Bio floc Technology Industry Session

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1. Limited exchange ponds and build up
Of microbial community.
2. Control of ammonia
3. Bio flocs. Feeding on bio flocs

Intrinsic features of intensive ponds:

Highly mixed, Fully aerated.

With Zero or limited Exchange, organ

substrate accumulate in the water

Identical to bio-technological reactors.

Optimal conditions for microbial activity

Characteristics of water:

- **1. Generous supply of feed to microbes**
- A. Assume **3 kg fish/m3**, 15 g feed/day

~ 7.5 g C

- B. ~ 50% released to the water ~ 3.8 g/m3* day
- C. On a steady state basis, with $\varepsilon = 50\%$, daily added microbial biomass carbon = 1.9g
- Average cell volume = 0.7 μm3
- Average carbon/cell = 5.6 * 10^{-16} g
- **Computed number of bacteria produced per day = 4.8 x 10^{9}/ml**

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Characteristics of water: 2

- **D. Turbid water**
- E. Organic carbon in water in the order of 100 mg/l
- F. Number of bacteria counts in ponds
- Around 10^7 - 10^9 /ml
  - (Compare with computed production of 10^{10} /ml, We see high turn over rate and young microbial population)

Characteristics of water: 3

- Rate of organic matter degradation in ponds and tanks ~ 0.15 /day (Avnimelech et al., in tanks and 113 commercial ponds samplings) to 0.27/day in laboratory experiments (Torres Beristain 2005), as compared to 0.1-0.2 in waste water treatment plants.

i.e: **10-20% of the organic matter degrade daily.**


Conclusions:
BFT systems are actually
Very efficient
bio-technological plants

The nitrogen syndrome

- Fish use just about 25% of feed nitrogen. The rest excreted. <u>4 kg of feed protein are needed to produce 1 kg fish protein!!</u>
- Excretion and microbial mineralization generate ammonium. Ammonia is highly toxic.
- Nitrite is also toxic, especially in fresh water systems.
- Ponds are enriched in N as compared to C. Carbon is emitted as CO_2. Nitrogen is left in the pond. Can we revert this feature??

Two Problems

- 1. Elevated inorganic N levels in the water is often the limiting factor toward high performance of intensive systems. Inorganic nitrogen concentrations have to be controlled.
- 2. Low efficiency of protein utilization is a waste of money (Protein is the most expensive feed component). In addition, since major source of protein is fish meal, harvested from over exploited oceans, This is also a major environmental issue.

Microbial "nutrition"

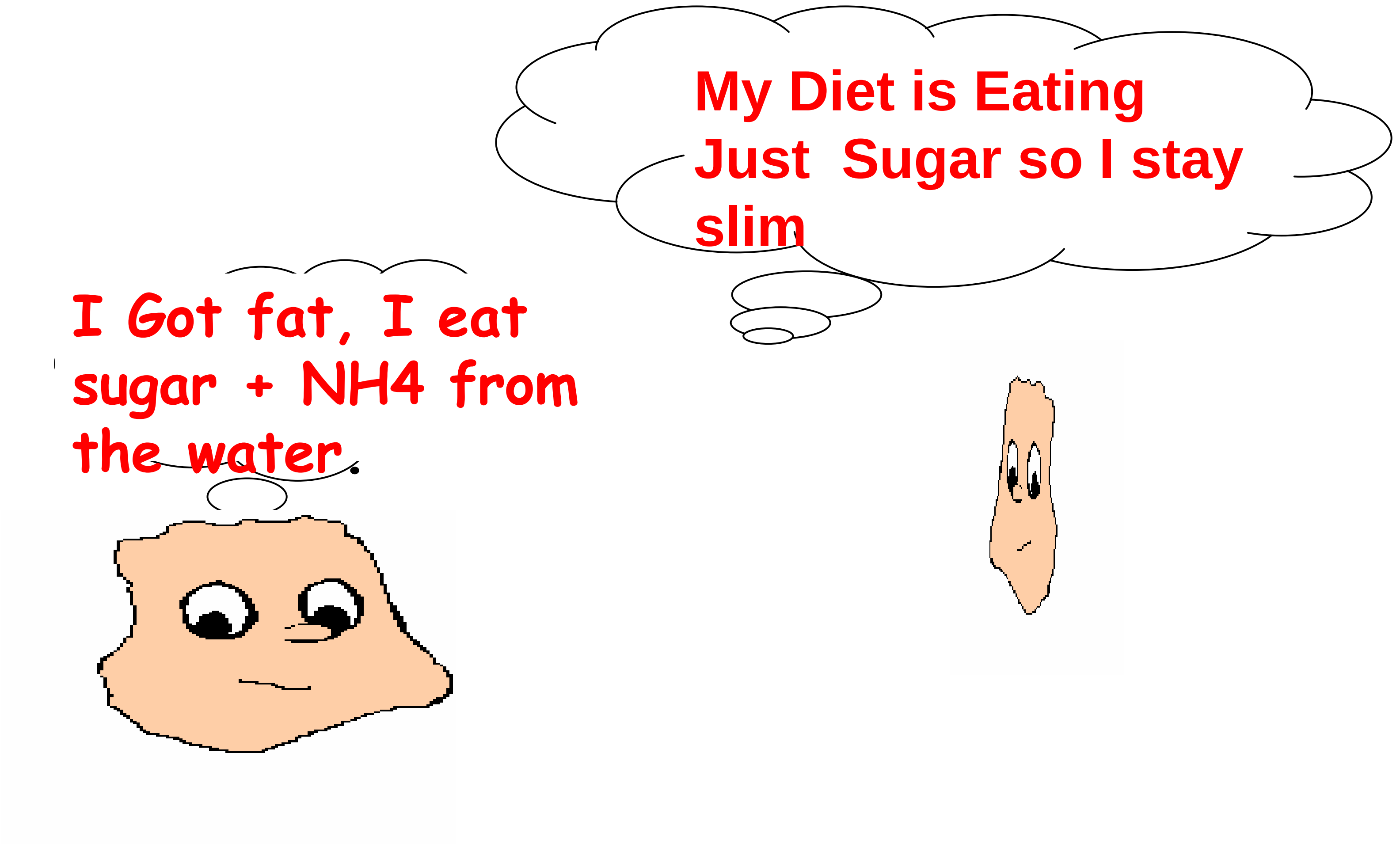
***Bacteria are made of protein**

Assume feeding with sugar:

CHOH --> CO_2 + H_2O + energy (~50%)

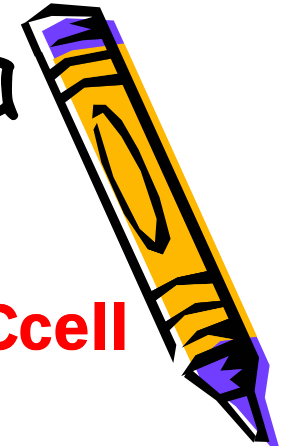
The rest --> Microbial growth

Yet, for growth they need nitrogen that is taken from the water!!


My Diet is Eating Just Sugar so I stay slim
I Got fat, I eat sugar + NH4 from the water.


