Bio floc Technology Principles and application

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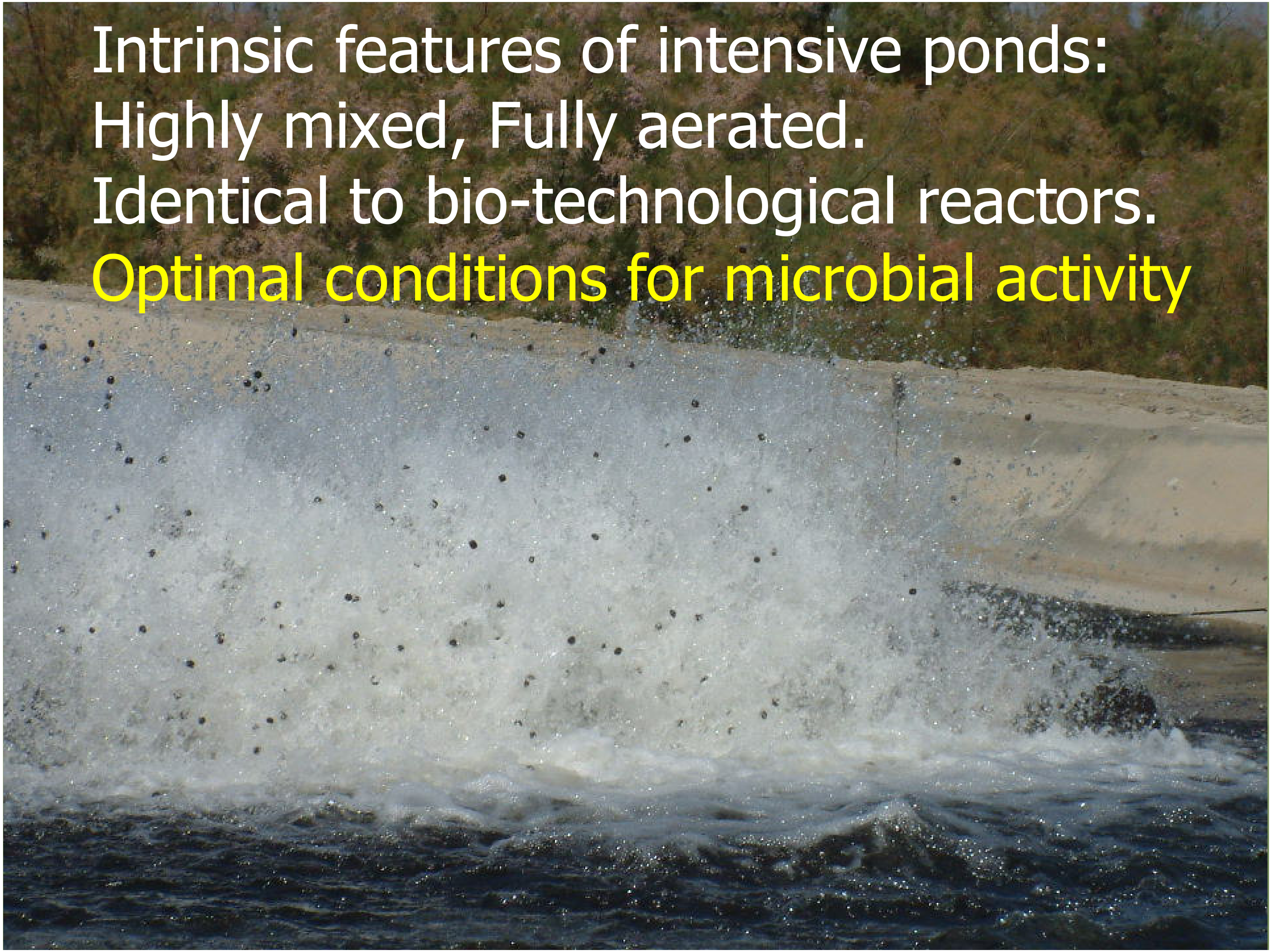
Bio floc technology (BFT) is used
Mostly in intensive systems,
With zero or low water exchange
Later we will present
Its usage in traditional extensive
systems


Why do we need intensive
closed ponds???

1. Environmental regulation prohibiting or limiting water disposal.
2. Bio-security concerns limiting water intake.
3. Water scarcity and/or cost. Conventional aquaculture uses usually 2-10 m3 water to produce 1 kg fish.
4. There is a demand for quality control and transparency, that are difficult to achieve in intensive systems.

