Environmental monitoring in fish experiments

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Agenda

- Basic needs
- Remember your photobiology
- Water Quality – monitoring
- Gills and DGT
- Estuarine mixing zones
- Some high tech
- Recommended parameters

Basic need – for a fish

- Breathe
- Swim
- Eat
- Run / Hide
- To keep homeostasis

Basic need for a researcher

- Valid experimental conditions
  - # n high
  - Individually measured parameters - relevance for a herd (group of farmed fish)
- Manipulate the environment – and to monitor the response of the fish / fish group
- Keep his budget

Theory vs Practical life

- Science
  - Small units
  - Controlled environment
  - Relevance?

- Aquaculture
  - Large units
  - Dynamic environment
  - Lack off scientific data in a relevant scale

Most fish are – environmentally timed
“a combination of endogen and exogenous biological rhythms”

- Some commercial relevant fishes changes physiological status up to three times during their life span
  - EX. Salmon
    - *Born with limited hyp-osomtic regulatory capacity*
    - *Young fish develop excellent hyp-osmotic regulatory capacity and changes environment*
    - *Mature fish returns from hyper-osmotic environment to hyp-osmotic environment at the latest stages of their life*
    - *Endogenous hormonal rhythms - Controlled by light and modulated by temperature*

Water Quality - a useful definition

- Water quality - fish
  - My definition pr 21.05.05 .

    "Water quality is the <u>expression</u> and <u>consequence</u> of all physical and chemical characteristic of the water that is individually or comprehensive relevant for the fish"

The NIVA VK –package for water quality monitoring

Raw water

Analytical parameters	Unit	
Acidity, pH		
Conductivity	mS/m	
Alkalinity	mmol/l	
Turbidity at/ 860 nm	FNU	
Nitrogen, total	µg/l	N
Nitrate	µg/l	N
Carbon, organics (TOC)	mg/l	C
Chloride	mg/l	Cl
Sulphate	mg/l	S
Aluminium, total	µg/l	Al
Aluminium, reactive	µg/l	Al
Aluminium, non labile	µg/l	Al
Calcium	mg/l	Ca
Iron	µg/l	Fe
Potassium	mg/l	K
Magnesium	mg/l	Mg
Sodium	mg/l	Na
Silicate	mg/l	Si

Production water

Alternative to raw water

When treatment:

pH, alkalinity,
Calcium, silicate
salinity/chloride

Tank water

Always complete raw water and “treatment parameters”:

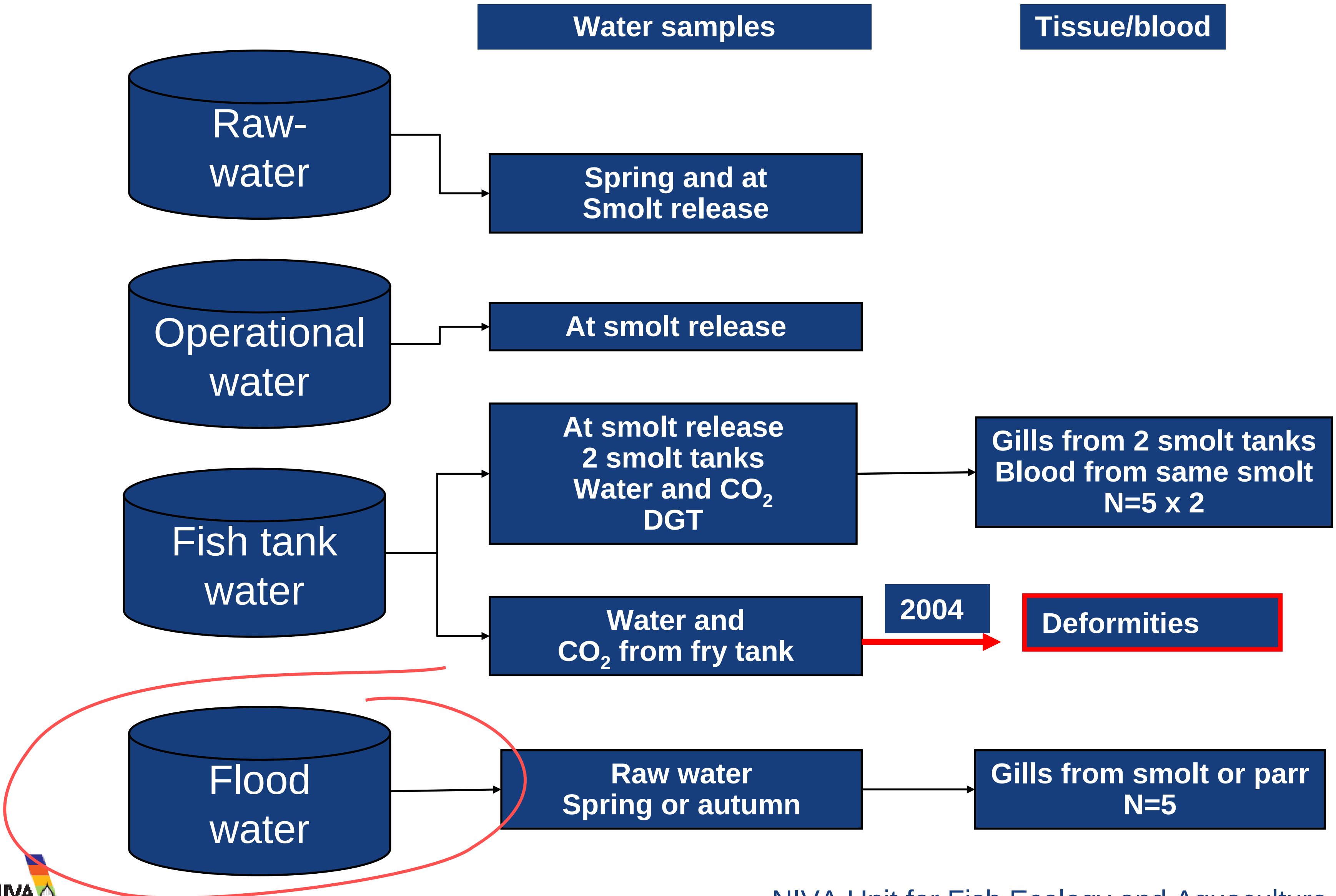
pH, alkalinity

NH_4

CO_2

NOK 1600 - 4500 per package

Sampling WQ-2003

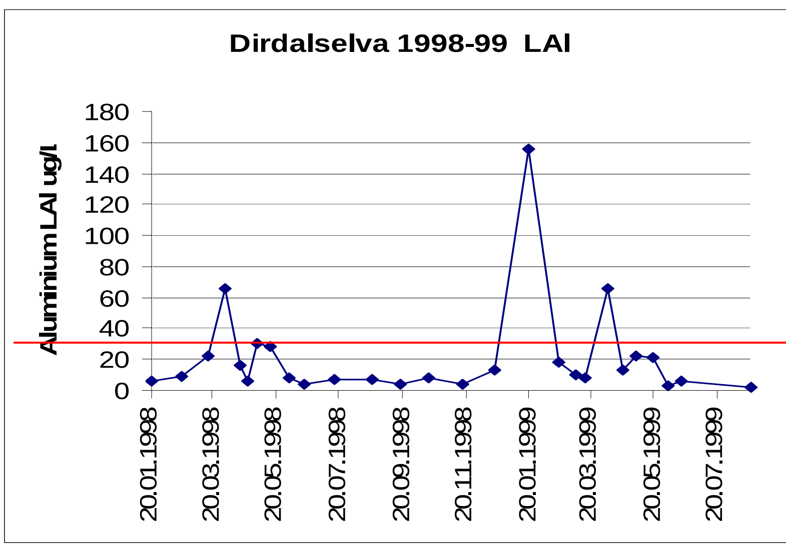


Ex – water quality measurements
from the NIVA WQ-program in Norwegian hatcheries (since 1999)

