RACEWAY MANAGEMENT PART 2

Reference material for this lecture:Westers & Weeks
“Principle of Intensive Fish Culture” workshop.
Aquaculture Bioengineering Corp.

Some of the basics:

1. Gills take in oxygen and give off CO_2
2. Hemoglobin in blood is the oxygen carrier
3. Carbon Dioxide (CO_2) is a gas which can readily combine with water
4. Fish "pee" ammonia compounds (NH_4 and NH_3^+) these also combine with water
5. All gasses abide by the rule that high pressure will always seek out low pressure and try to equalize
6. pH is a measure of acidity – the HIGHER the number, the LESS acid a substance is. LOW pH means HIGH acidity.
7. Alkalinity is a measure of hardness, or how much Calcium is in the water. Calcium likes to combine with other elements and acts as a good "buffer"

Factors Limiting Production

- Oxygen
- Metabolic Wastes Produced by Fish during and after feeding
  - Ammonia Nitrogen
  - Carbon Dioxide

- Without fish in a raceway the water coming in goes out as clean as it entered. Adding fish and feed that the fish consume to gain energy results in waste excreted into the raceway in the form of feces, CO_2, and Ammonia combined with uneaten feed, deteriorates water quality.
- The main factor responsible for deteriorating the rearing environment of a raceway is **feed**. Not just as a waste product either.
- The main factor that limits fish production is **oxygen**.

Available Oxygen

- DOin – DOout = Available Oxygen
  In = 10mg/l – Out = 7mg/l the DO available for production = 3mg/l
- DOout for rearing salmonids in a non-recirculating system should not fall below 7mg/l.
- The more oxygen flow to a raceway the more fish it can support up to a certain point. Increased feed and excreted metabolic wastes combined with density will eventually become limiting for the rearing area regardless of flow.

Respiration

The problem with very high DO’s:

(>200% Super saturation)

1. Fish “pump” less water and this can interfere (reduce) CO_2 excretion – less water contact.
2. Fish reduce hemoglobin – reduction can create problems (e.g. removal of waste products)

Metabolic Rate as it relates to dissolved oxygen available

DO mg/l	100	200	300	400	500	1000
20(s)	15.6	30.6	46.8	63.0	1.30	2.60
16(s)	19.8	39.0	58.8	78.6	1.62	3.24
12	26.4	51.6	78.0	104.4	130	259
10	31.8	61.8	93.6	126	156	312
8	40.2	77.4	117	157	194	389

l/h of water fish must pump across their gills based on an uptake efficiency of 32% at various DO levels and MR's.

Carbon Dioxide

- For every mg/l of oxygen consumed by fish 1.37gms of CO_2 is excreted into the water.
- Through respiration CO_2 is released into the water giving up hydrogen ions thereby reducing the pH.
- CO_2 in reaction with water yields four types of carbon compounds.
  - H_2CO_3 = Carbonic Acid
  - HCO_3 = Bicarbonate ion
  - CO_3 = Carbonate ion
  - CO_2 = Carbon Dioxide gas or free CO_2

Carbon Dioxide gas is harmful to fish

Carbon Dioxide

- Can combine with water to form H2CO3 or carbonic acid → can lower pH
- Additional CO2 gas in water increases the pressure on the water side – this means it's harder for the fish to get rid of what's inside
- If fish can't get rid of CO2, it builds up inside them.
  - Lowers blood pH
  - Reduces ability of hemoglobin to deliver oxygen

A Dynamic Equilibrium

Free CO_2 (Gaseous) Is Toxic

How much free CO_2?   Table I-3

May have to control CO_2:

1. De-gas
2. Chemical (pH control)

Table 3 Approximate Values for free CO_2 (In mg/l)

pH	Alkalinity in mg/l (15° C)				
	50	100	150	200	250
6.4	46	92	138	184	230
6.6	29	58	87	116	145
6.8	18	37	55	73	92
7.0	12	23	35	46	58
7.2	7	15	22	29	36
7.4	5	9	14	18	23
7.6	3	6	9	12	15
7.8	2	4	6	7	9
8.0	1	2	3	5	6
8.2	.75	1.5	2.3	3.0	3.7

For practical purposes, CO_2 concentration are negligible above pH 8.4.