We can control NH4 Accumulation
By adding carbo-hydrates
(Sugar, mollasses, cassawa etc.
BACTERIA WILL TAKE UP NH4
AND CONVERT IT INTO
MICROBIAL PROTEIN

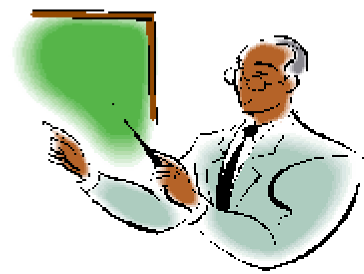
Manipulating bacteria



- We can add carbon rich and protein poor material (carbo-hydrate, CH), such as starch or cellulose (ground grains, molasses, cassawa etc.) To induce accelerated nitrogen uptake.

$\Delta C = CO_2 + \Delta C_{cell}$

$\Delta C_{cell} + NH_4 \rightarrow$ Microbial protein



Inorganic nitrogen control is achievable and predictable

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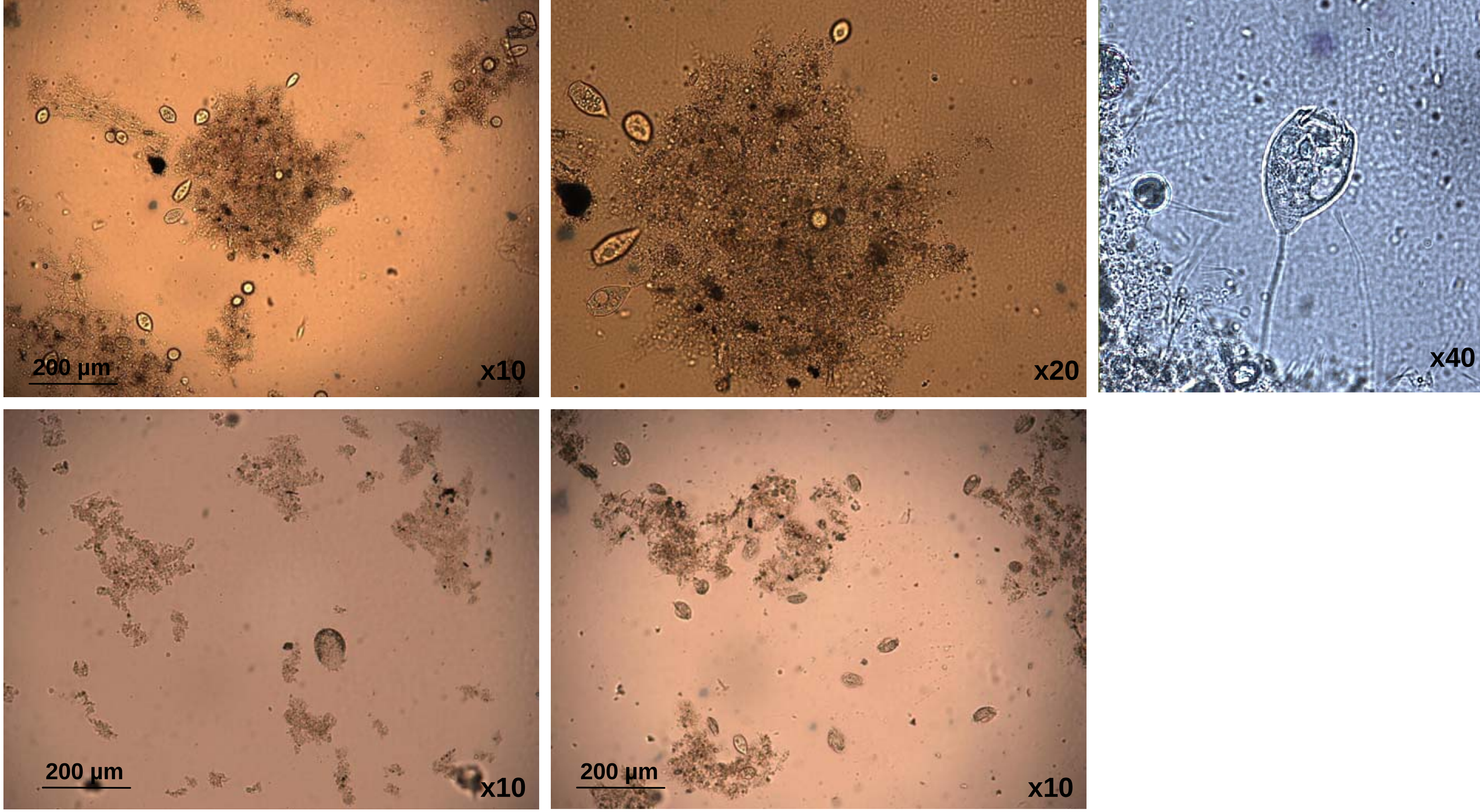
Feeding fish with bacteria

- We can induce the production of microbial protein. Will it be a good feed source for fish???
- Can they physically harvest bacteria? Individual bacteria are too small (~1μm)
- Is it nutritive? Bacterial proteins are different.

Will they digest it? Probably so



Bio flocs are made of bacteria, protozoa, etc. Typicaly their diameter is 0.1-2 mm.