5. Feed utilization may be higher than in conventional systems. This may be an important point.
6. In cases where production is close to the market, space limitation is also of concern.
7. Intensification enables easier temperature control.
8. Intensification and automation may save labor.

POND TYPE	INTERVENTION	YIELDS (kg/ha*yr)	LIMITING FACTOR
Minimal feed	Feeding with grain, farm 7 home residues. Fertilizers	~2,000	Limit of Primary productivity. Food chain efficiency
Fed Ponds	Feeding by complete diet pellets	~4,000	Night time oxygen deficiency
Night time aeration	Night time or emergency aerators ~1-5 hp/ha	~10,000	Sludge accumulation. Anaerobic pond bottom
Intensive mixed – aerated ponds	24 h/day aeration (~>20 hp/ha), constant and full mixing	20,000 - 100,000	Water quality control


Intrinsic features of intensive ponds:
Highly mixed, Fully aerated.
Identical to bio-technological reactors.
Optimal conditions for microbial activity

Characteristics of water: 1

- **1. Generous supply of feed to microbes**
- A. Assume **30 kg fish/m3**, 150 g feed/day

~ 75 g C

- B. ~ 50% released to the water ~ 38 g/m3* day
- C. On a steady state basis, with $\varepsilon = 50\%$, daily added microbial biomass carbon = 19g
- 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^{10}/ml**

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: <u>**10-20% of the organic matter degrade daily.**</u>

Conclusions:

BFT systems are actually bio-technological plants

The nitrogen syndrome

- Fish use just about 25% of feed nitrogen. The rest excreted. **4 kg of feed protein are needed to produce 1 kg fish protein!!**
- 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 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

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.**
- **Normally, there is more than enough nitrogen for new cell production.**

$$\Delta C = CO2 + \Delta Ccell$$

$$\Delta Ccell + NH4 \; -> \text{Microbial protein}$$

Inorganic nitrogen control is achievable and predictable

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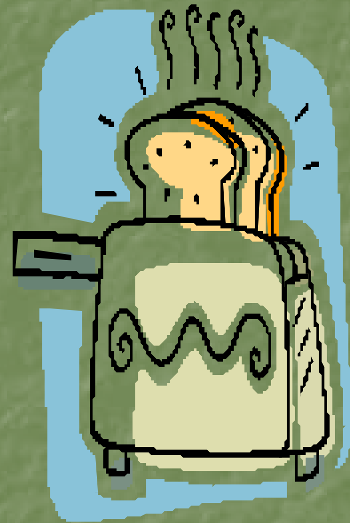
HOW MUCH CARBON IS NEEDED?

- $\Delta N = \Delta Cmic / (C/N)mic = \Delta CH \times \%C \times E / (C/N)mic$
- (%C = ca 0.5; E = 0.4-0.6 ; [0.5] / (C/N)mic =4-6 [4]
- $\Delta N = \Delta CH \times 0.05$
- $\Delta CH = 20\ \Delta N$
- **We have to add 20g carbohydrate (mollases, casawa etc.) to sequester 1 g ammonium nitrogen**