Carbon Dioxide – some fundamental facts

- CO_2 can build up in the blood of a fish especially if the rearing water has a high content of the gas such as a closed system that is not properly stripping the excess CO_2.
- CO_2 can build up in the blood of a fish *even in a highly oxygenated environment.*
- CO_2 buildup can be a limiting factor to fish production especially in recirculating aquaculture systems.

- Through respiration by the fish CO_2 is released into the water giving up hydrogen ions thereby reducing the pH.
- CO_2 can increase in the fish's bloodstream reducing pH
  - In a highly oxygenated environment the fish does not have to move much water across it gills to get oxygen, therefore less CO_2 is removed from the bloodstream.
  - If the rearing environment has a high concentration of CO_2 the simple process of osmosis can make it difficult for the fish to expel the gas.
- Once again, CO2 buildup in the bloodstream lowers blood pH and makes it difficult for the fish to bind oxygen.

Ammonia Nitrogen

- 60 – 90% of ammonia produced by fish is excreted through the gills, it requires less energy than forming urea.
- Meters used to measure ammonia only sense total ammonia. Ammonia excreted into the water ionizes into NH_4 and unionized NH_3 which is toxic to fish.
- There are tables to calculate what portion of the total ammonia nitrogen measured is the toxic form (NH_3) with known temperature and pH.
- One full increase in pH creates a ten fold increase in harmful NH_3
- In flow through systems with low pH and hardness, Ammonia is not a factor limiting production.

Ammonia Meter Kit

This meter kit measures total ammonia directly in ppm or mg/l. With its pH probe and conversion chart, you will quickly know that all-important un-ionized ammonia concentration. The kit includes a pH Plus Direct meter (**LM1936**), temperature probe, pH probe, ammonia probe, buffer solutions, case, 9V battery and complete instructions. Replacement ammonia reagents and probes can be found under ion selective electrodes. One-year warranty on meter and probe.

Ammonia levels as they relate to temperature and pH

Table 1. Percent of total ammonia that will be in the toxic form over the range of pH and temperature listed.

	Water temperature (°C)			
pH	5	10	15	20
6.0	0.01	0.02	0.03	0.04
6.2	0.02	0.03	0.04	0.06
6.4	0.03	0.05	0.07	0.10
6.6	0.05	0.07	0.11	0.16
6.8	0.08	0.12	0.17	0.25
7.0	0.13	0.18	0.27	0.40
7.2	0.20	0.29	0.43	0.63
7.4	0.32	0.47	0.69	1.0
7.6	0.50	0.74	1.08	1.60
7.8	0.79	1.16	1.71	2.45
8.0	1.24	1.83	2.68	3.83
8.2	1.96	2.87	4.18	5.93
8.4	3.07	4.47	6.47	9.09
8.6	4.78	6.90	9.88	13.68
8.8	7.36	10.51	14.80	20.07
9.0	11.18	15.70	21.59	28.47

<u>SOURCE:</u> G.A. Wedemeyer, 1996. Physiology of Fish in Intensive Culture. pp 232
Chapman and Hall, New York (**HIGHLY RECOMMENDED RESOURCE!**)

Now that we have the simple stuff out of the way………………

Raceway Waste Management

- The aquatic environment a fish lives in provides everything it needs to survive and grow.
- Food and oxygen are obtained from the same water the fish excretes metabolic waste into.
- Maintaining a healthy rearing environment can be a challenge essential to producing healthy smolts.
- The unique environment the fish lives in combined with other factors that exert negative pressures can lead to stress and disease.

Production Theory

The theory of production of intensive aquaculture systems is based on <u>feed</u>.