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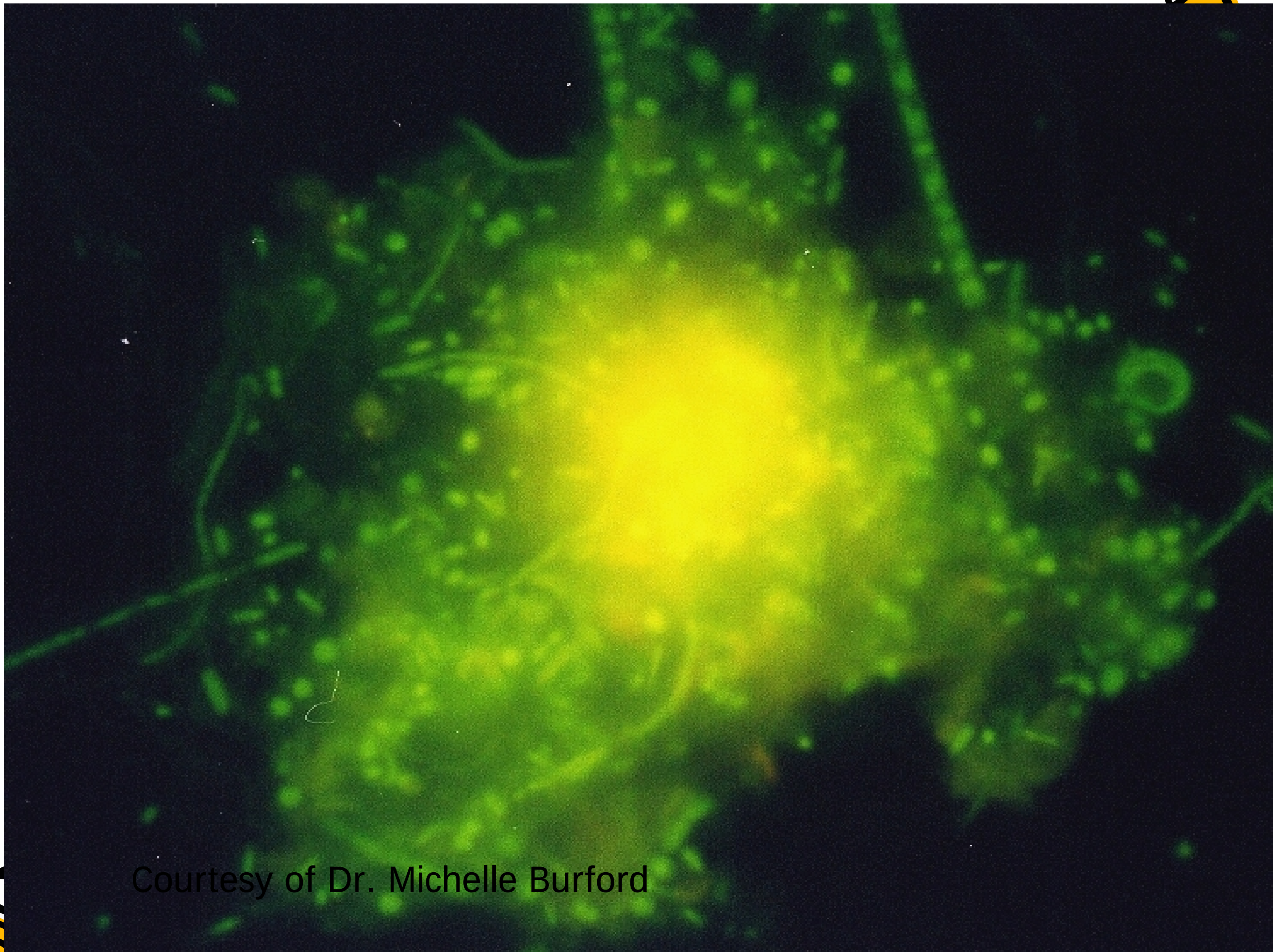
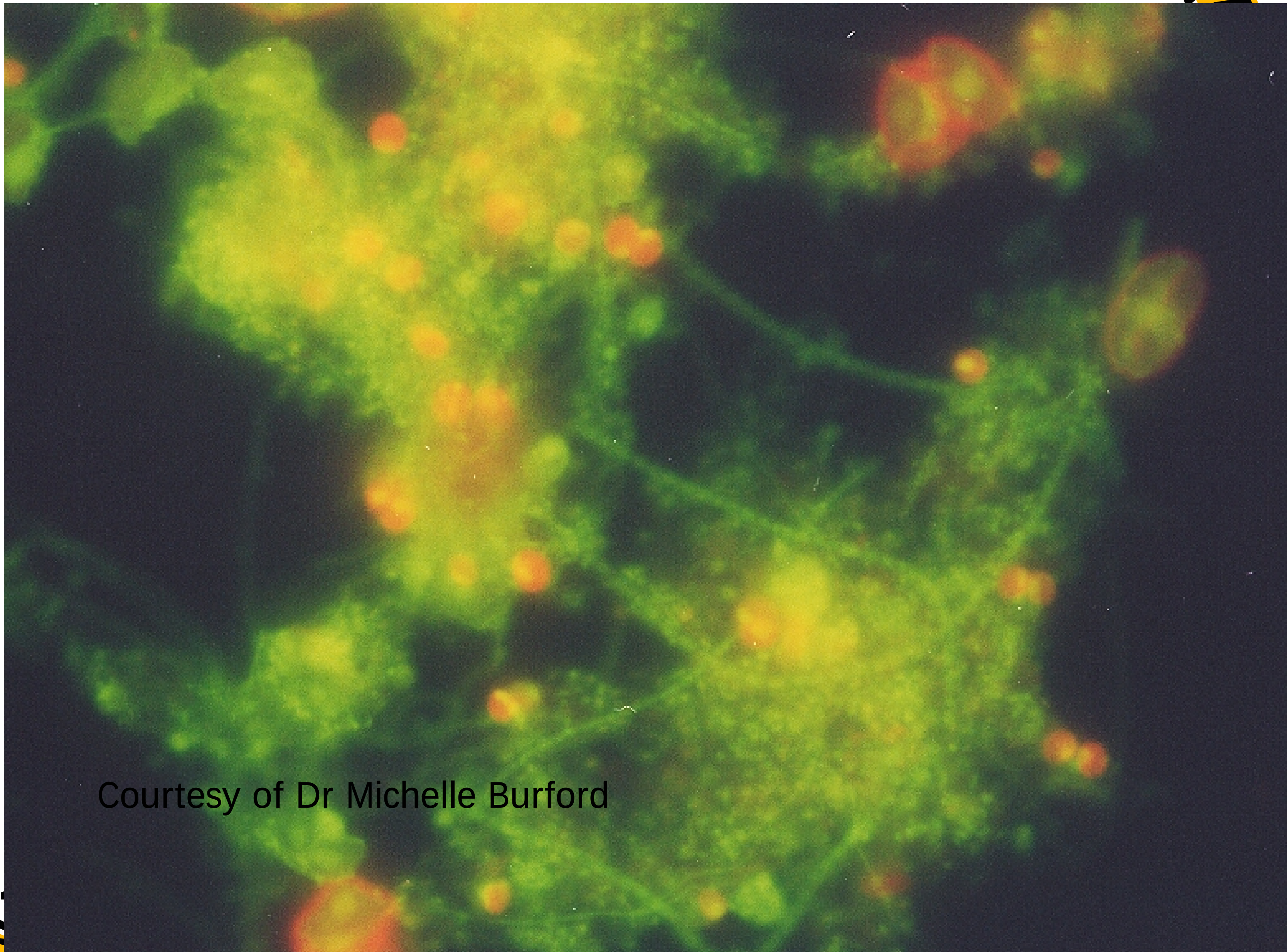