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**



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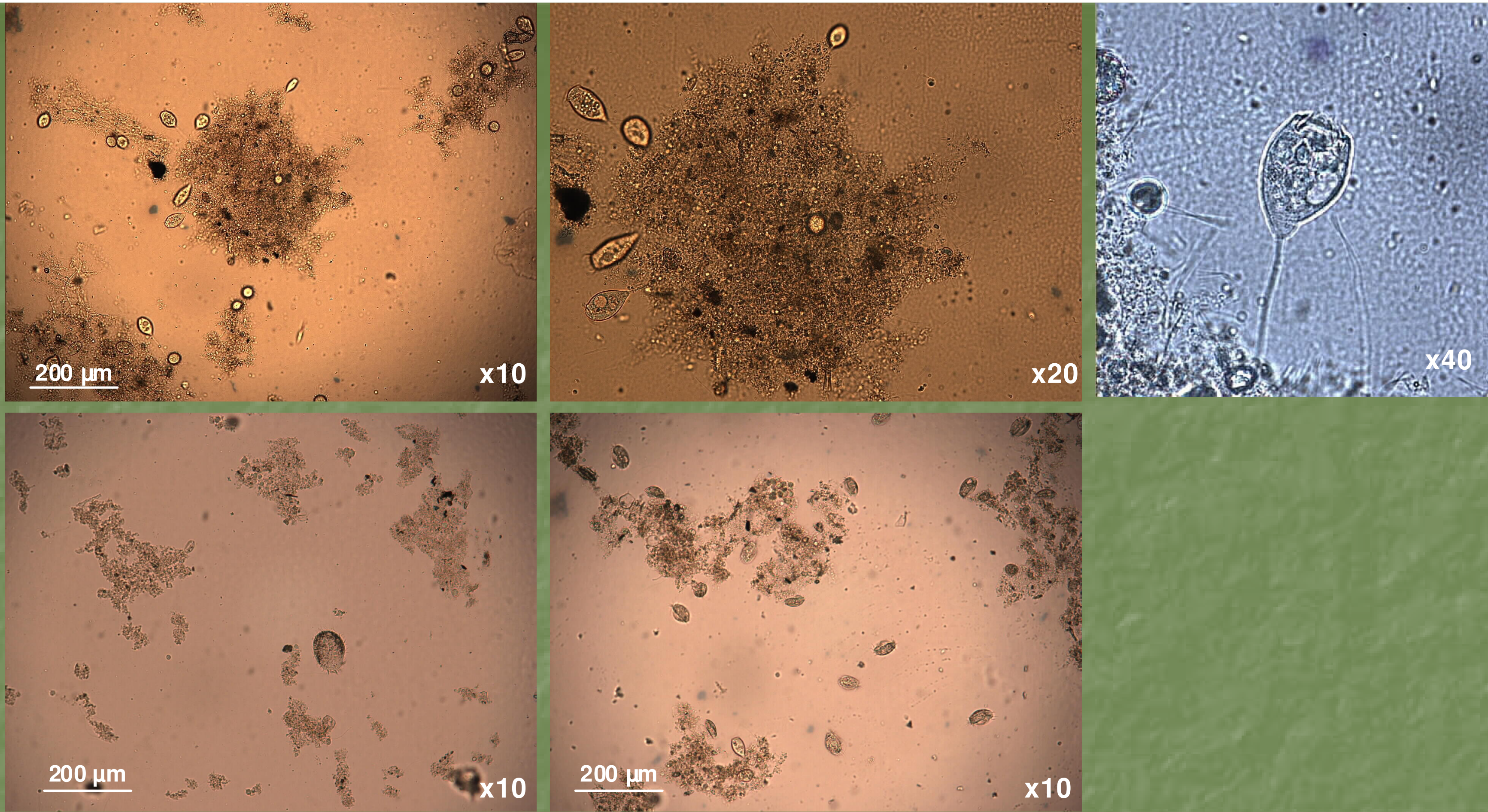

Bio flocs are made of bacteria, protozoa, etc. Typicaly their diameter is 0.1-2 mm.