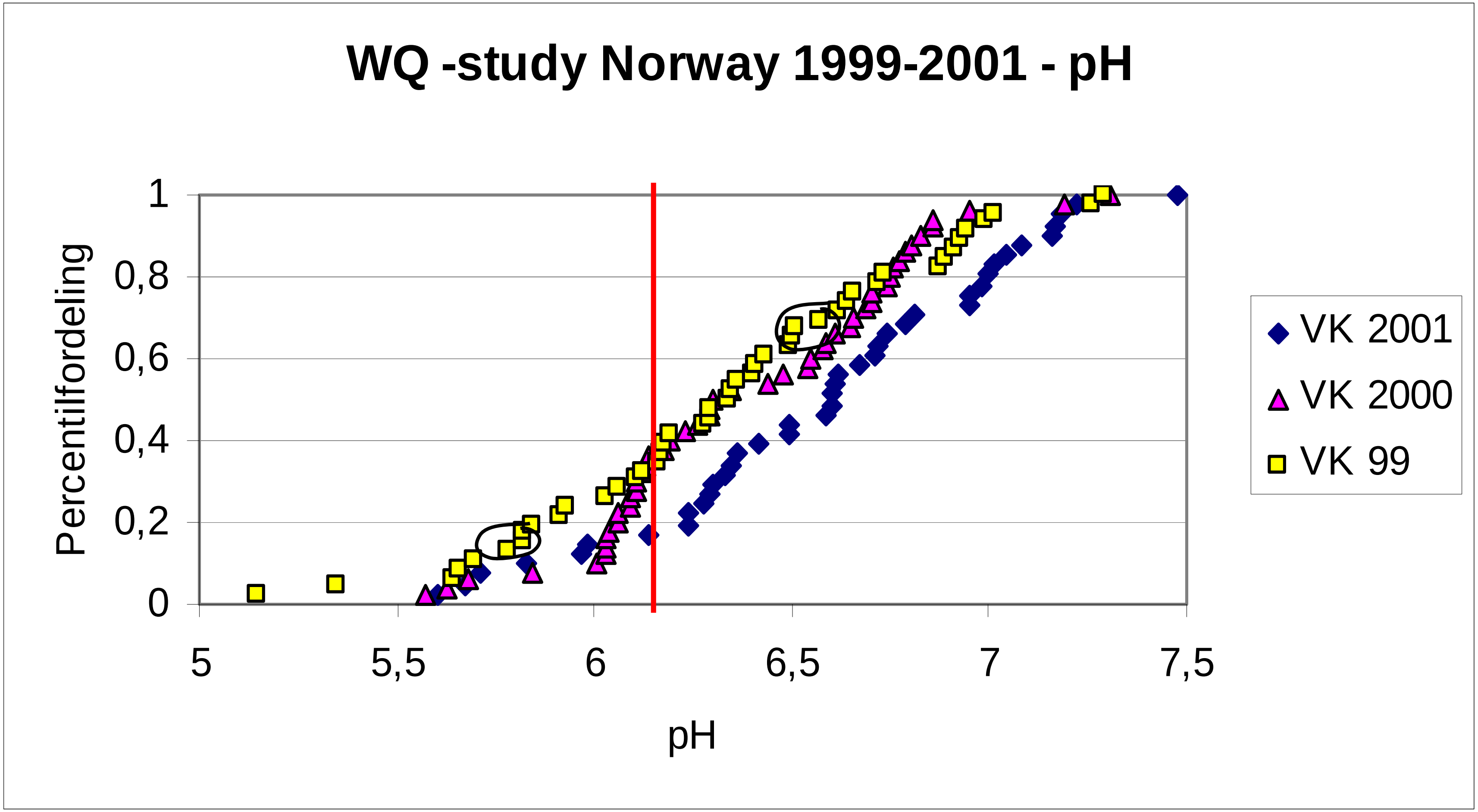
Prøve Analysevariabel	Enhet	Raw W. 11/4	Flood 23/5	Raw W 17/8	Operat. Water 17/8	Tank 43 17/8	Tank 23 17/8
Surhetsgrad		6,18	6,06	6,58	6,59	6,62	6,64
Ledningsevne	mS/m	4,78	4,37	2,14	2,13	4,01	3,92
Alkalitet	mmol/l	0,058	0,046	0,058	0,058	0,182	0,184
Alkalitet, korrigert*	mmol/l	0,027	0,015	0,027	0,027	0,150	0,152
Nitrogen	µg/l N	78	63	99		2810	3250
Nitrat og nitritt	µg/l N	16	15	4		4	5
Ammonium	µg/l N				<5	1280	1770
Ammoniakk* 13 °C	µg/l NH3 -N					1,25	1,81
Karbon, organisk	mg/l C	1,5	1,8	1,4	1,3	3,4	2,6
Klorid	mg/l	10,7	9,9	3,5	3,6	4,7	2,1
Sulfat	mg/l	2,3	1,9	1,5			
Silisium	mg/l SiO2				0,7		
Aluminium, total	µg/l	51	39	33	29	44	24
Aluminium, reaktivt	µg/l	23	<5	18	17	<5	10
Aluminium, ikke labil	µg/l	20	<5	16	15	<5	9
Aluminium, labil*	µg/l	3	0	2	2	0	1
Kalsium	mg/l	1,50	1,26	0.83	0.80	1.31	0.94
Jern	µg/l	52	13	40			
Fe/TOC		34,7	7,2	28,6			
Kalium	mg/l	0,32	0,29	0,14			
Magnesium	mg/l	0,82	0,71	0.33			
Natrium	mg/l	5,03	4,84	2.55	2.55	3.27	2.77
Natrium, sjøsaltkorr.*	µekv./l	-39,6	-28,5	26,4			
Karbondioksyd, fritt	mg/l C					5,3	7,4
Karbondioksyd, gass*	mgCO2/l					19,5	27,4
Karbondioksyd, teoretisk*	mgCO2/l					4,3	4,2
ANC*	µ ekv./l	18	19	53			
Turbiditet v/ 860 nm	FNU	0,32	0,40	0,28		8,02	4,82

The Quality of the raw-water vary

- Frequency
- Duration
- Levels
- Temperature
- Vulnerability due to life stage



pH – WQ 1999 – 2001
Great variations



Why cationic metals can bind to gills and cause toxicity

Water purification

Al^{3+}

Humics in drinking water
$R\text{-}COO^{n-}$

Phosphate in sewage
PO_4^{n-}

Gill surface (neg. charge)