Feed input

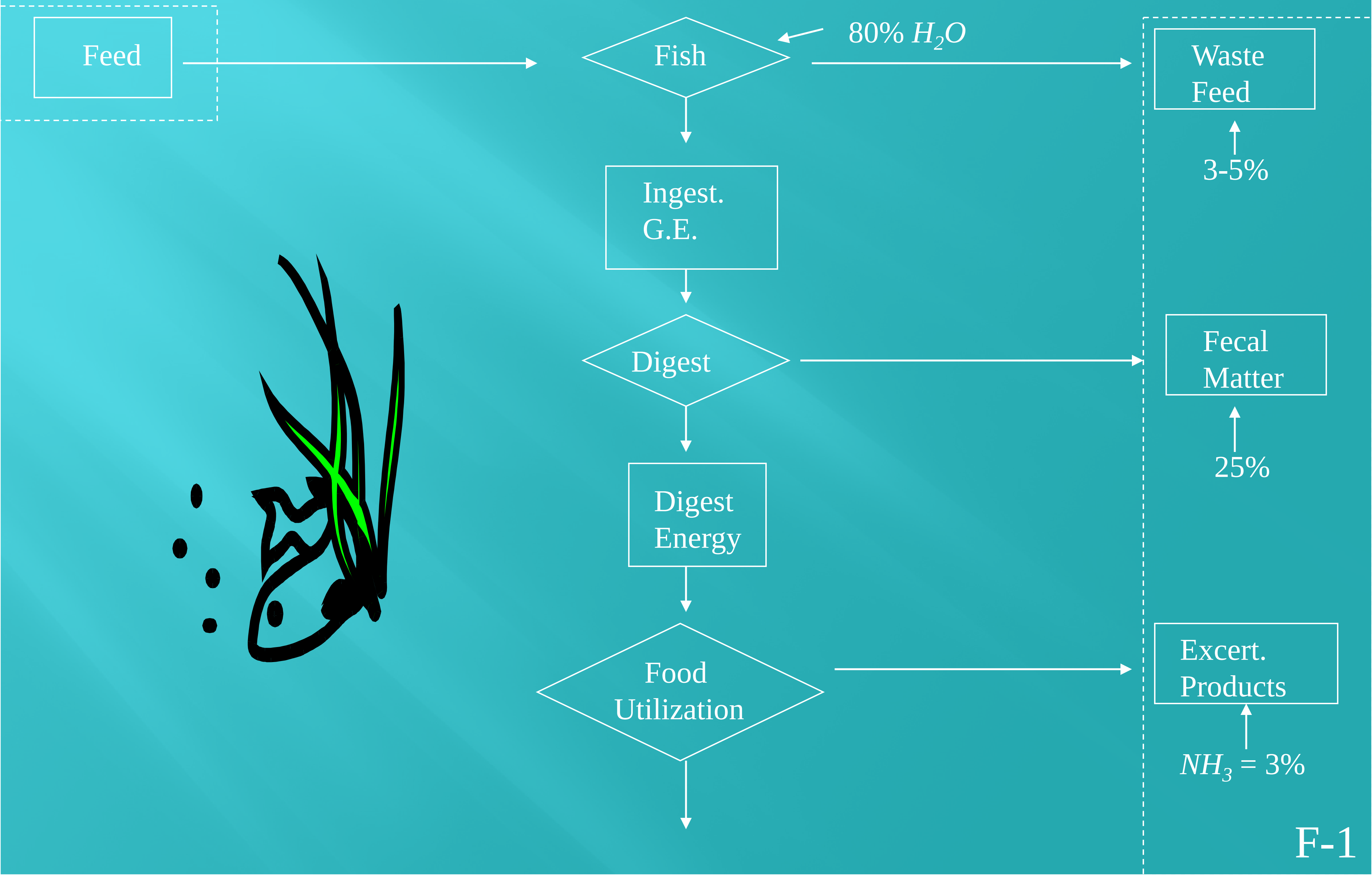
↓

Growth and production

↓

O_2 consumption & waste build up to fish tolerance levels

Energy In; Lost; Used; Stored.