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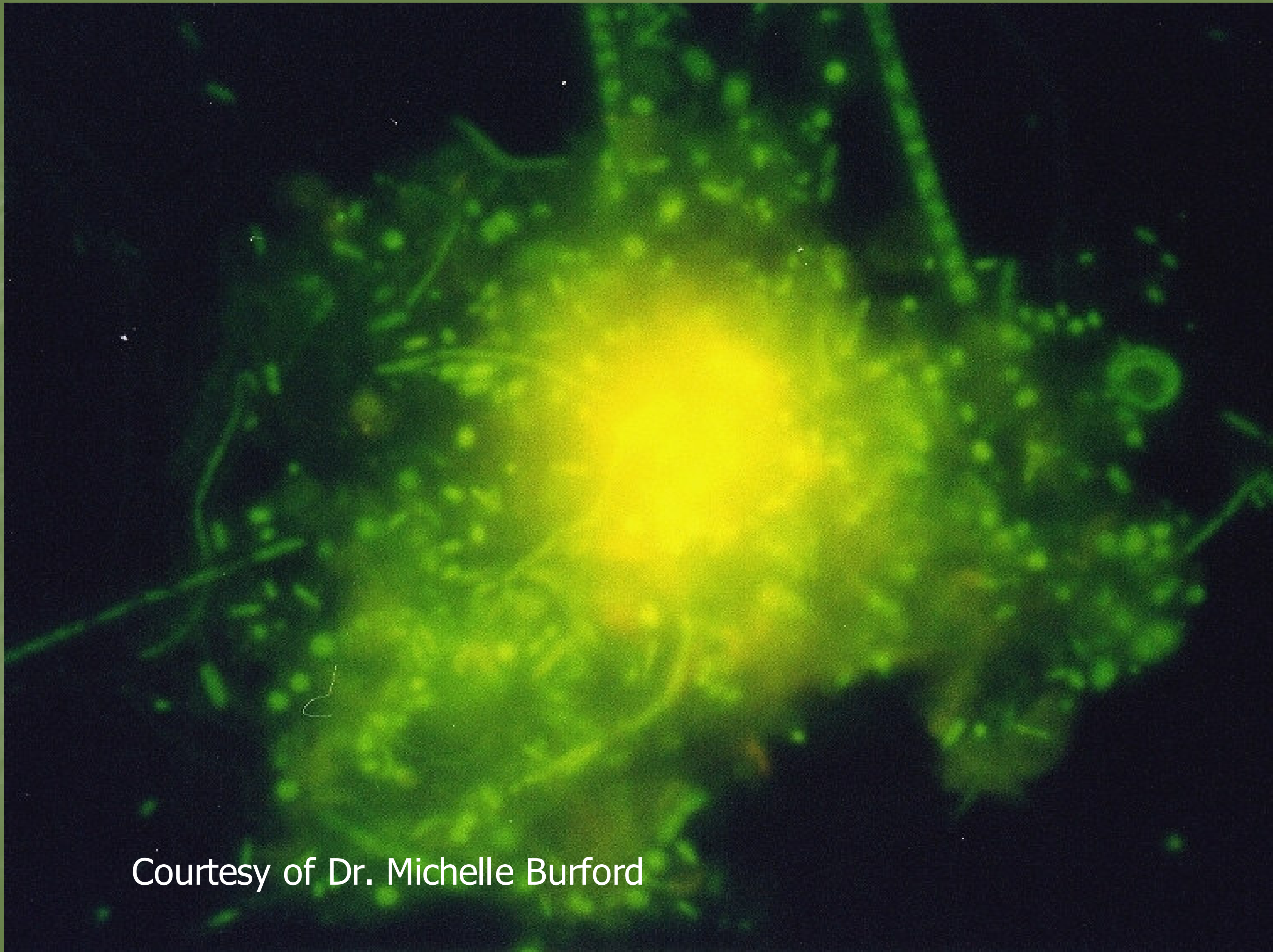