Al^{3+}

Mucus on gills and skin
$R\text{-}COO^{n-}$

Phosphate in cell membrane
PO_4^{n-}

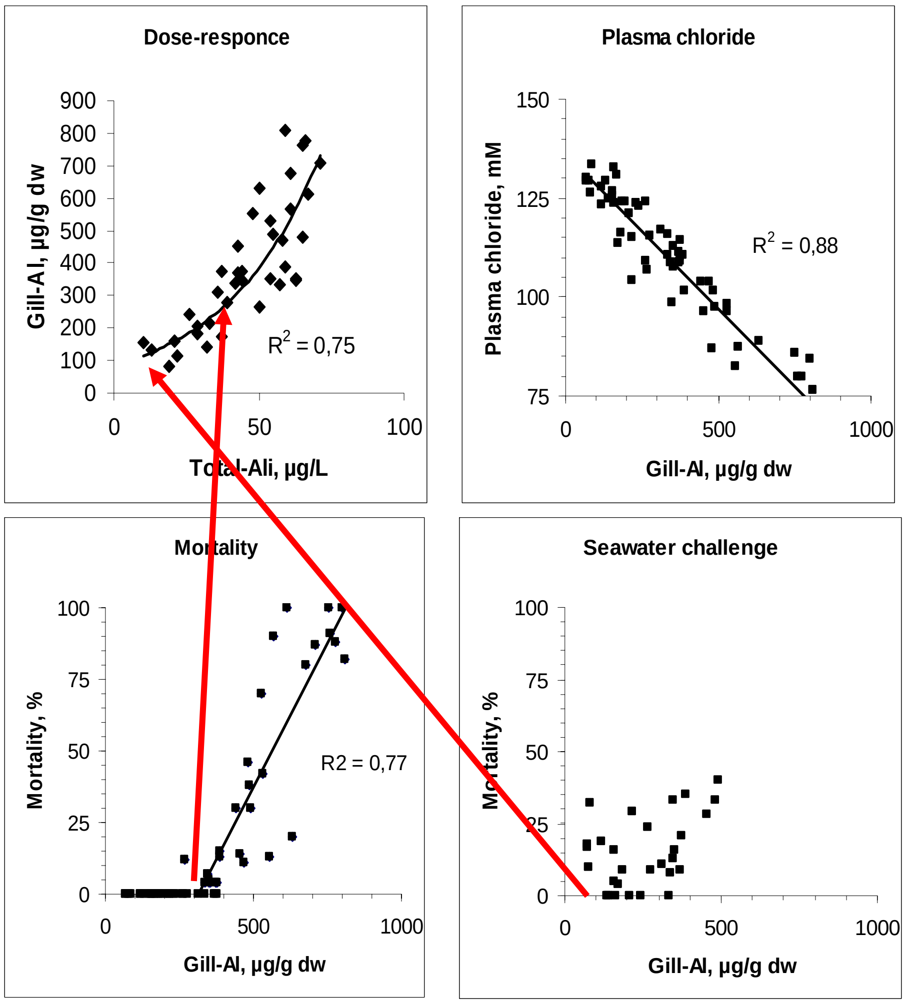
Ionic charge determine binding strength

After: Lydersen et al. 2001

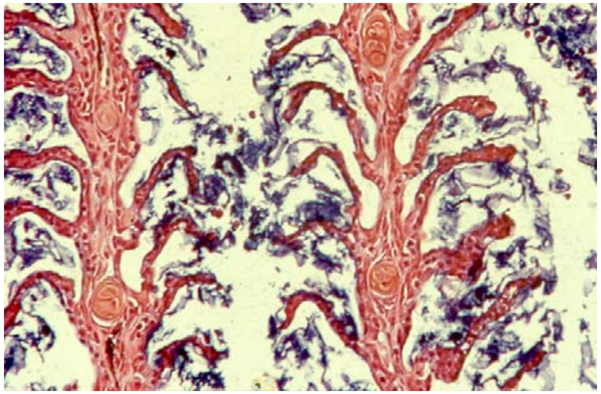
$Al_{i\ water}$ - Al_{gills} - osmoregulation-toxicity

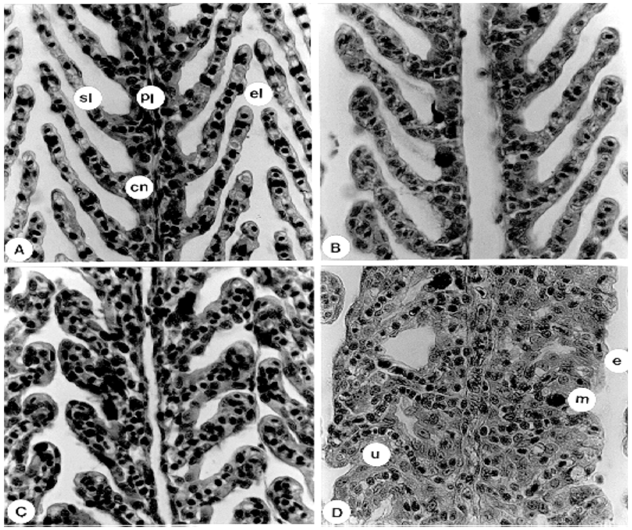
Increased inorganic Al - increased Al precipitation on gill

FW



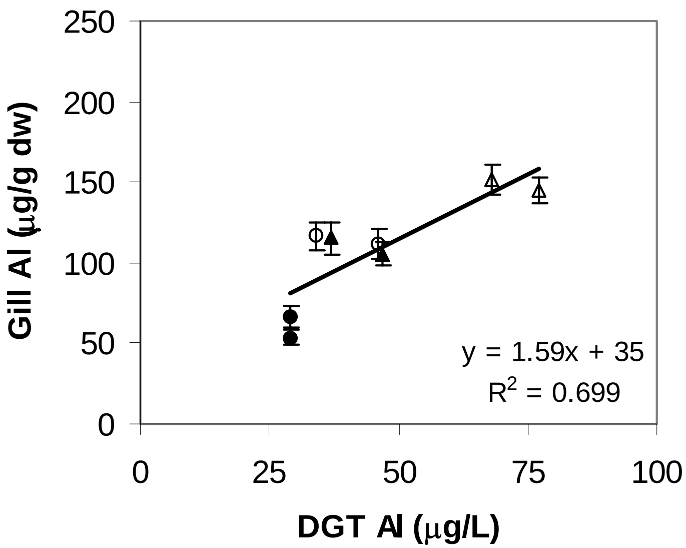
SW



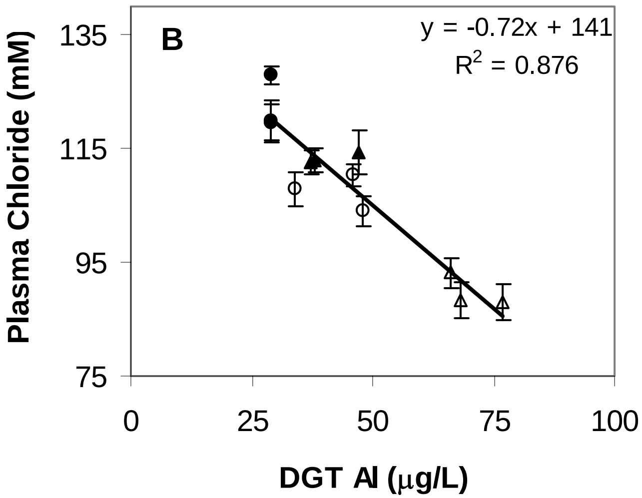


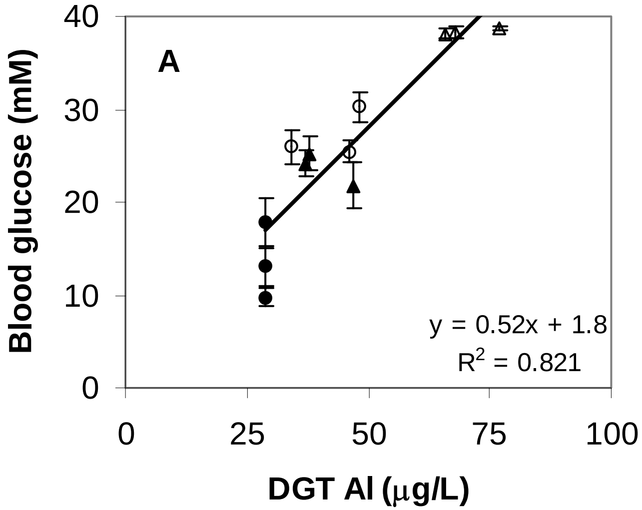
Kroglund et al. 1998, 2001

Can "New technology" substitute BIOMARKERS?
DGT – "Diffusion Gradient Thin Films"
Can DGT "simulate" gill and physiology responses?