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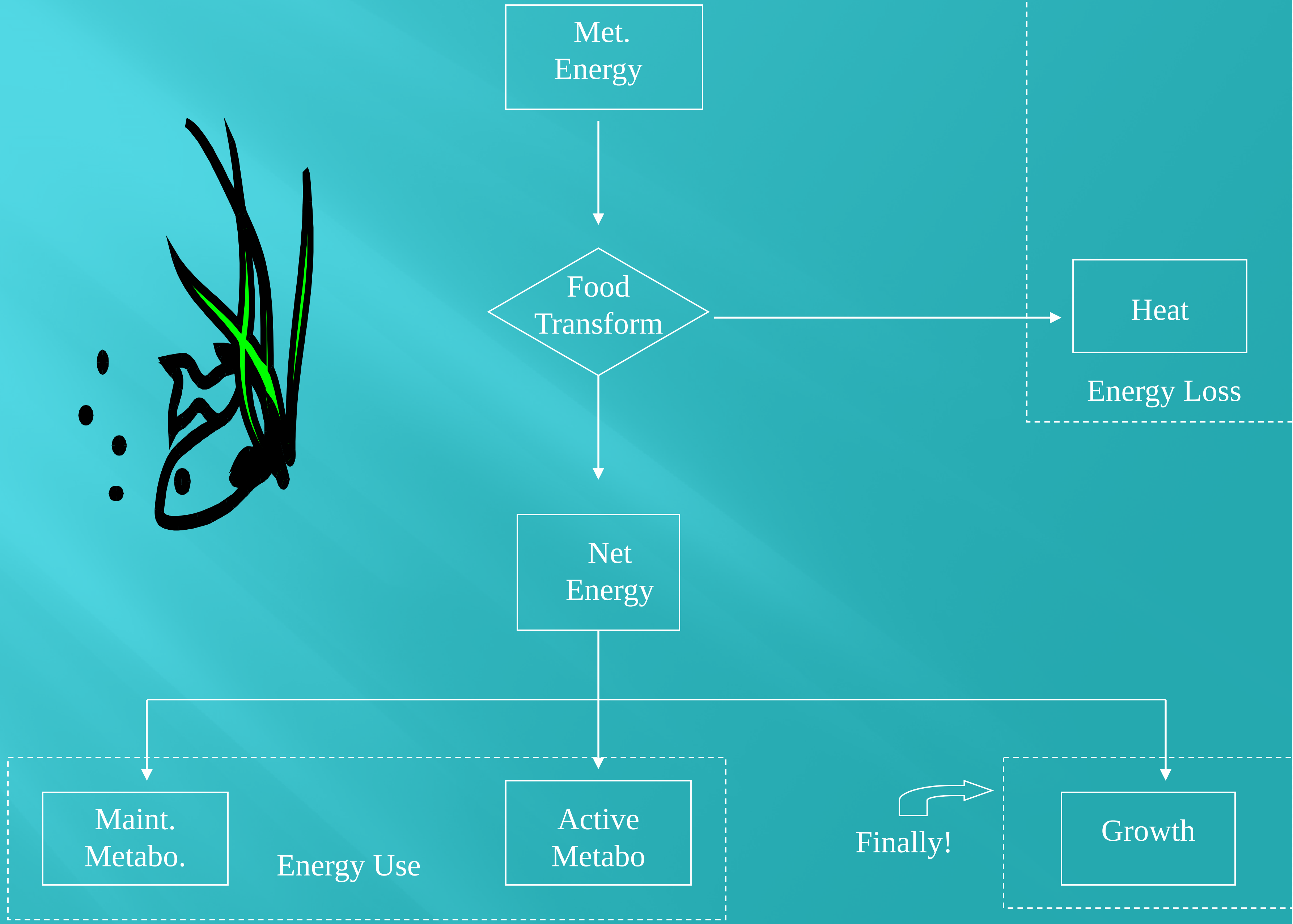


Flow diagram of Fish Bioenergetics modified after Ernst (2000)

Establishing Loading Values

Dissolved Oxygen (DO) First limiting carrying capacity factor.

Demand for oxygen best expressed in terms of feed! (OF)

