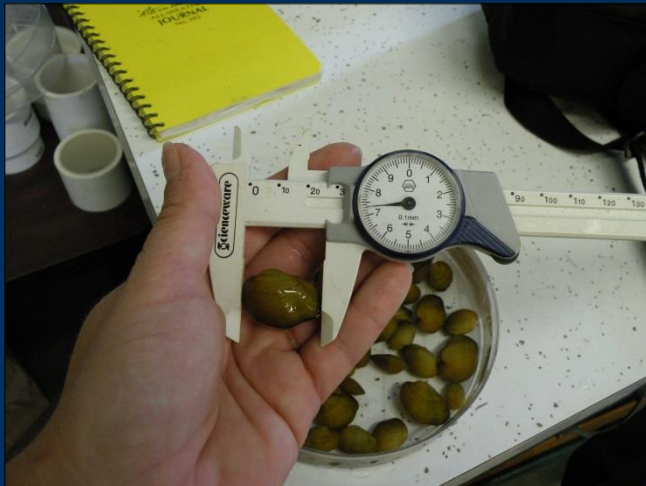
- Depends on what you're feeding
- Live algae stays in suspension longer
- Experiment at your facility
 - 30 minutes cell counts drop by half
- Survey results showed
 - Feed every 7 minutes to 4 x day
 - Every hour most common (4)

Are your mussels getting enough?

- Daily
 - Mussels should be visually inspected
 - Notice if food is present in gut
 - Observe any shell material



Are your mussels getting enough?



- Are they producing waste?
- Are they growing?
- Are they actively filtering?



Monitoring food in systems

- Monitor food
- Visual inspection
 - Slight green tinge
- Use cell counter
 - Manual
 - hemacytometer
 - Automatic
 - coulter counter