Røyset, Rosseland *et al.* 2004





Yes!

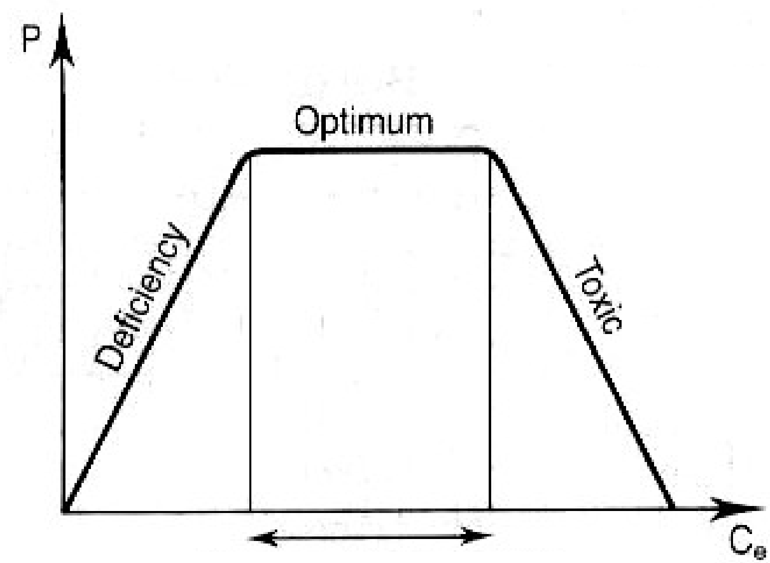
Keeping fish in a tank - like keeping a human in a respirator?