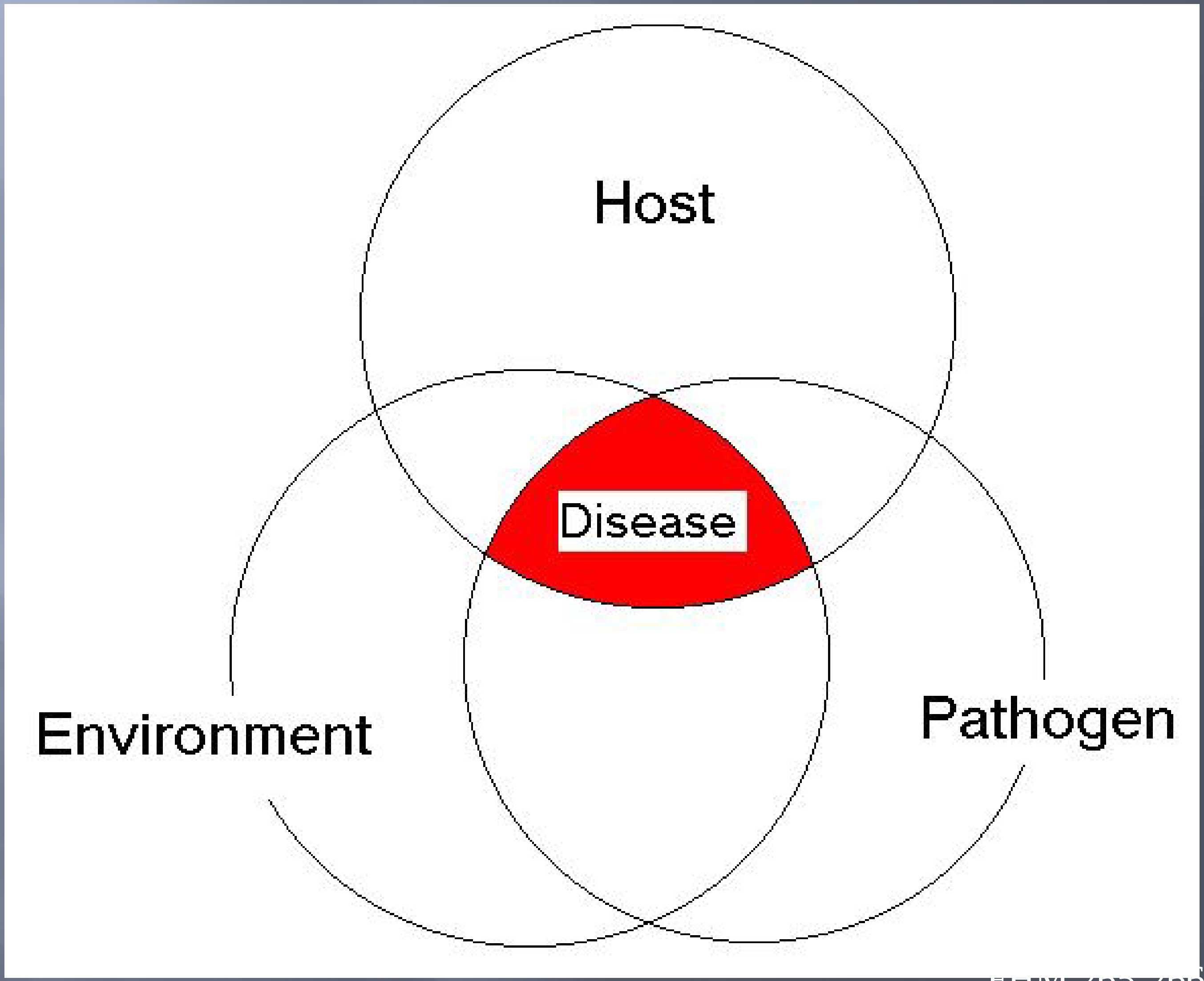
OF = Gram O_2 per kg feed

Per kg: 200 to 250g

Other factors affecting production levels

- Negative pressures such as
  - Gas supersaturation
  - Poor water quality
  - Crowding
  - Pathogens
  - Inept fish culturists
- Providing a stress free healthy rearing environment will minimize disease and enable you to meet production goals.

Stress in the presence of pathogens & poor water quality will often lead to disease



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- Good management by providing
  - High water quality
  - Optimum rearing densities
  - Quality feed

Will minimize negative pressures on fish thereby reducing stress and the likelihood of an *epizootic* (disease outbreak).