Courtesy of Dr. Michelle Burford


Courtesy of Dr Michelle Burford

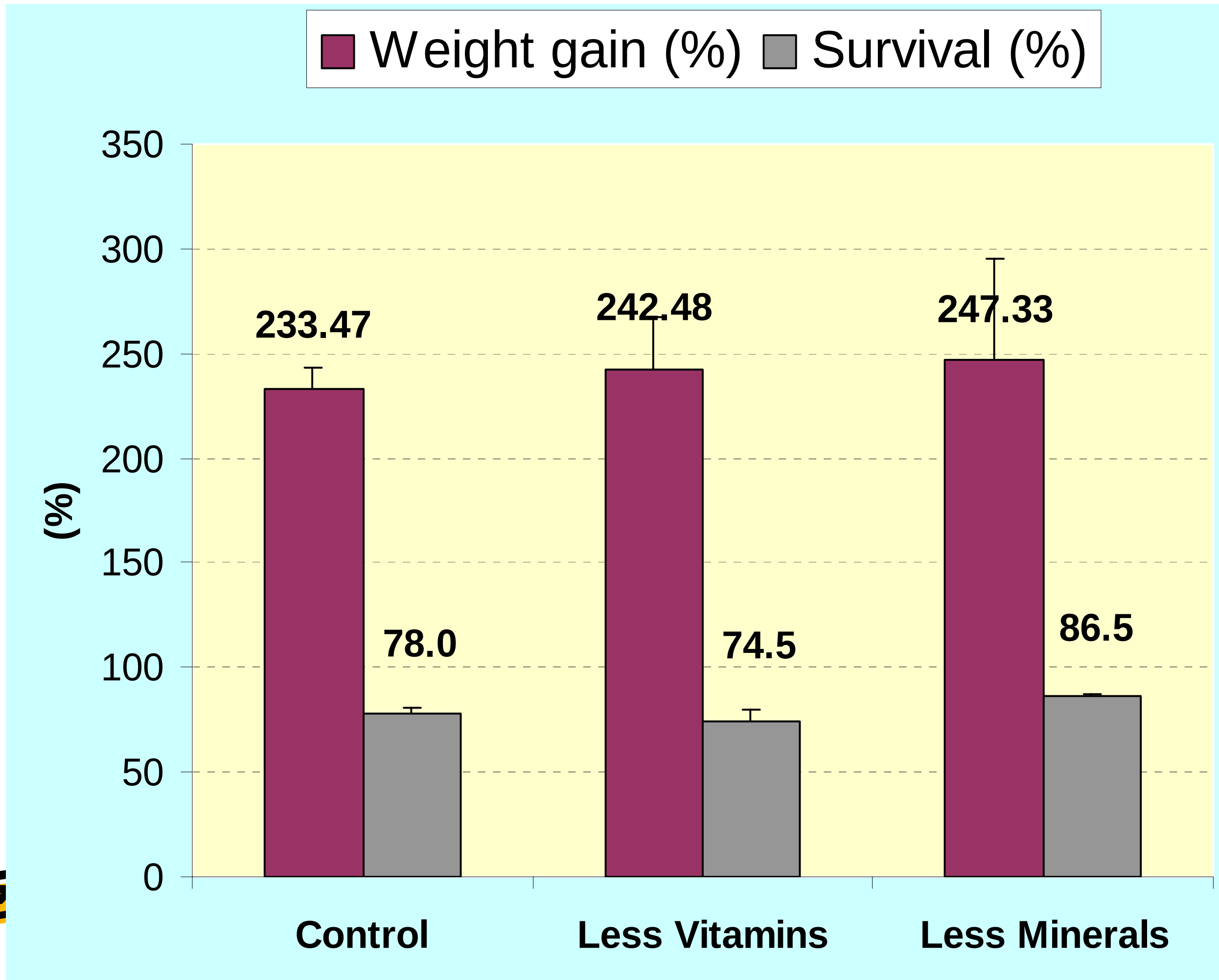
Results of a study in Belize (Burford et al., 2003

The proportion of daily nitrogen requirement of shrimp contributed by natural biota (present mostly as bio flocs) was found, using 15N uptake study, to be **18-29%.**

Protein Recycling

- Normally, fish or shrimp recover just ~25% of feed protein.
- In bacterial controlled ponds, they eat the protein twice; Once in the feed and then they consume microbial protein. The protein recovery in experimental and commercial systems reaches almost 50%. An efficiency of 63% was achieved in experimental tanks (Velasco et al., 1998)
- Protein is the most expensive part of the feed!!

Results of Albert Tacon (2002)



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Expt. # 1 51 days	30% Protein	***20% Protein***
FEED C/N	**11.1**	***16.6***
Daily Gain (%)	**1.59[a]**	***2.0[illegible][b]***
FCR	**2.62**	***2.17***
PCR	**4.38**	***2.42***
(Kg fish/US$)FEED COST	**0.848**	***0.583***

Exp. # 2 (30 days)		
C/N	**11.1**	***16.6***
Daily gain (%)	**1.63[a]**	***2.22[b]***
FCR	**2.62**	***2.02***
PCR	**4.35**	***2.18***
Feed cost (US$/Kg fish)	**0.848**	***0.543***

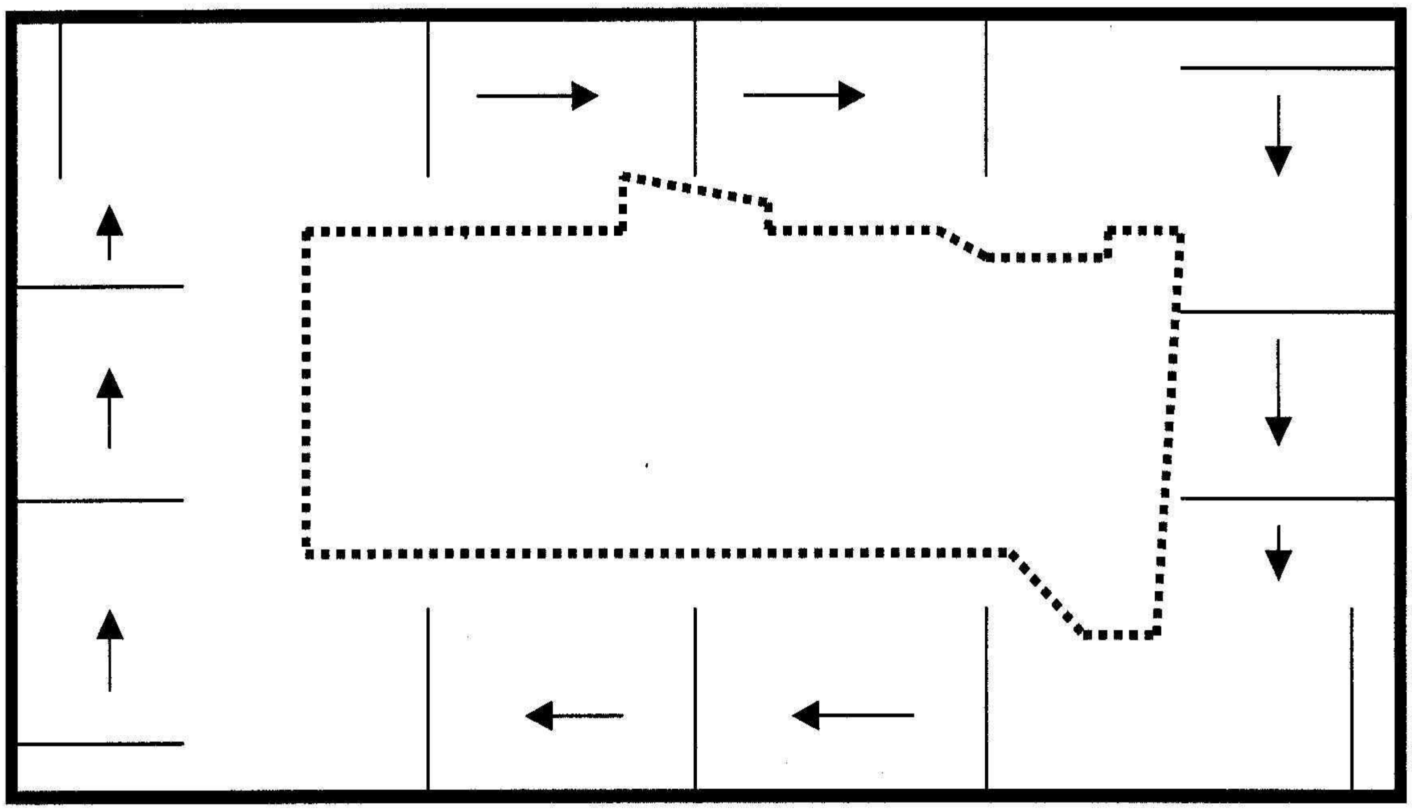
Pros & Cons of microbial N recycling

- **1. Effective, reliable and predictable inorganic nitrogen control.**
- **2. Double protein utilization, thus enables to use cheaper feed: lower protein feed.**
- **3. Lower aquaculture dependence on marine fish meal & oil.**

- 4. lower pollution
- 5. Slightly higher oxygen consumption.
- 6. High water turbidity, may be a problem to some species.
- 7. Probiotic effects

How to do it??