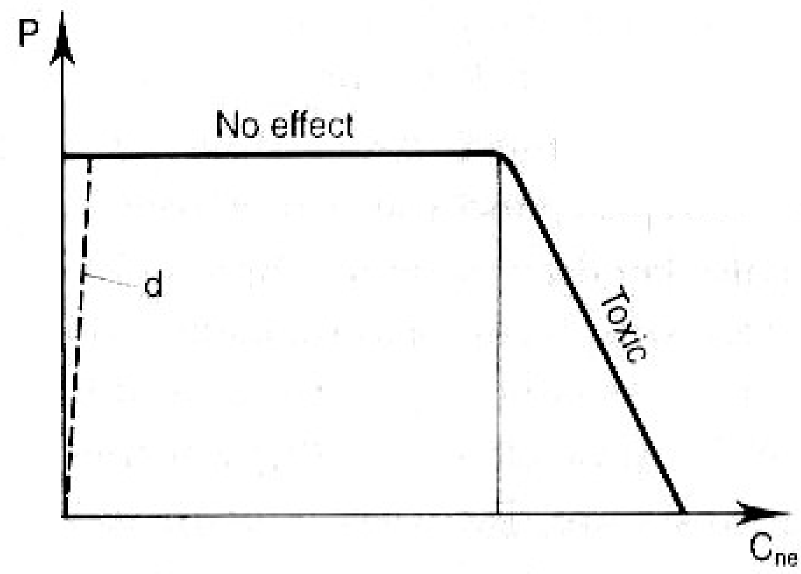
Water quality and biological relevance

Case I : Oxygen + combinations of CO_2 in interaction with TAN

Case II: H^+, Al^{3+}, $Fe^{2+/3+}$ Ammonia, CO_2

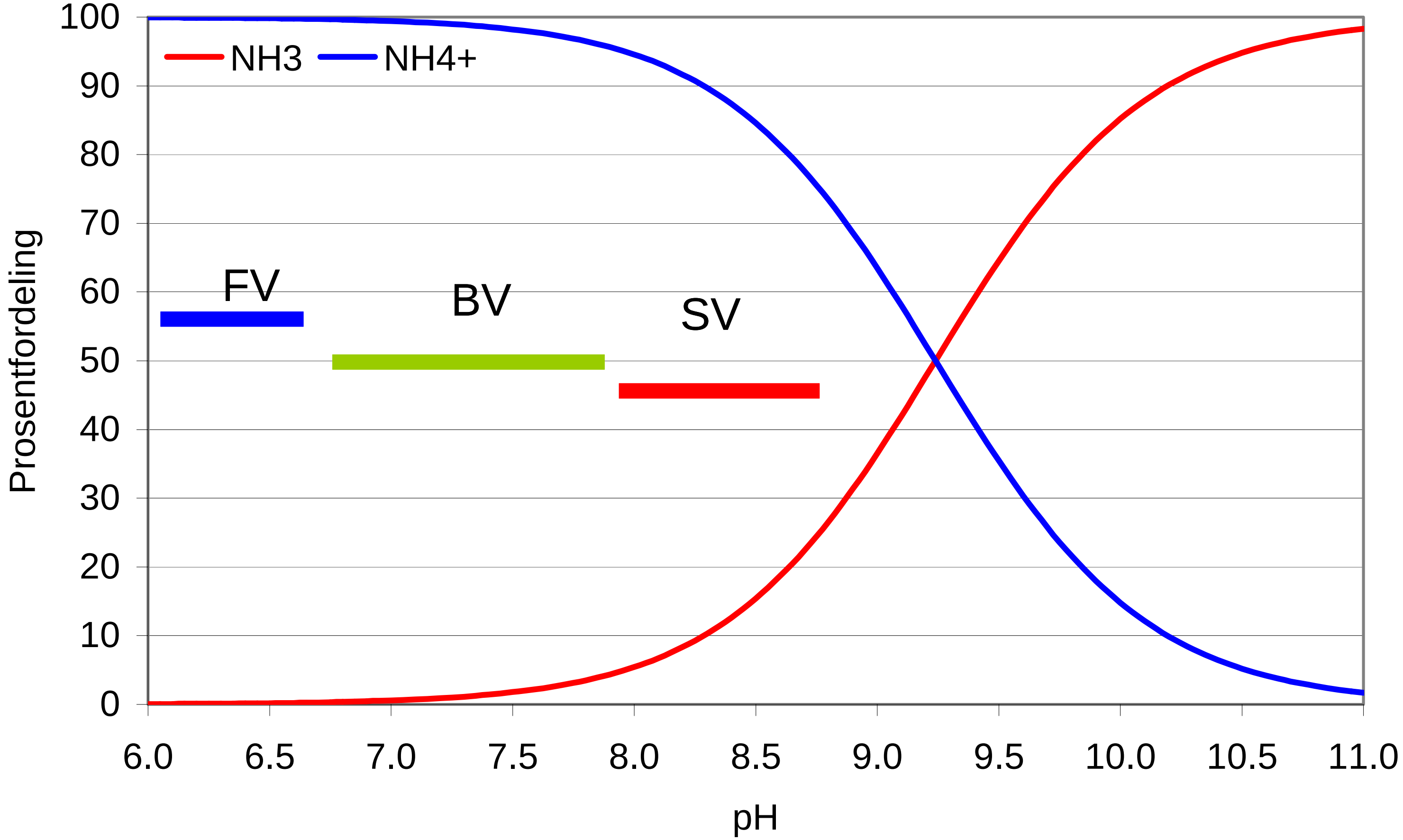
Performance





Modified after Walker et al. 2001

pH – NH_4^+ / NH_3

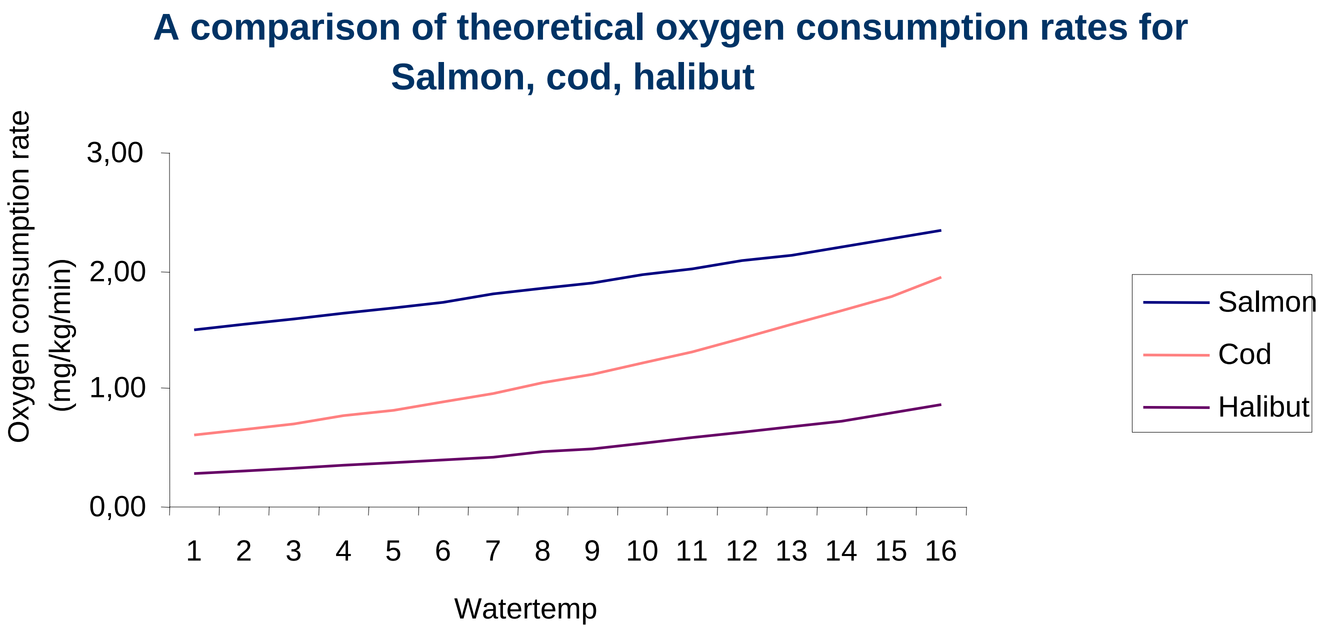


100
90
80
70
60
50
40
30
20
10
0
NH3
NH4+
FV
BV
SV
Prosentfordeling
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
pH

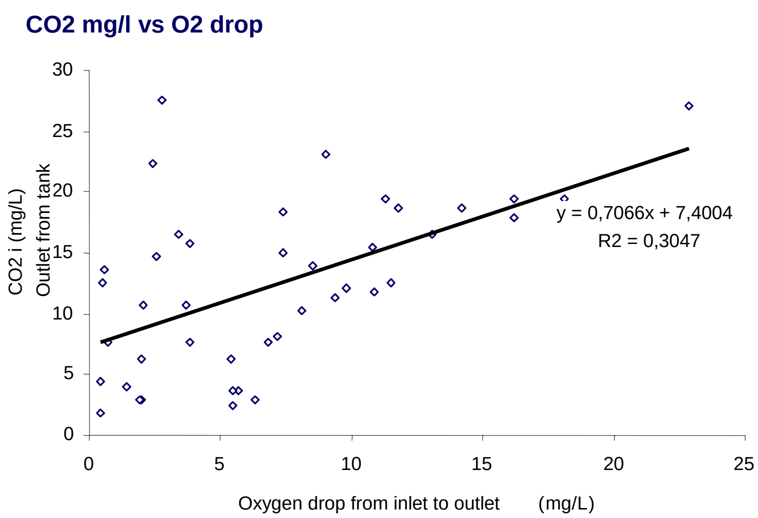
The joint metabolism of a fish “herd”

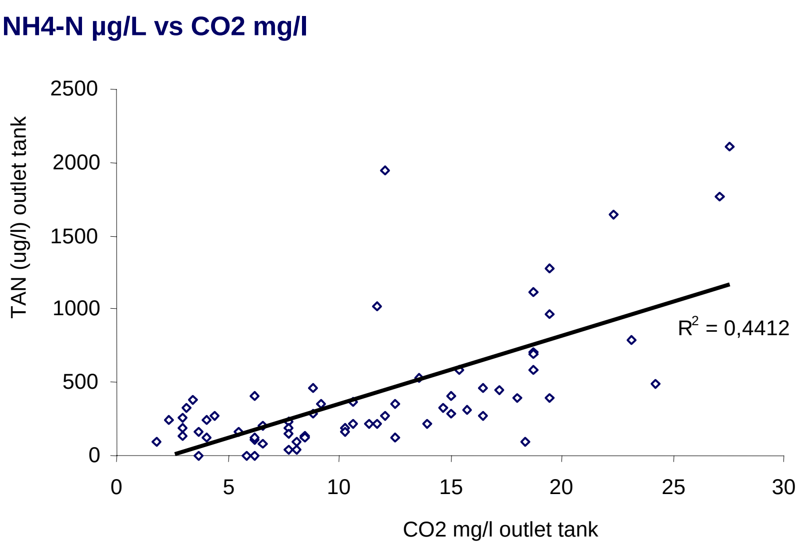
- Work load on the water package in the fish tank is decided by
  - The joint metabolism (JM) of the herd
  - The specific water exchange rate (litre water kg^{-1} min^{-1})
- What decide the JM
  - Water temperature
  - Fish size
  - Food consumption
  - Activity (swimming speed)
  - Stress
  - species

The oxygen consumption rate



Some fish herd (Atlantic salmon – smolts) relevant data (sampled and analyzed) from WQ – 1999 – 2001 Norway





- We can se that the oxygen consumption give an indication of the CO_2 levels
- We can see that TAN and CO_2 levels follow each other – as one should expect from metabolism

To log or to lab ?