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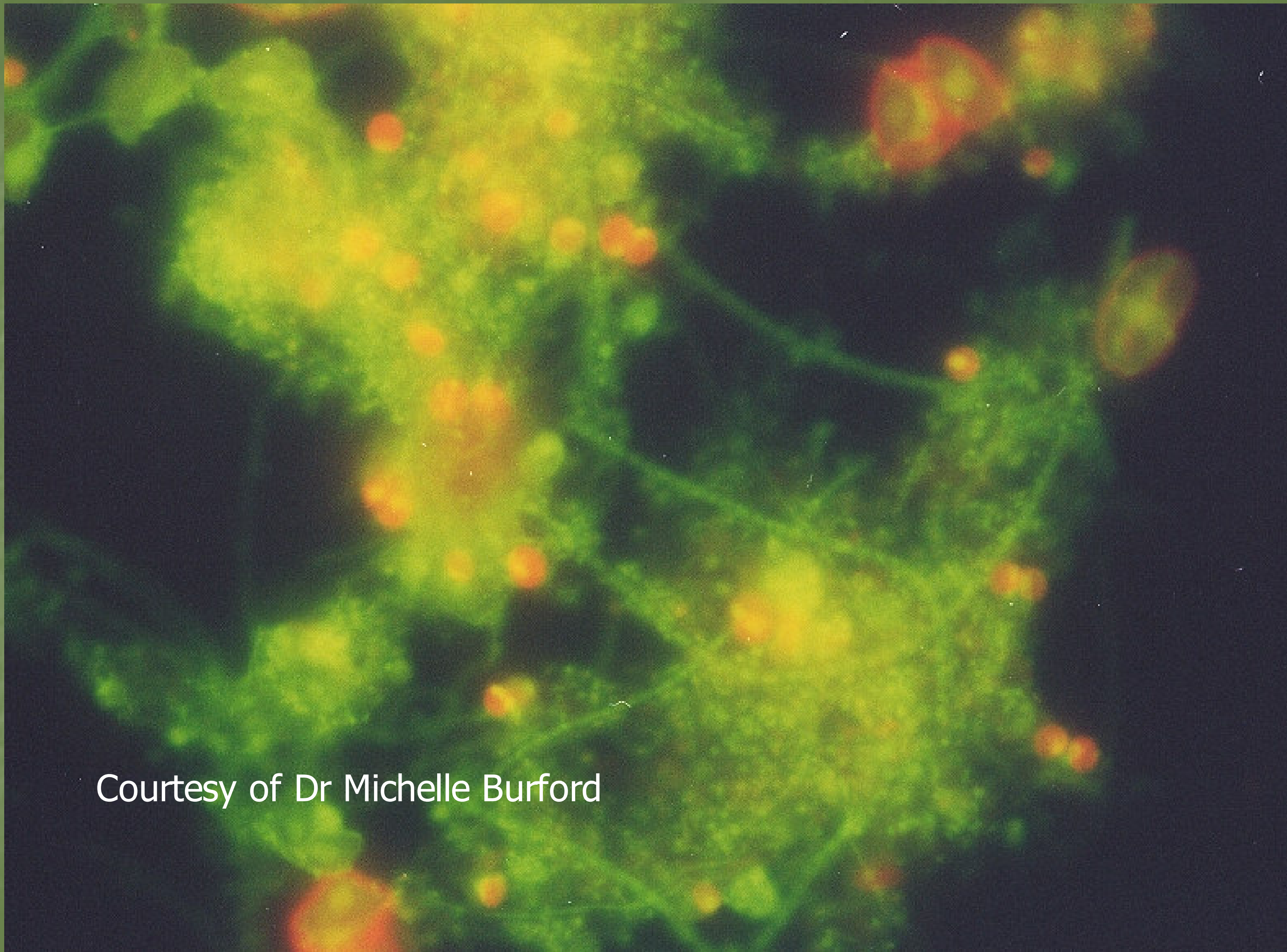
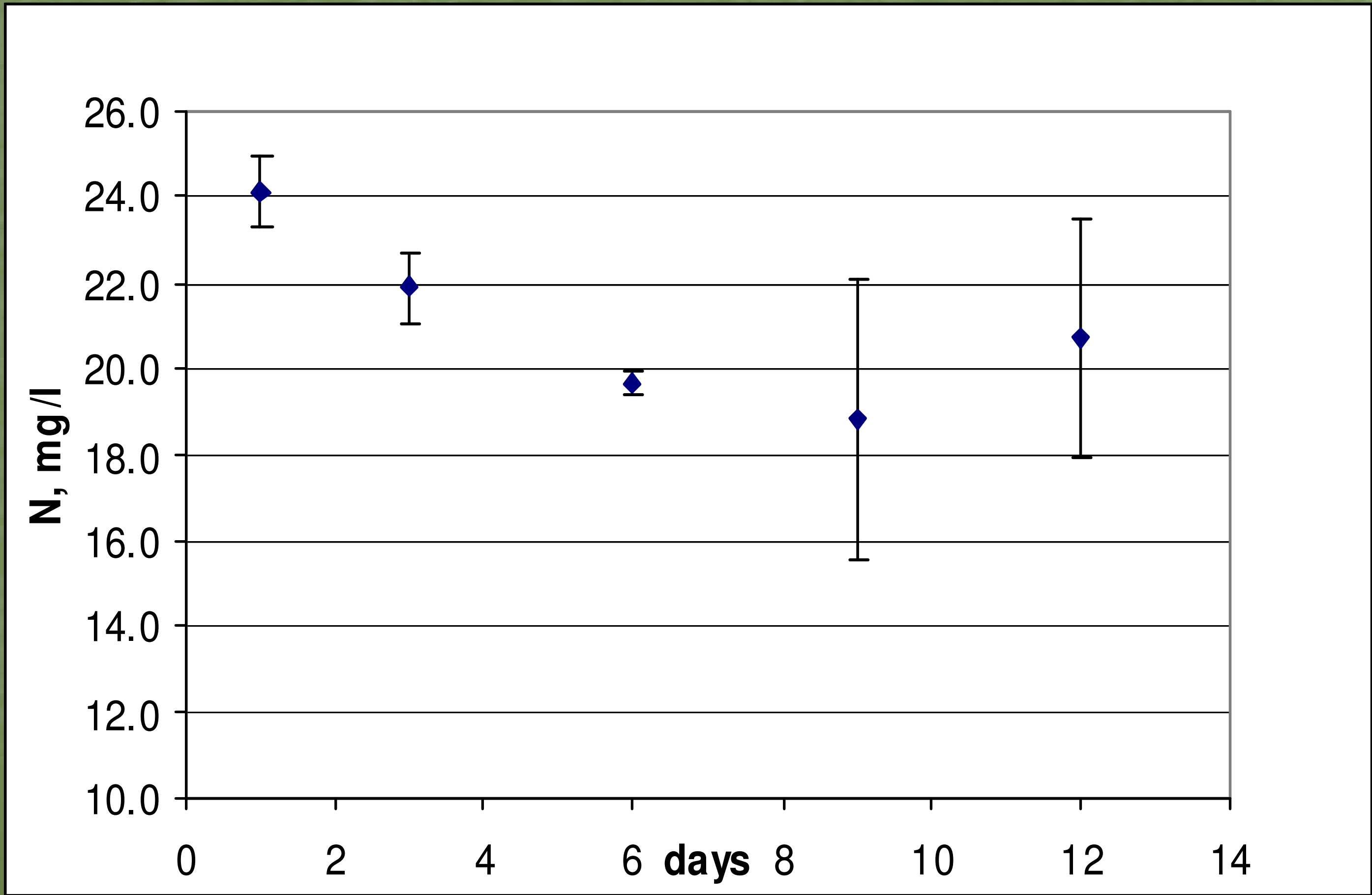