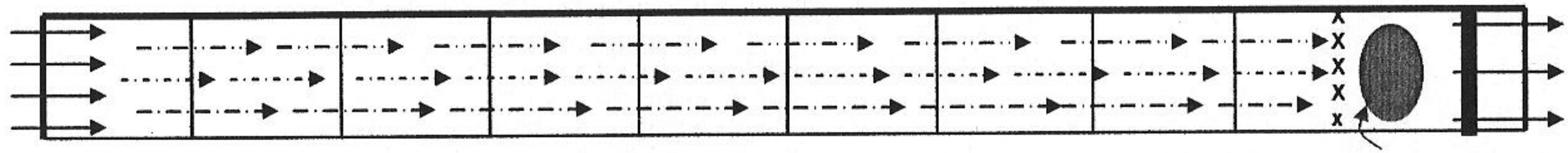
Waste Management continued

- Creating a healthy rearing environment is a matter of good water quality with adequate flow.
- Most horizontal raceways are essentially settling basins with typical flow velocities in the range of 1-3cm/s.
- Low velocities do not enable the raceway to self clean. Self cleaning raceways require a velocity of 10-20cm/s.
- Suspended solids in raceways are elevated due to
  - Uneaten Feed
  - Fecal Material
  - Silt, sand and organics in influent water supply

Typical Raceway Dimensions

(Plug-Flow Rearing Unit)

A.



Michigan 100' x 10' x 2.2' with Baffles

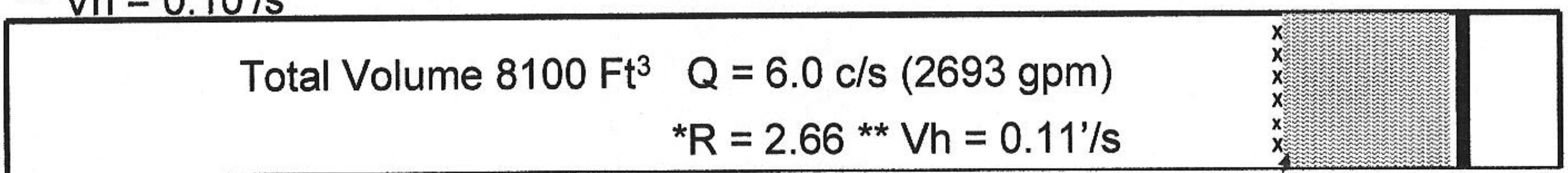
QZ = 100 Ft²

Total Volume 220 Ft³

Baffles Move Solids

*R = 3.6 Q = 990 GPM

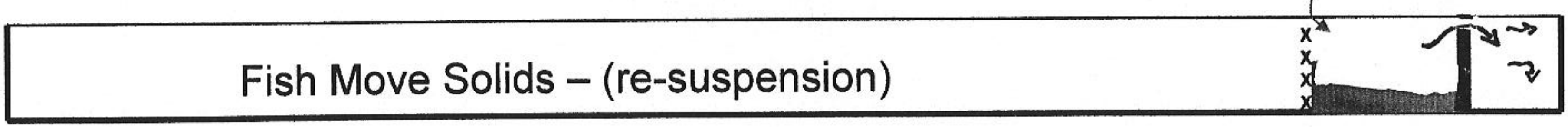
** Vh = 0.10'/s



B.

"Idaho" 150' x 18' x 30'