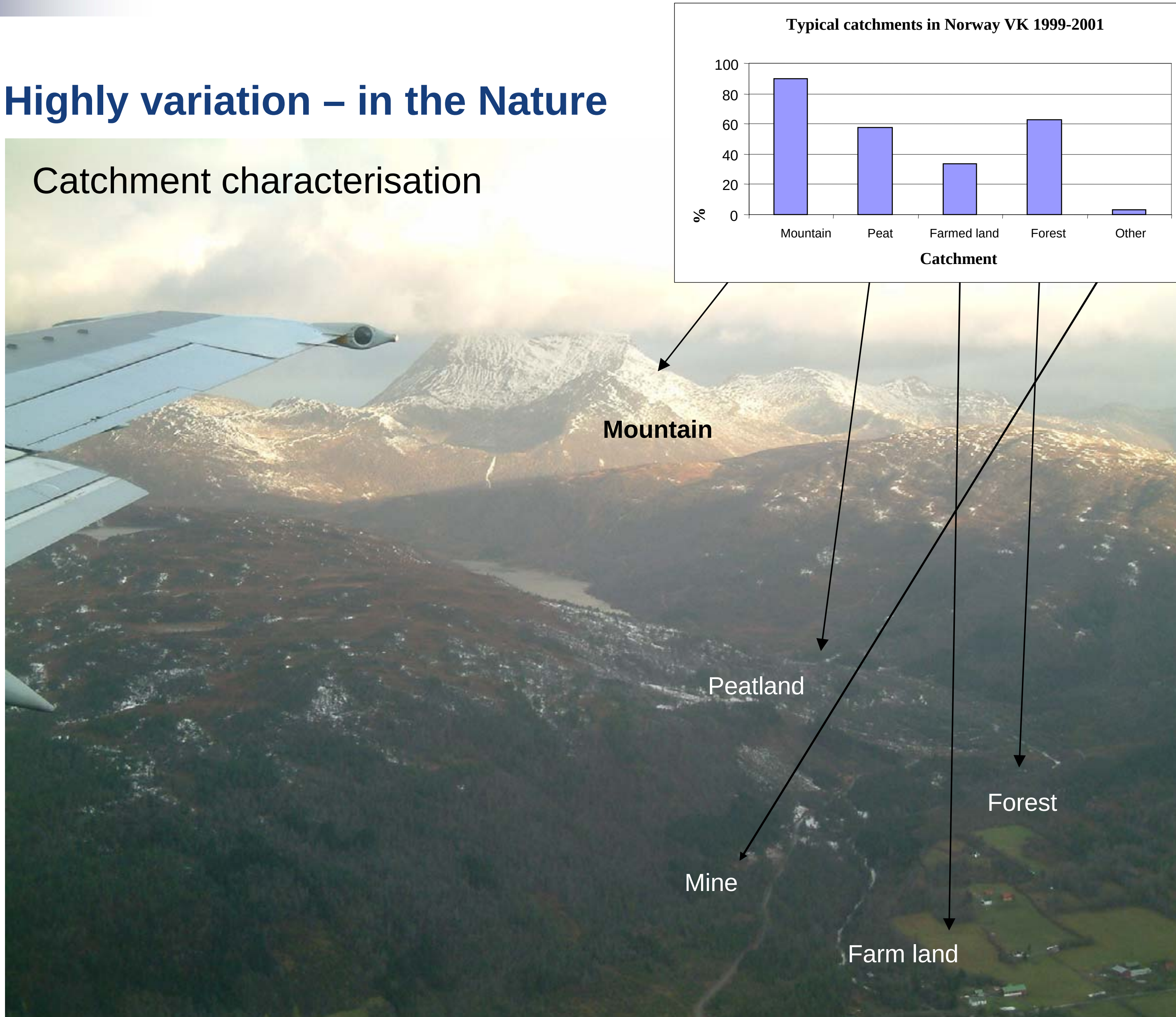
www.ysi.com

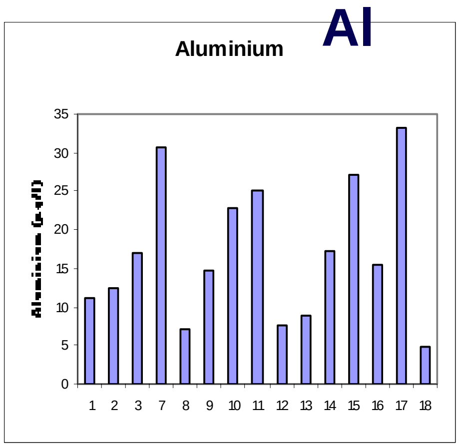
www.ysi.com

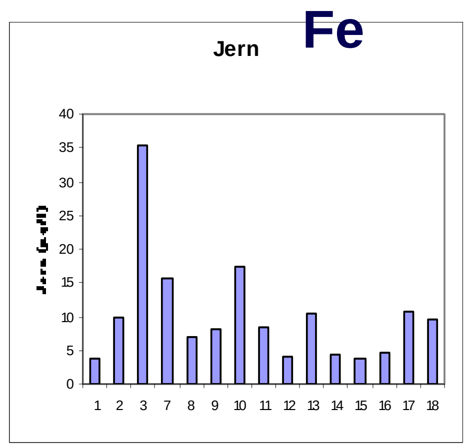
- What is functional today to log
  - Oxygen
  - pH
  - Temp
  - Salinity
  - Total gasspressure
- Estimates
  - CO_2
    - *Royce Instrument (a pH sensor with a alkalinity based calculator)*
    - *Orion (ionic selective)*
    - *Oxygard - new under development (partial pressure)*

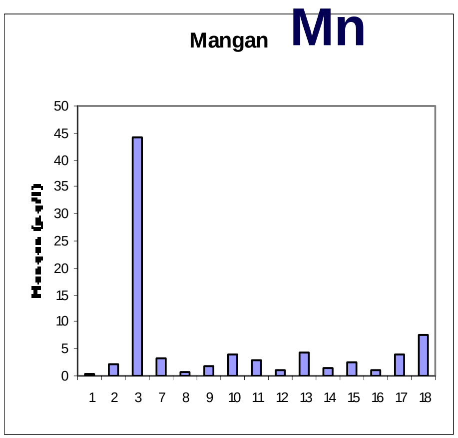
- What is necessary to lab
  - Al
  - Fe
  - TOC
  - Metals
  - TAN (NH_4 –N)
  - CO_2