Courtesy of Dr Michelle Burford

Some preliminary figures:

Each cm3 of floc plug contain 10-30 mg dry matter

Experimental Results (Avnimelech, 2007)
Tilapia in tanks. For 6 days no addition of feed
The only source of feed is the bio flocs

Decrease of N in suspended matter with time



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Daily decrease of TSS, FV, suspended carbon and nitrogen, during the no – feed period.
Changes in equivalent suspended solids (SS) concentration (as dry weight) and daily uptake attributed to 1 kg fish

	TSS	Floc Volume	Carbon	Nitrogen
Daily measured change	20 mg/l	1.74 ml/l	6.61 mg/l	0.87 mg/l
Equivalent dry SS change (mg/l)	20	24.3	26.9	23.5
Daily uptake by fish as equivalent SS (g/kg fish)	8.91	10.79	11.03	9.66 **(6.2 g, calculated from 15N Uptake**)

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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%.**

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Tilapia fed with cellulose (Avnimelech et al., 1989)

	δ13C, /00
Feed Materials	
30% protein pellets	**-14.8**
20% " "	**-13.8**
Cellulose powder	**-23.5**
Fish (Muscle) fed for 57 days with:	
30% protein pellets	**-20.5**
20% " "	**-20.8**
20% prot pellets (50% ration)	
+ Cellulose + $(NH_4)_2SO_4$	**-23.0**