- 1. Enough aeration to maintain oxygen above 4-5 mg/l.
- 2. Lined pond: Plastics, concrete, soil concrete, laterite.
- 3. Placement of aerators in a way that all pond volume will be mixed. **NO ACCUMULATION OF SLUDGE!!**



Stagnant area (Water velocity < 1 cm/sec)
in 1.2 ha shrimp pond
equipped with long arm paddle wheel aerators (2 hp each)

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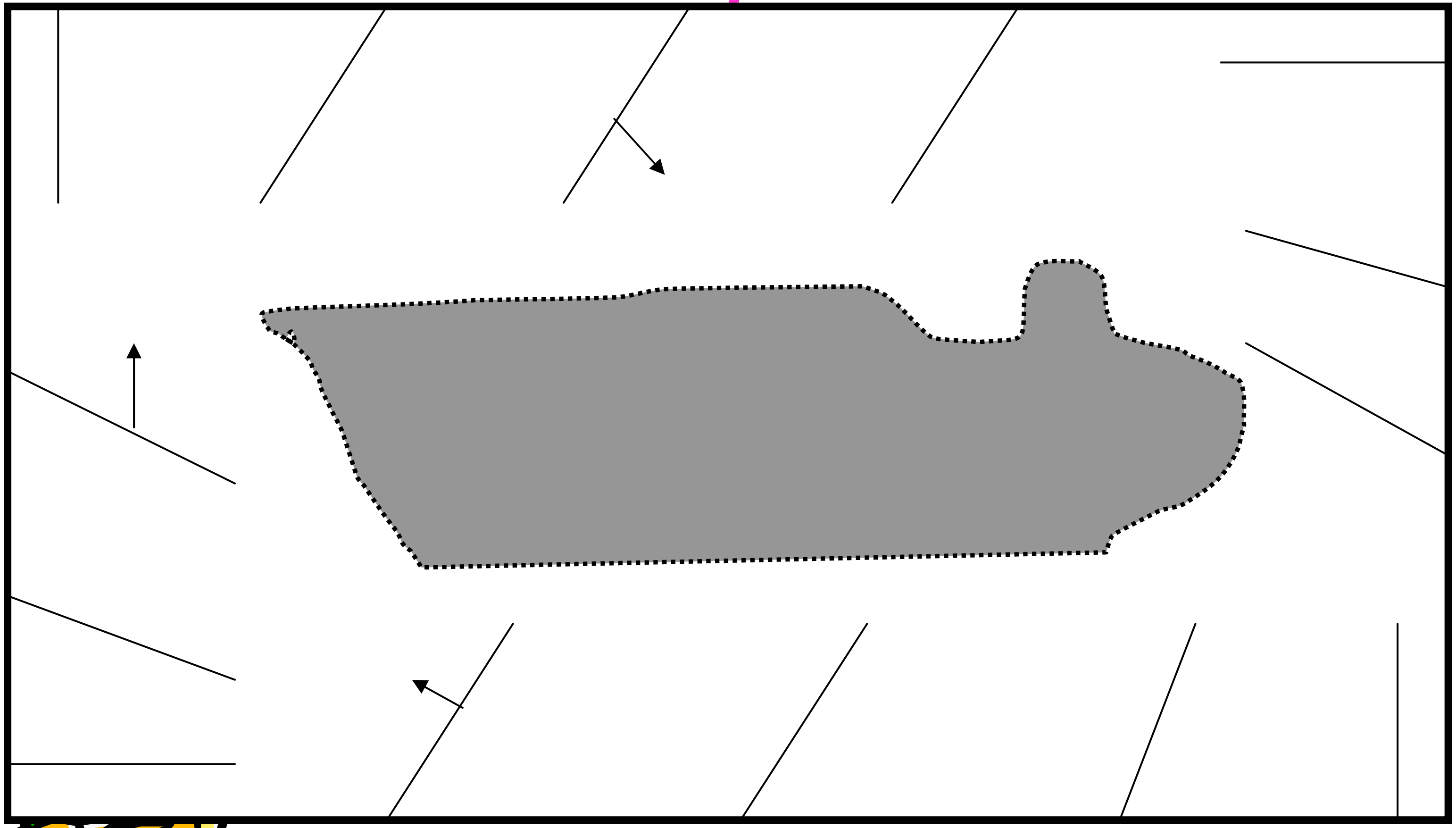
Redirecting aerators



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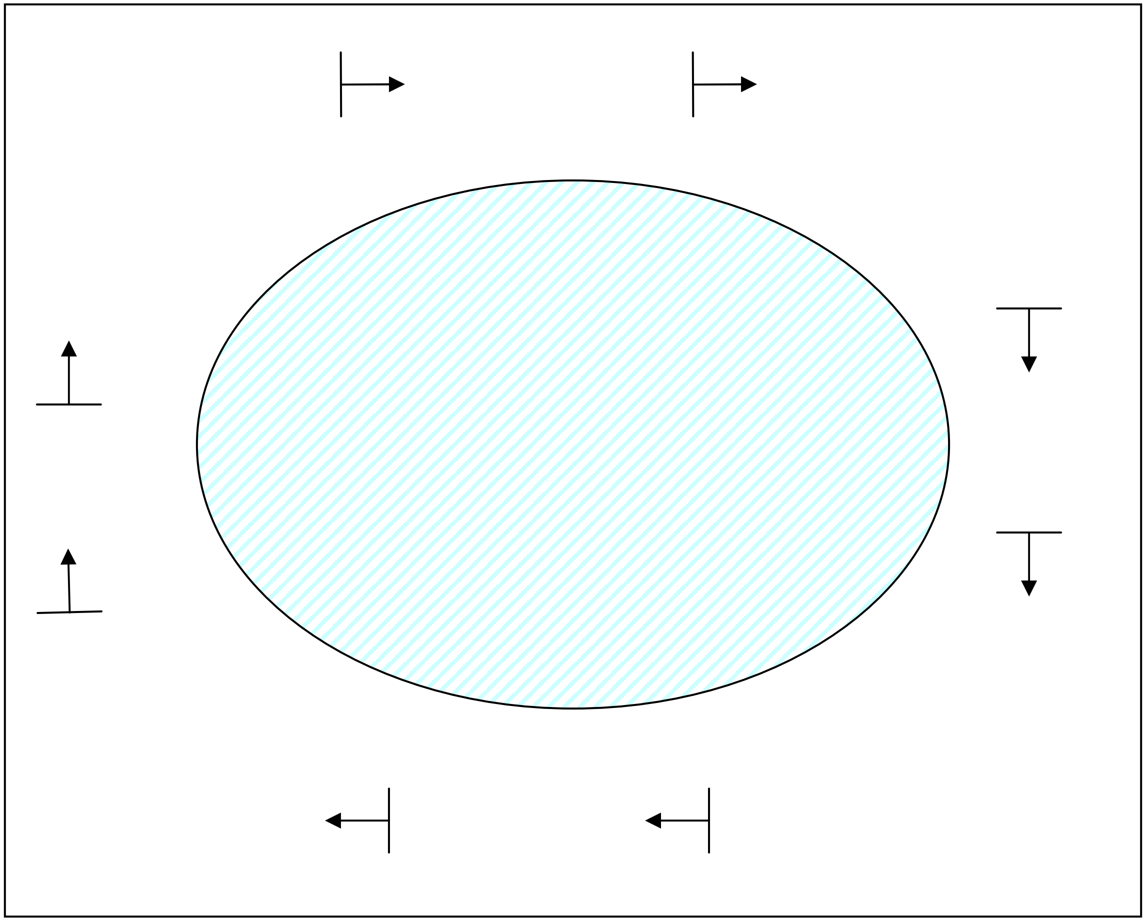
From conventional to active