QZ = 360 Ft²

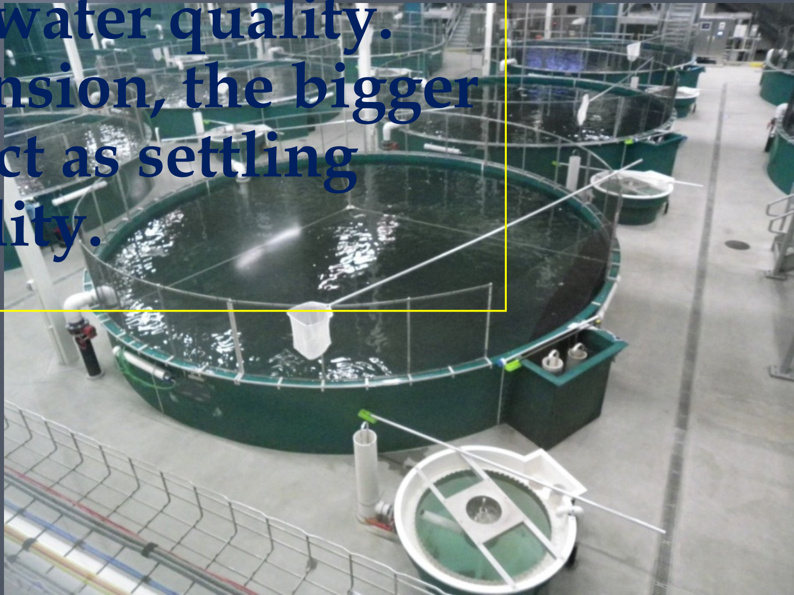


*R value - R = ⟶ $\frac{Q \times 8}{RV}$

**Vh value – Vh = $\frac{I \times R}{3600}$

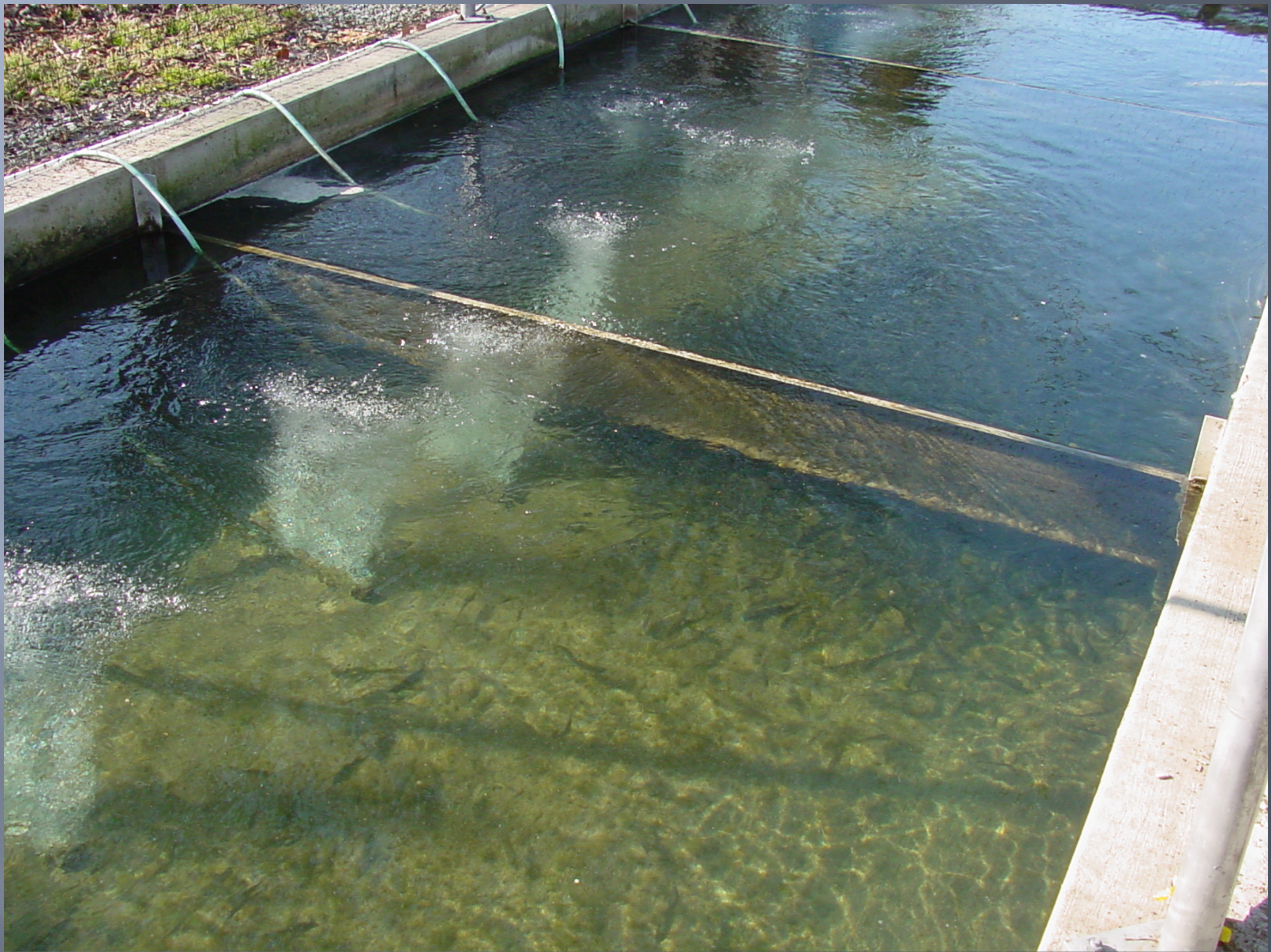
H.W. '02

- The presence of fish in the raceway contribute to degrading water quality by excreting metabolic waste and breaking down solids by agitation through swimming. "Fish – we could get so much more done around here if we didn't have 'em"
- Since most raceways function as settling basins, solids on the bottom disturbed by fish activity break down into smaller particles.
- Smaller particles remain in suspension longer and become gill irritants.
- **Smaller particles also leach nutrients into the water at faster rates deteriorating water quality. The smaller the particles in suspension, the bigger the raceway would have to be to act as settling basin to maintain good water quality.**



Managing the Problem

- Unfortunately most raceways have not been designed with self cleaning or water quality as the driving design force.
- Most have have been designed to accommodate a production number and to fit a footprint.
- The ideal design would have a 10:1 length to width ratio with a velocity of 10-20cm/s.
- Raceways can become self cleaning by installing baffles. The distance between the baffles should be equal to the width of the raceway.
- In order for baffles to be effective the velocity in the raceway needs to be a minimum of 3cm/s.