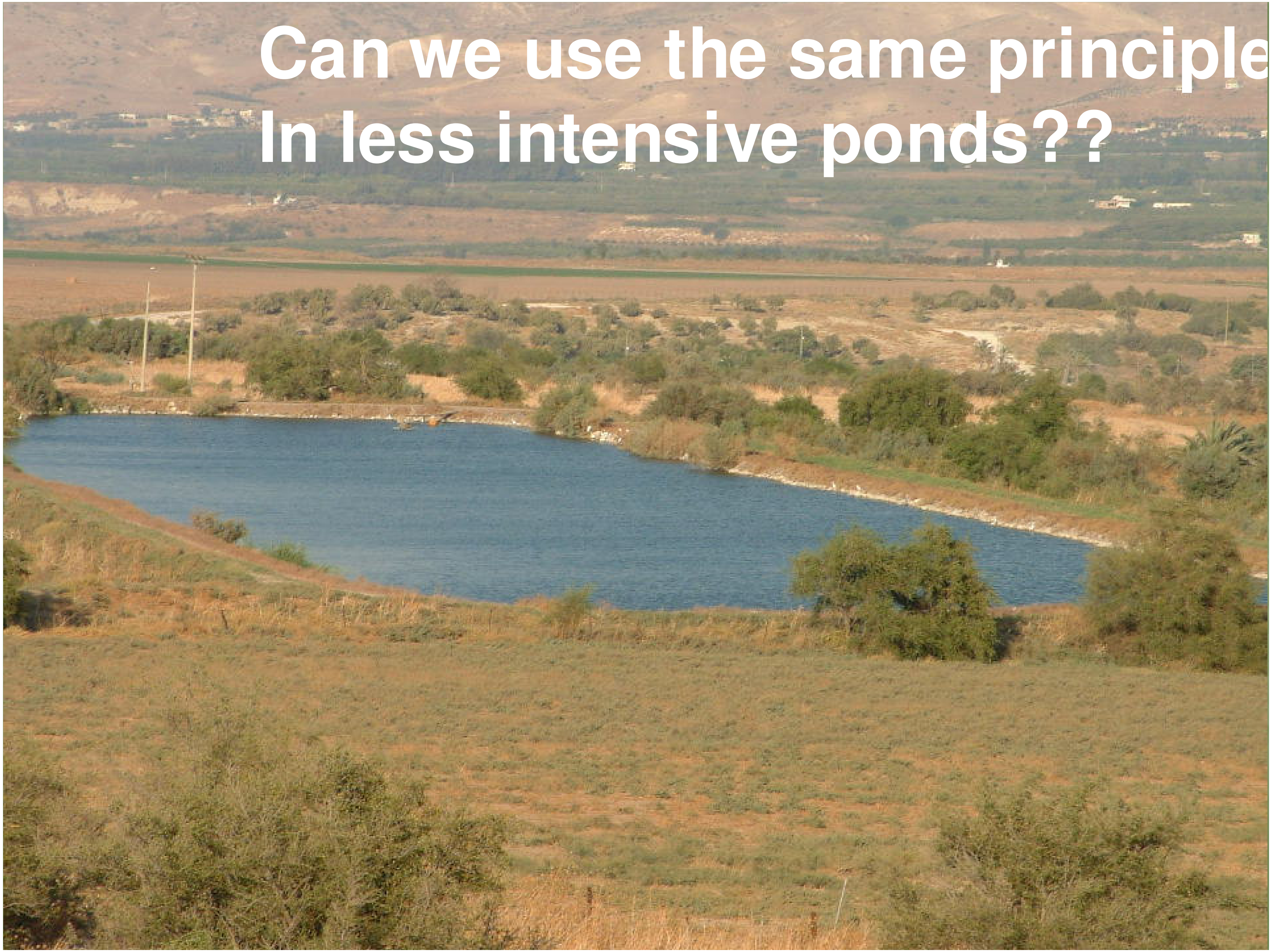
Protein Recycling

- **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!!

Expt. # 1 51 days	30% Protein	*20% Protein*
FEED C/N	11.1	*16.6*
Daily Gain (%)	1.59[a]	*2.0[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*


Can we use the same principle
In less intensive ponds??

- Very interesting work conducted recently in Cochin India by -

  Hari, Kurup, Varghese, Schrama & Verdegem (2004)

Indicated that it is possible

	P25 + CH	P 40
FCR	**1.6**	**2.2**
N Retention, %	**45**	**20**
Net yield, g/m^2	**64**	**45**
Gross Return (Rs/ha)	**193,275**	**125,406**
Production costs (Rs/ha)	**83,202**	**103,420**
Net Profit (Rs/ha)	**110,073**	**21,986**

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- Intensive ponds are fully mixed and aerated systems. This is not the case in conventional extensive aquaculture.
- In these ponds, organic substrates accumulate in the bottom of the pond, a zone characterized by poor aeration.
- It seems that in order to practice BFT in expensive ponds, pond bottom has to be well treated and aerobic.
- Another alternative is to deploy natural (periphyton) or synthetic vertical substrates, where organic residues adsorbed are aerobically metabolized.

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.**

How to do it??

- 2. Enough aeration to maintain oxygen above 4-5 mg/l.
- 1. 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!!**

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.

How to do it (3)

- 7. Minimize water exchange.
- 8. If sludge accumulate, drain sludge out or dry/clean between seasons.

- Every farm is some what different. Learn from yours and others experience.