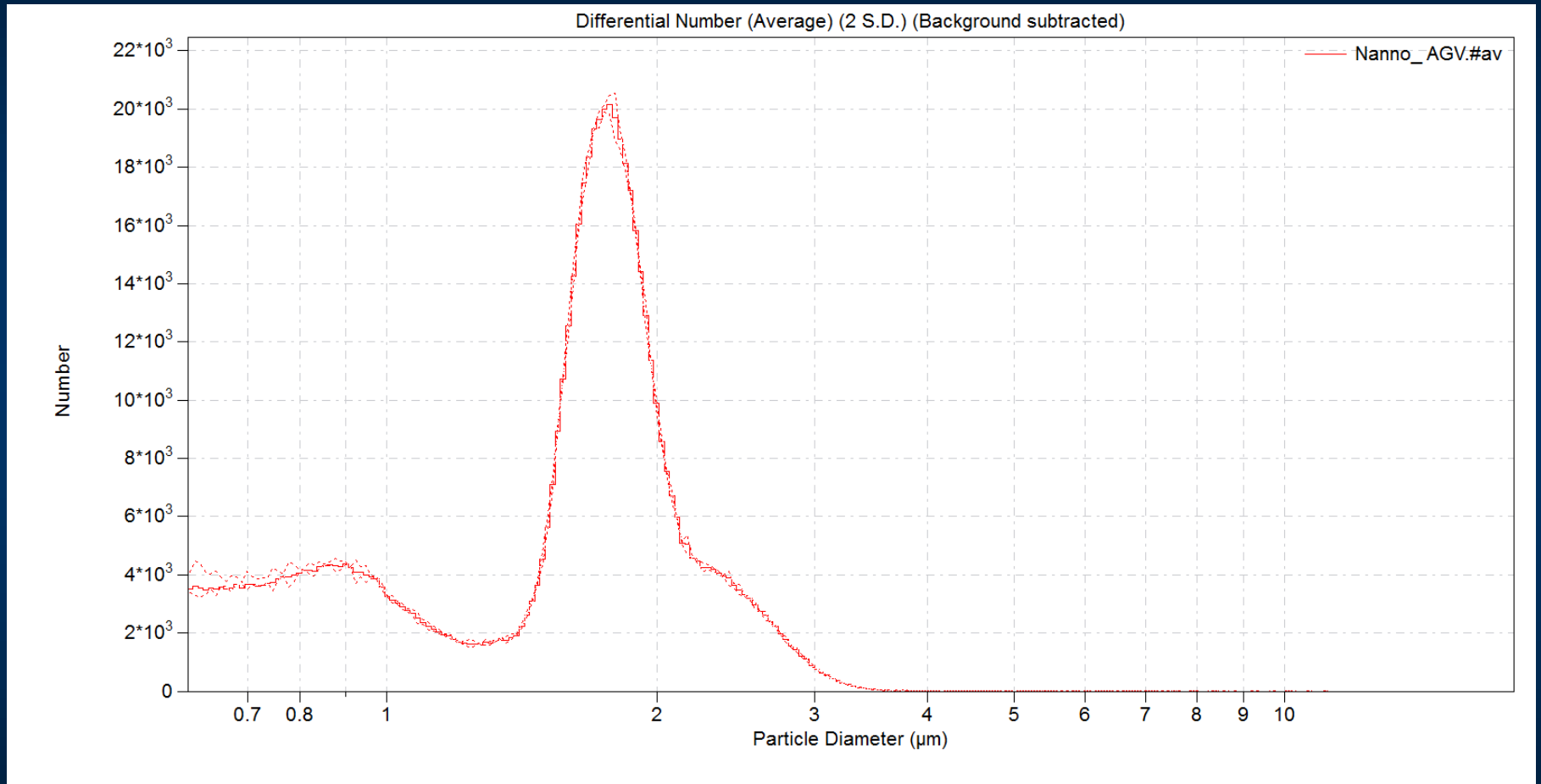


http://www.gotalgae.com/algae_solutions.htm

Monitoring algae in systems

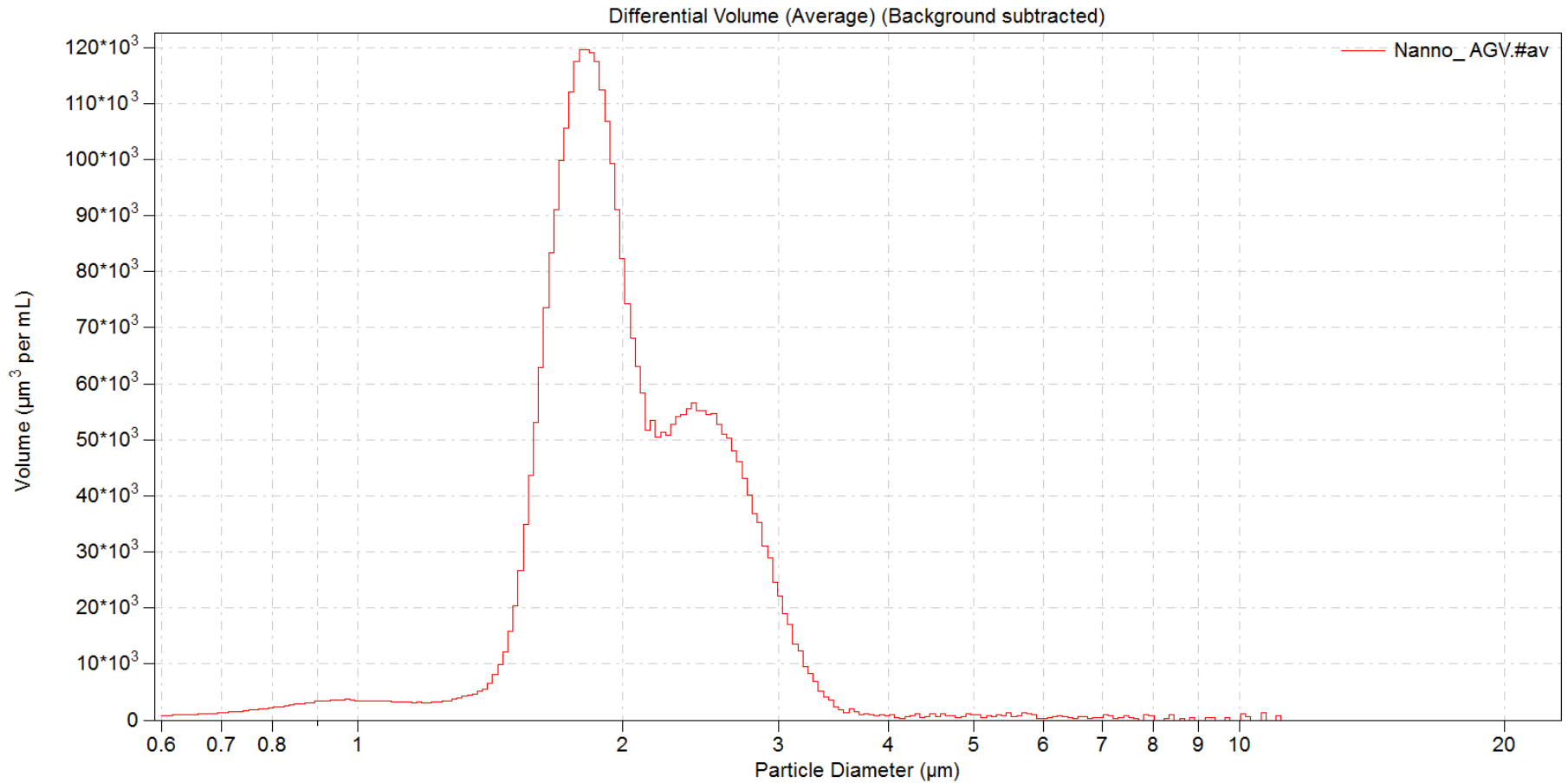
- Hemacytometer
 - Very time consuming
 - Inexpensive
- Cell counter software gives you cells ml⁻¹ or volume of cells in each system
 - Great at counting algae cells
 - Doesn't give good count of bacteria and other FPOM
 - Expensive but worth it