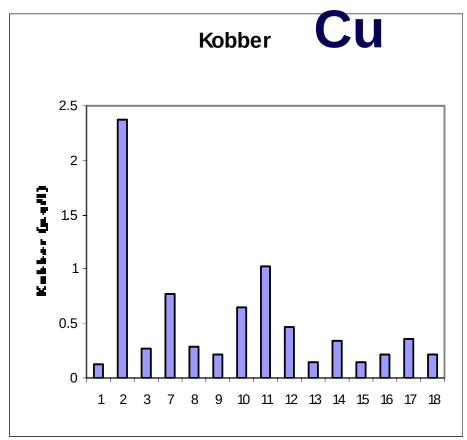
Highly variation – in the Nature

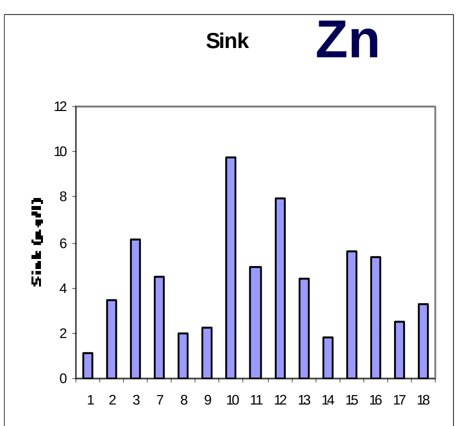


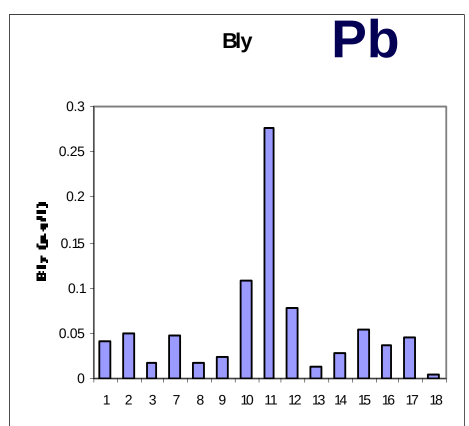












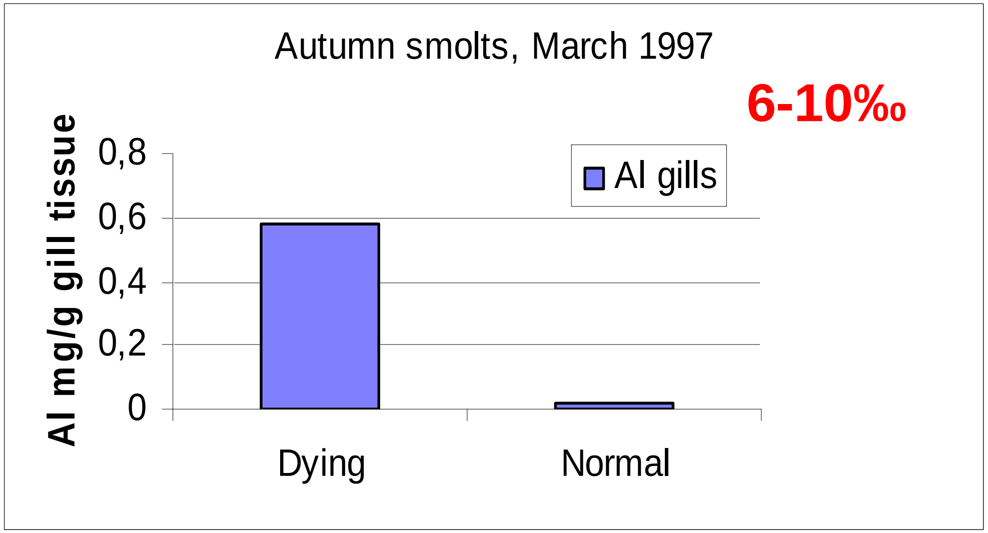
WQ-2002

DGT based mean concentration of metals in fish tanks

Al in seawater can kill salmon!
Estuarine mixing zones – consequence for experiments in aquaculture

- Estuarine mixing zones
  - Aluminium from acid rivers can kill salmon in net pens in fjords during high flow

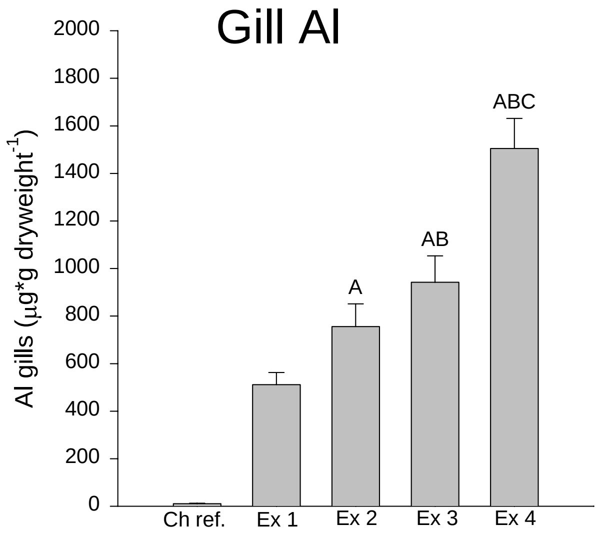
Bjerknes et al. 1998



Cod is affected by Al in Estuarine Mixing zones at 10‰

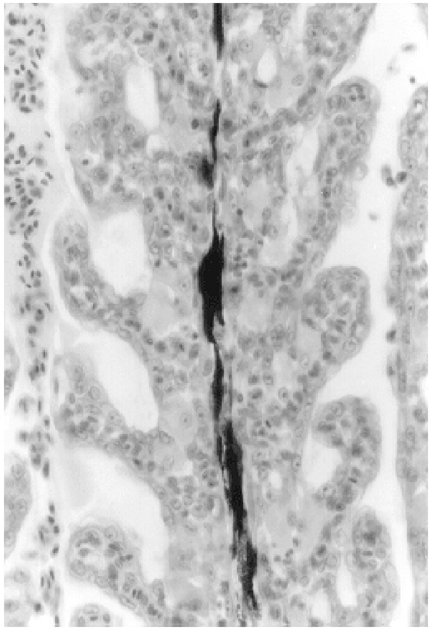
- Metabolism decreases
- Al deposits on gills
- Mortality

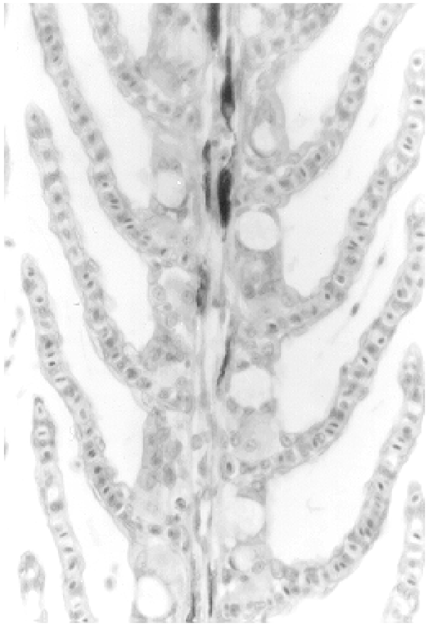
Kristensen 2001



Marine species
Turbot is also affected by Al in estuarine mixing zones (10‰)