Part 2

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

Economical data

- No comprehensive analysis. Some indications:
- Feed to grow 1 kg tilapia, $0.56 in BFT as compared with $0.85 in conventional pond. Similar data for shrimp in Belize Aquaculture.
- In a commercial tilapia farm in California, the change to ASP saves $0.40/kg fish
- Tacon et al. in OI estimated feed price to be lowered by 30%
- **It may be anticipated that overall feed cost reduction can reach almost 50% of feed cost in conventional systems.**

Anticipated future developments

How will BFT ponds look following another 10 years period ?

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Microbiology

- **On initiating and developing BFT systems, the overall microbial activity was considered, but very little was known as to the details of the relevant microbes and microbial ecology. Work done by Burford et al (2004) and By Tacon et al (2002) initiated the efforts to better understand and control the microbial processes.**
- **WE hope that work, as presented here by Verstraete is just the beginning of needed developments**

Flocs

- . McIntosh started with selection of bacteria that form flocs. It is anticipated that with the interest in the BFT ponds more studies will be made and more insight will be obtained. Specifically it is anticipated that more control
- of floc formation will be obtained, in line with similar work done in water treatment technology.

Feed Efficiency

- **Feeds and feeding of ASP systems is in its beginning. We need specially formulated feeds with lower protein. Ph.D. work done very recently (Panjaitan, 2004) demonstrated that the feed requirement in BFT shrimp systems is just about 70% of that needed in open systems where feed is not recycled and the non-eaten portion is wasted.**

Feed Cost

- **The lower feed quantity required and lower cost of feed due to lower protein and avoiding vitamin and minerals inclusion in the feed will raise profitability of using BFT systems.**

Turbidity Control

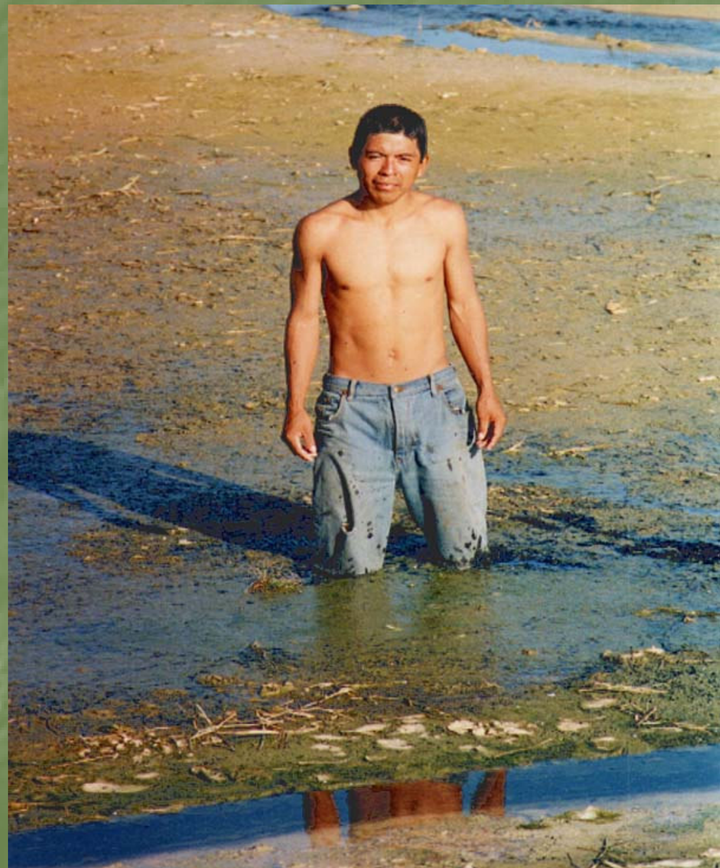
- **Turbidity can be controlled by mixing and through drainage of excessive suspended matter. Presently. We do not know what is the optimal level of suspended matter in the water. This may well be different for different species grown. It is rather easy to automatically control turbidity Ponds can be drained so as to maintain about constant turbidity.**

Aerators and pond structure

- **Efficient resuspension, mixing and draining of ponds call to the use of efficient aerators, ones that will be better adapted as compared to ones we have presently, and to pond structure that assist getting efficient mixing and drainability.**

Sludge disposal - reuse

- **There is an urgent need to either recycle or properly dispose of sludge. Among possible options is its reuse as an organic rich amendment to ponds or agricultural soils, as a base material for composting or as a material for construction, either as such or following sanitation and stabilization processes.**




Thanks for your attention
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