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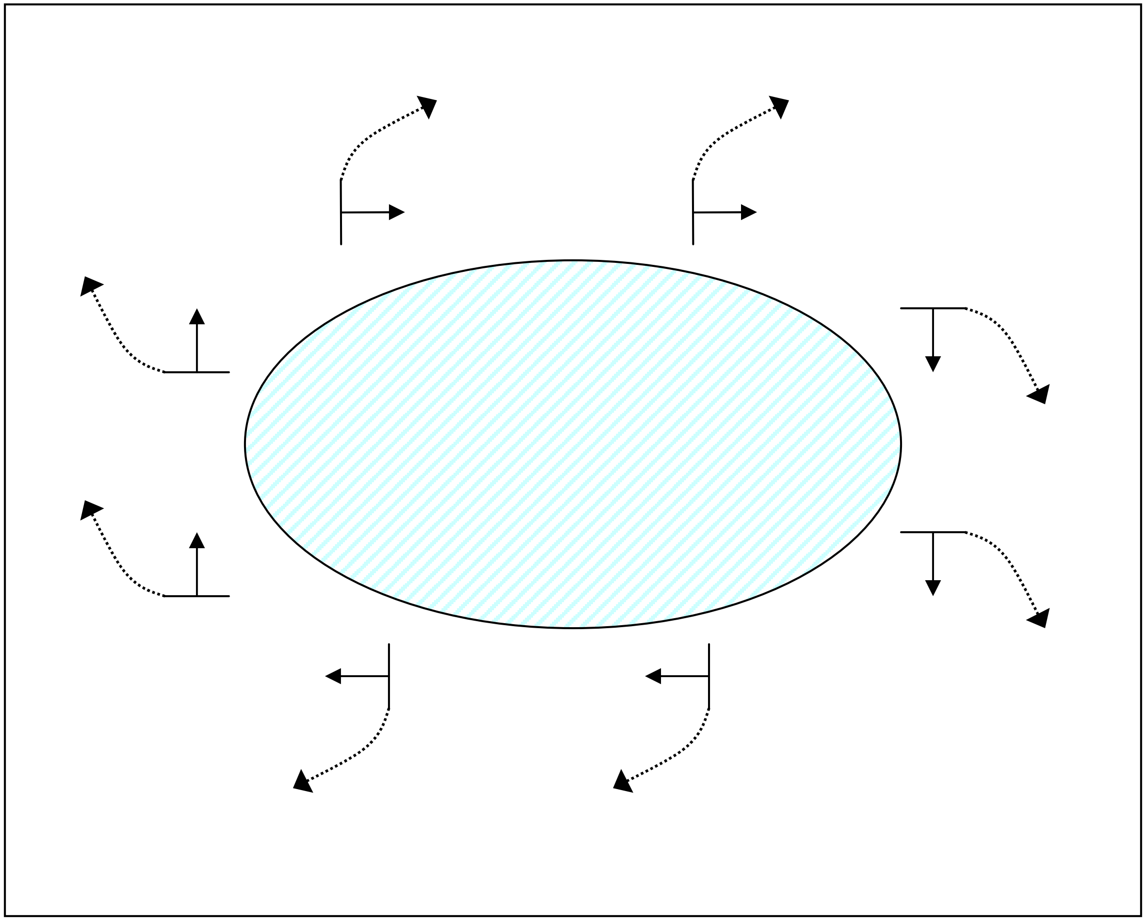

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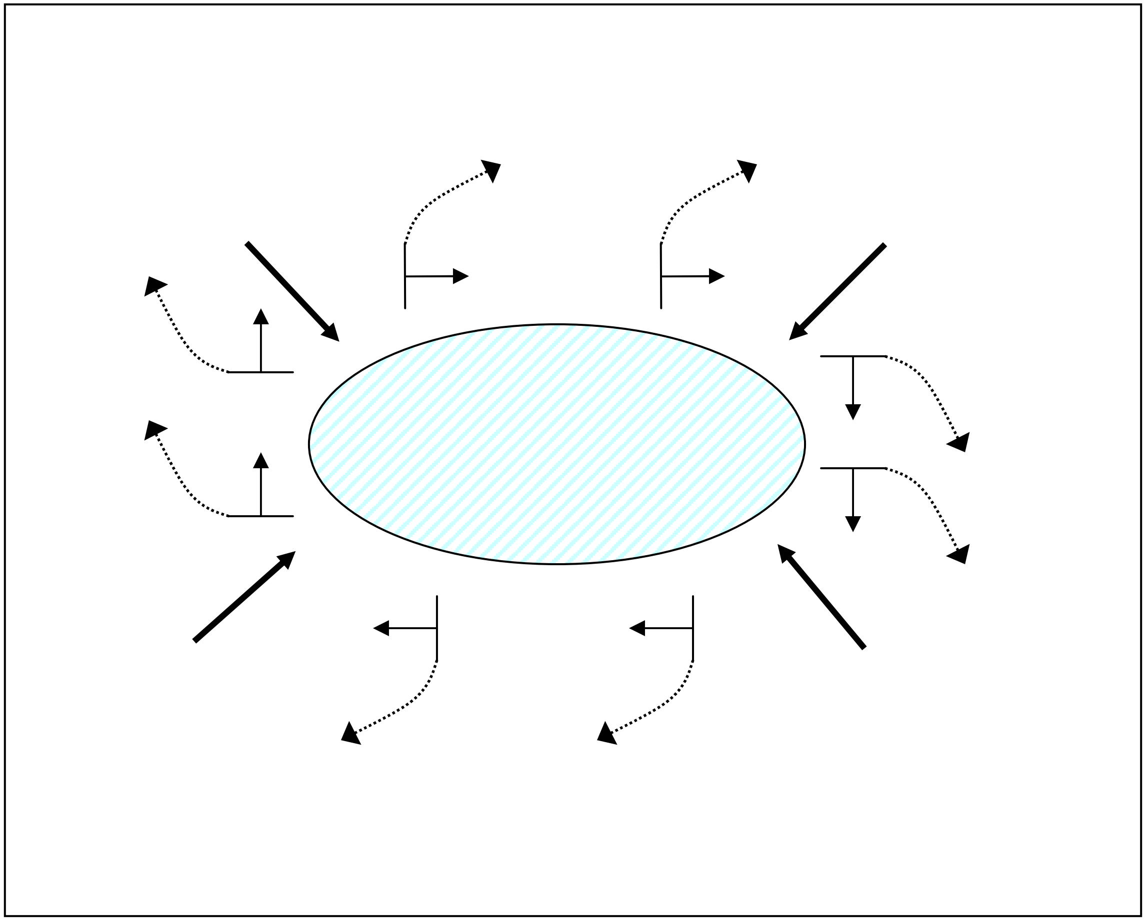
From conventional to active



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How to do it (2)

- 4. Feed with low protein % (20%) or add enough carbon (molasses, starch, cassawa etc.)
- 5. If inorganic nitrogen accumulates, add carbohydrates at a rate of 20 kg per kg N you want to remove.
- 6. Maintain alkalinity > 50-100 mg.