Nannochloropsis oculata



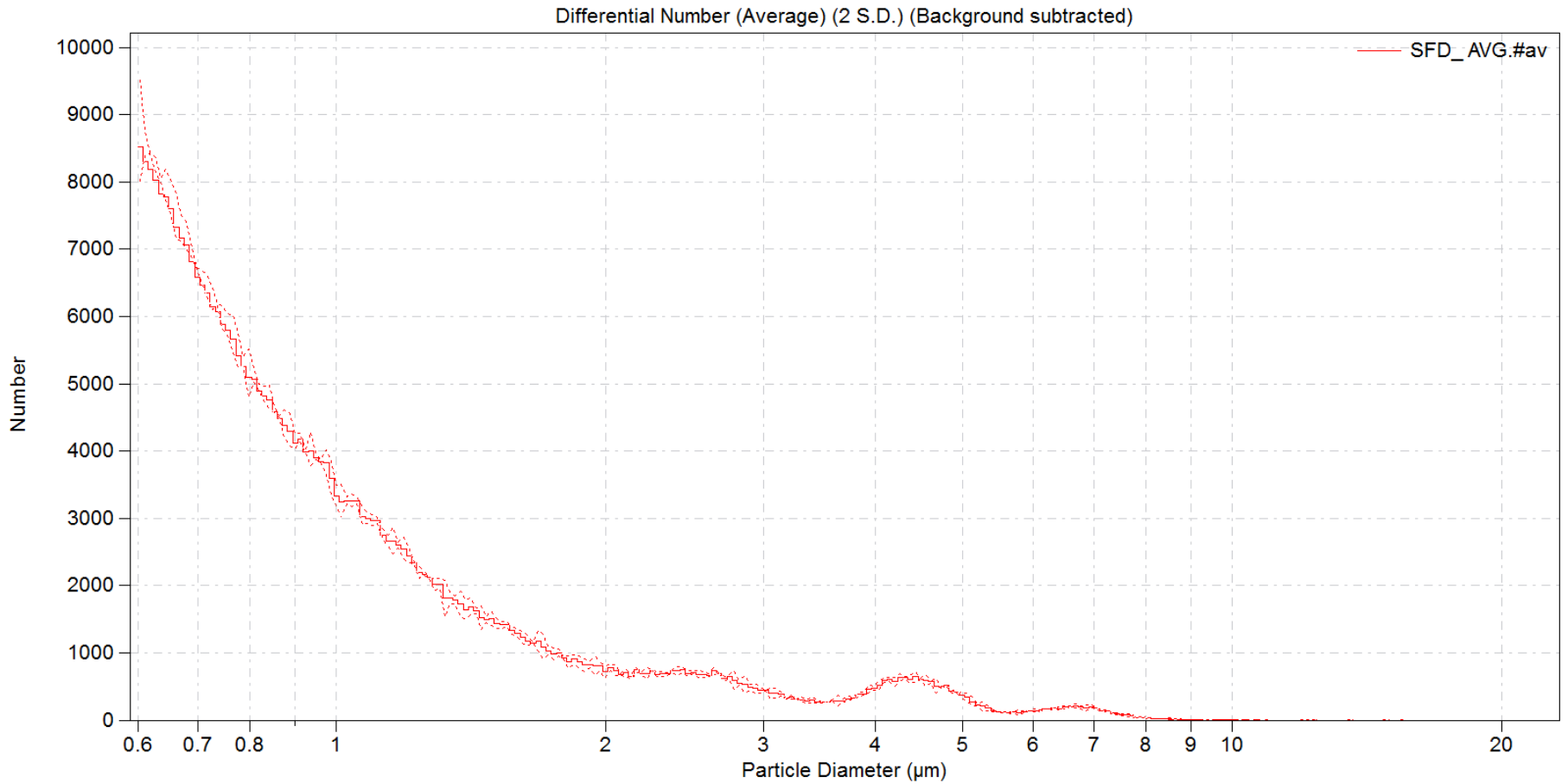
Graph courtesy of M. Pletta

Nannochloropsis oculata



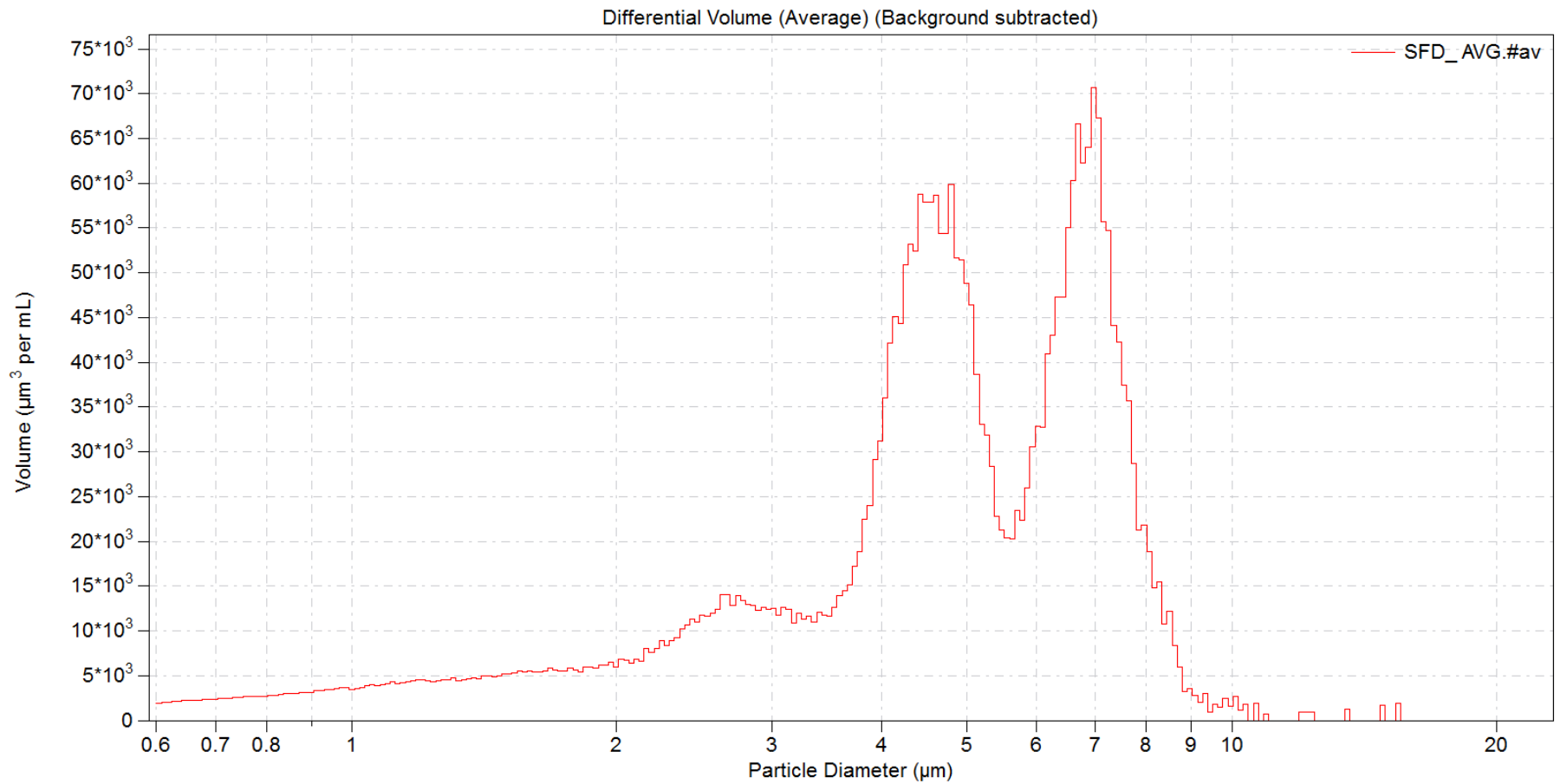
Graph courtesy of M. Pletta

Shellfish Diet



Graph courtesy of M. Pletta

Shellfish Diet



Graph courtesy of M. Pletta

Algae culture



Algae culture



Should you grow or buy algae?

- Increased growth when fed live algae (Gatenby et al. 2003, Heasman et al. 2001, Helm and Bourne 2004, Mair 2013)
- No difference in survival (Ponis et al. 2003, Aji 2011, Mair 2013)
- Is the growth worth the cost?



Growing algae

- A controlled environment necessary for algae culture
 - Increased operational costs for the hatchery
 - Specialized equipment
 - Sterile technique is required
 - Increased labor costs
- For freshwater mussels, great success using a natural food source (i.e. pond or river water)

Growing algae

Requirements

- Staff
- Algae
 - Light: red and blue light, 2500-5000 lux
 - Temperature: 5-33 °C (16-27)