- Baffles act as solids barriers forcing the water through a small gap between the bottom of the baffle and raceway floor. Forcing the flow through this gap increases the velocity and moves solids to tail end of the raceway.
- The end of the raceway should have a quiescent zone (QZ) equivalent to 15% of the volume to act as settling basin for solids removal.



Remember our old friends?

Loading

Rearing Density

Turnover Rate

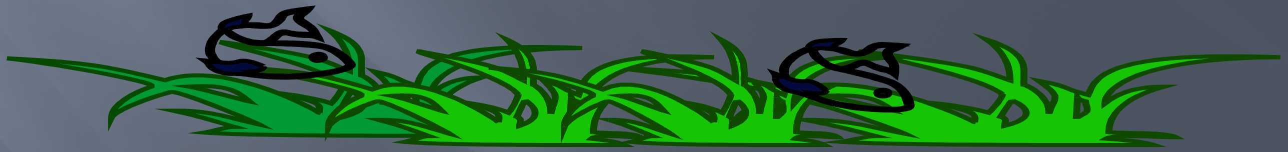
Like it or not, we need to know about the various factors that affect the fish in our care

Relationships Ld; D; R

$$Ld = \frac{D \times 0.06}{R}; \quad D = \frac{Ld \times R}{0.06}; \quad R = \frac{D \times 0.06}{Ld}$$

R: Water turnover rates in #/hr

Example: R = 2 Every 30 minutes.



Loading (Ld) And Density

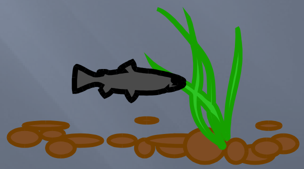
Loading (Ld): Capacity per unit of Flow (Q)

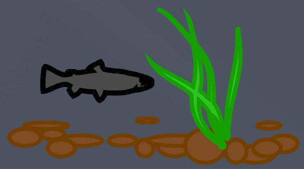
As: Ld = kg/lpm lb/gpm

Density (D): Capacity per unit of Volume (RV)

As: D = kg/m^3 lb/ft^3

DO NOT USE THE TERM “LOADING DENSITY”





Velocity in Linear Raceways – a relationship of flow and volume of the rearing container

The 4th stooge - velocity

$$V = \frac{Lm \times R}{36}$$

Example; WLH R1 (30.5 x 1.3)/36 = 1.1cm/s

$$36 = \frac{\text{seconds/hr}}{100}$$

Sample Problems

- Raceway = L 25m W=3m d= 1m
  - Density D= 22kg/m3

- RV = ?
- How much flow (Q) is required for an R of 1?
- If Q = 3,000lpm, what is the turnover rate (R)?
- If RV = 75m3 R=2.4 what is Q?
- What is R if D = 22kg/m3 and Ld =1.5kg/lpm?
- What is Ld if R = 2?