An Example: Over-wintering of tilapia

The Problem:

- One of the problems of growing tilapia in temperate regions is over-wintering. You need the whole year to complete the growing cycle of tilapia, yet, tilapia is sensitive to cold temperature and below ~ $13^{0}C$ mortality starts.
- In Israel, normally it is possible to hold juveniles in ponds without catastrophes, but if cold spells occur, mortality takes place and next year there are much less tilapia in the market.

Similar situation was report from China, where production declined by ~80% due to the cold winter 2008

Potential solution

- It is possible to keep juveniles and market size fish in green houses or similar structures during the winter, usually using solar heating, but in cases geothermal water.
- These structures are expensive. A dense biomass has to be held, in order to justify the investment. In case of dense biomass, metabolites, especially ammonium may accumulate and endanger the fish population.

Water replacement is not a reasonable option, – since you loose heat by releasing the warm water.

Materials and methods

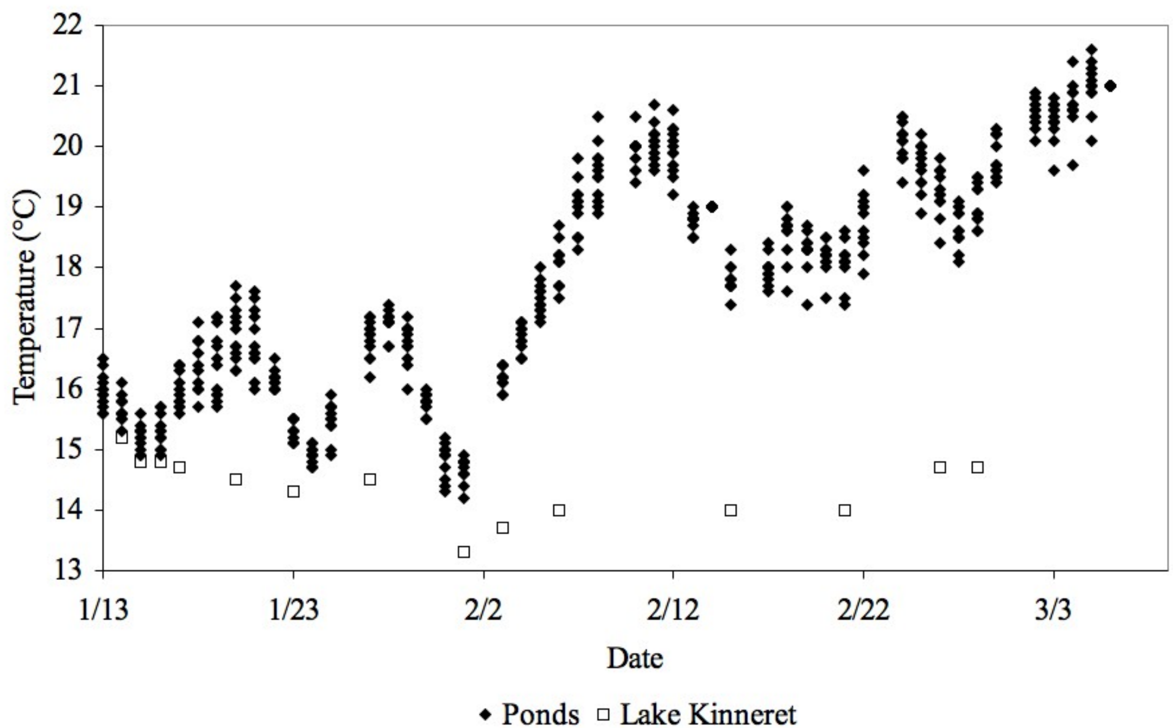
- Experimental design
  - Winter period 2008 (13th of January till 4th March)
  - 50 and 100 g tilapia hybrid fingerlings (*Oreochromis niloticus* x *Oreochromis aureus*)
  - **16 kg fish/m^3 pond water (could be raised!)**

Results

Temperature and oxygenO control

Dissolved oxygen: 9 – 10 mg O_2/LO

Average temperature: 18^0CO



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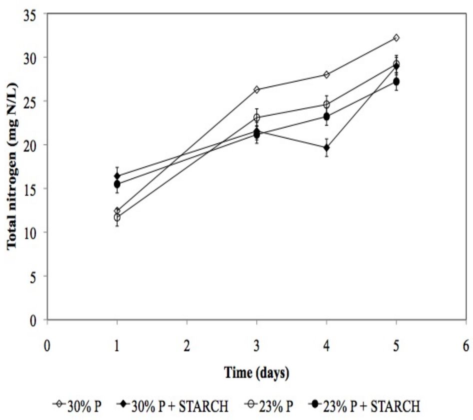
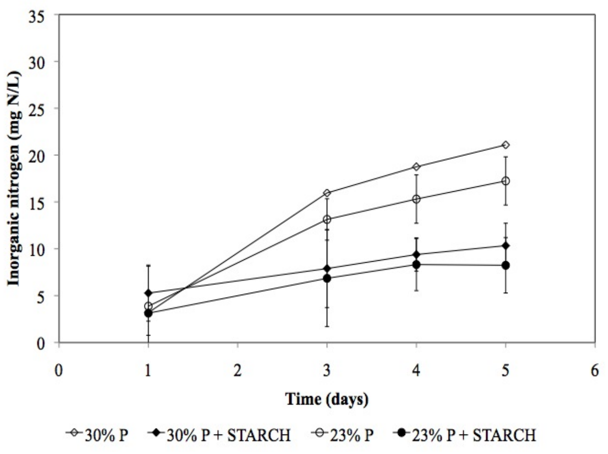
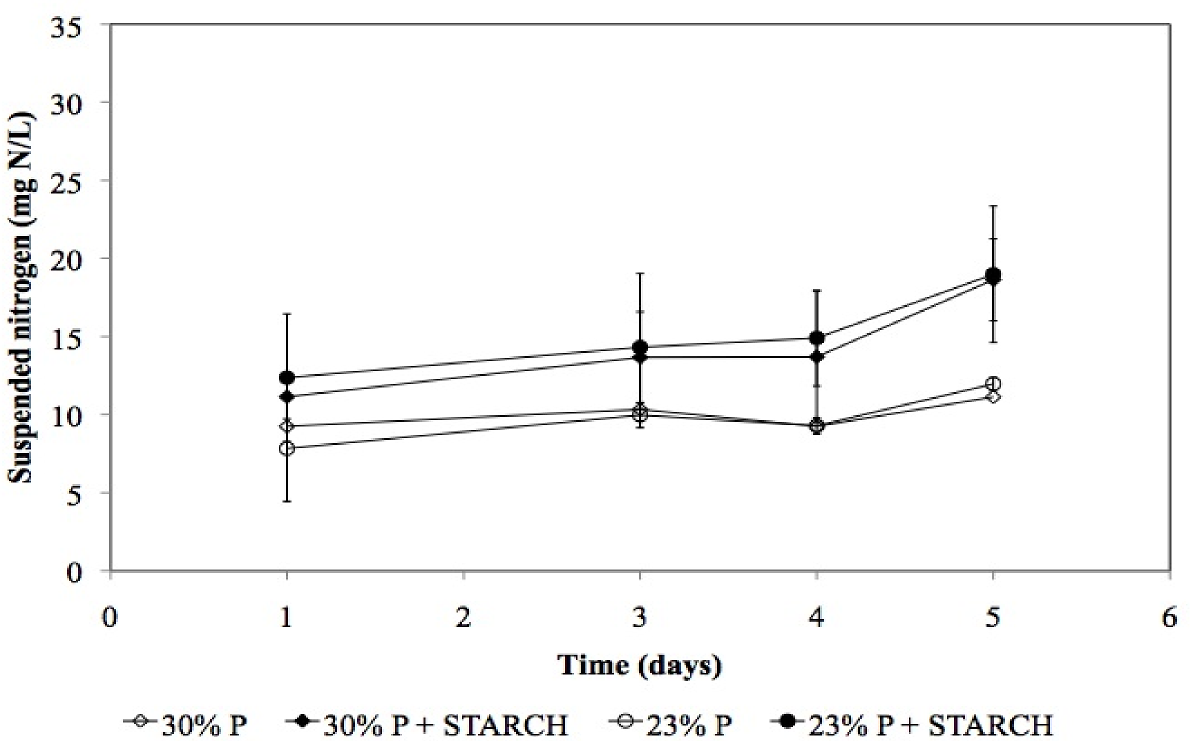
ONitrogen dynamics