 - Medium/Nutrients: F/2, Provasoli ES
 - Aeration/Mixing: filter air
 - Photoperiod
 - CO₂
 - STERILE ENVIRONMENT

Culture containers

- Many different types
 - Ponds
 - Carboys
 - Bags
 - Fiberglass tubes
 - Photoreactors



Other ideas



<http://www.waterworld.com/>



<https://biosarch.files.wordpress.com>

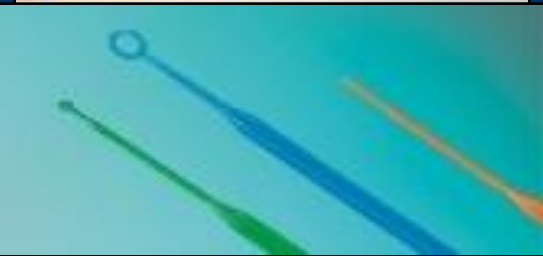
Sterilization/Cleaning

- Sterile procedure
- Clean equipment well
 - Muriatic (hydrochloric) acid
 - City Water
 - Mechanical filtration
 - Bleach
- Airlines need filters 0.2-2 μm



Culture methods

1.



2.



3.



You've got algae now what?

- Get nutrients out of culture water
- Centrifuge or allow to settle
- Storage
 - Refrigerate as liquid
 - Vacuum seal and store as paste
 - Freeze dry
- Reconstitute to desired density and feed

In Summary

- Feed several species of algae
- Feed small sized food
- Feed multiple times a day
- Incorporate 'wild water' source
- Use automatic feeders
- Use ponds/rivers for grow out