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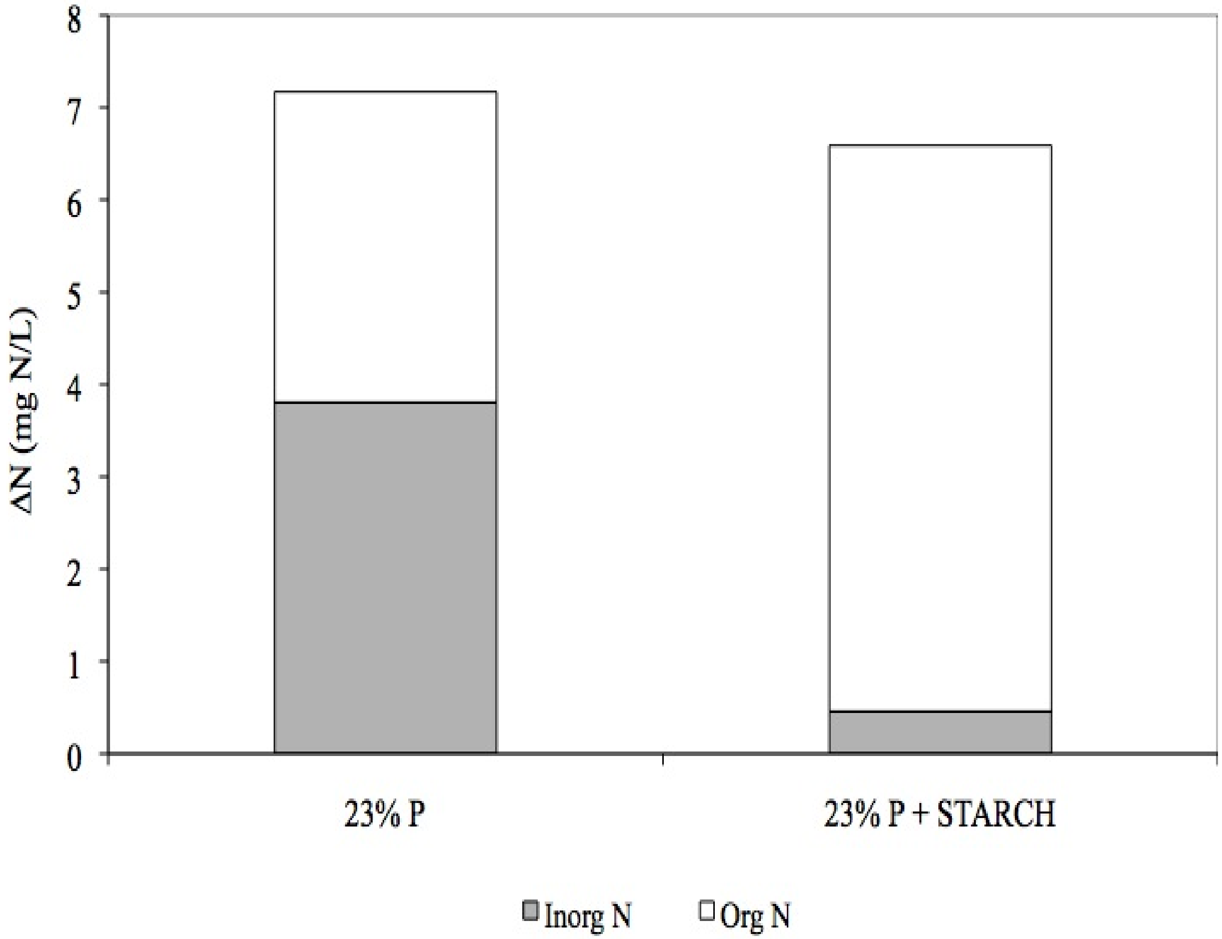
8
7
6
5
4
3
2
1
0
ΔN (mg N/L)
23% P
23% P + STARCH
Inorg N
Org N

Fish Responses

- Fish survival
  - 50 g fish: 80 ±4%
  - 100 g fish: 97 ± 6%
- Fish growth
  - 50 g fish: 0.27 ± 0.02 g/fish.day
  - 100 g fish: 0.29 ± 0.03 g/fish.day
- Condition factor, CF = 100.W/L
  - CF < 1.8 poor conditions
  - CF > 2 good physiological state

2.17 ± 0.06 50 g fi

2.19 ± 0.07 100 g fi

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How to do it (3)

- 7. Minimize water exchange.
- 8. If sludge accumulates, drain sludge out or dry/clean between seasons.
- **9. It was demonstrated that the same principles can be used in stagnant ponds!!!**
- Every farm is some what different. Learn from yours and others experience.


We have gone a long way:
Hundreds of BFT ponds
producing shrimp and tilapia
are operative successfully all
over the globe

- Assume 1 kg shrimp/m3
- 3% feed per day = 30g
- 40% protein = 12g
- 15.5% N in protein = 1.86 g N
- 75% is released to the water ~
- ~ 1.4 g N/m3 added daily to the water (= 1.4 ppm per day)

MICROBIAL CONVERSION

•MICROBES PRODUCE NEW CELL MATERIAL (protein) AND ENERGY:

$$\Delta C = CO_2 + \Delta Ccell$$

$$\Delta Ccell/\Delta C = \varepsilon$$

= Microbial conversion efficiency

=normally, 0.4-0.6 for aerobic microbial processes. Lower for anaerobic.

Bacteria are rich in respect to N (C:N ~ 4)

Thus, **1 Nitrogen is taken up for 4 ΔC**