- Gills from turbot
- **Al-exposed** **Reference**

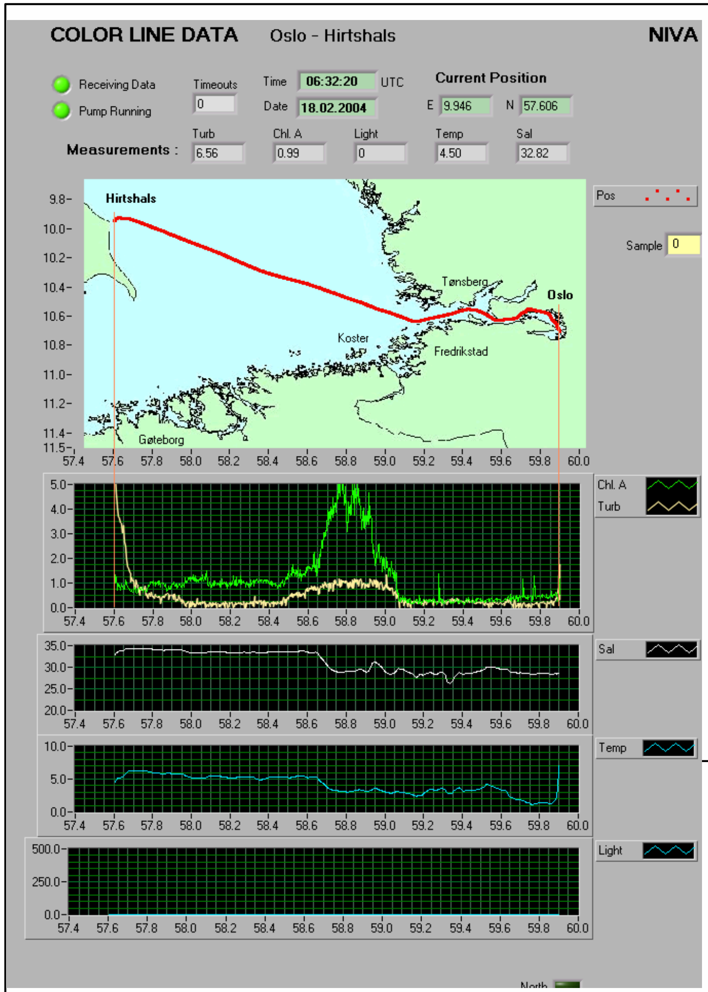




Rosseland et al. 1998

Some high tech

Validation based on ships of opportunity data for Skagerrak



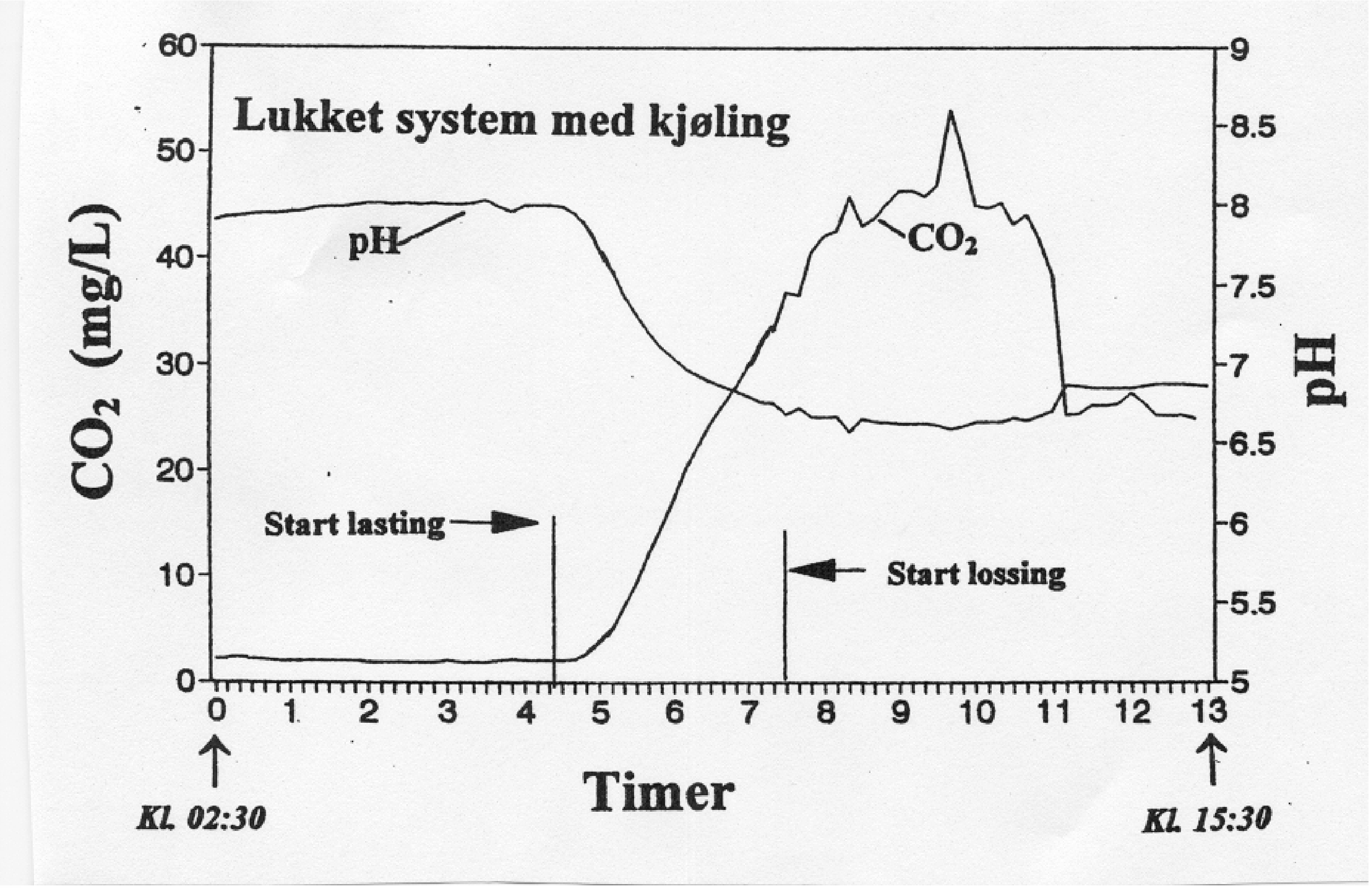
The Skagerrak route is part of the EU FerryBox project

The Hirtshals-Oslo line in Skagerrak used in validation

Censors and installations – on board

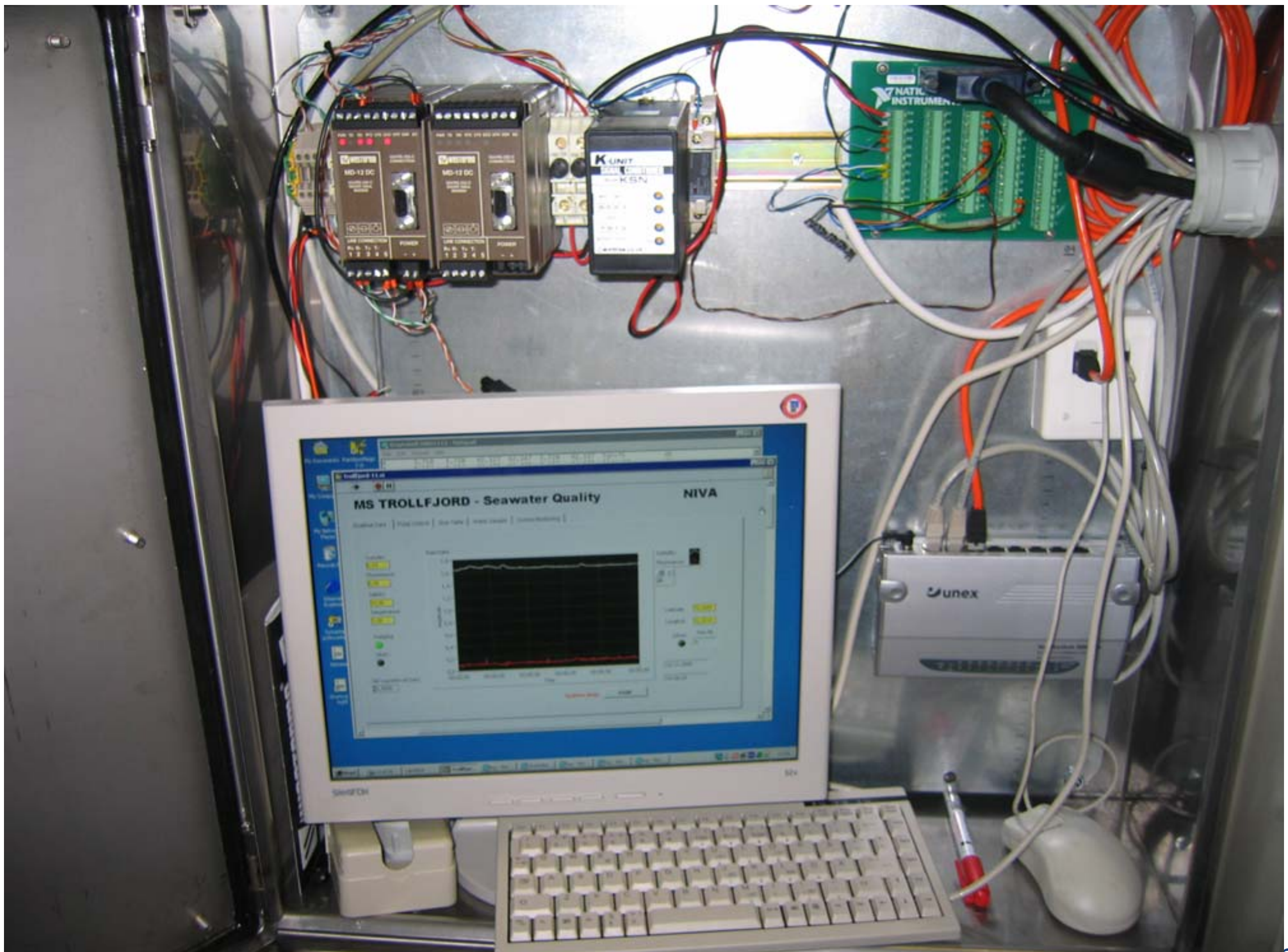
- Manifold for water
- Particles (turbidity)
- Algae (chlorophyll-a)
- Salinity and temp
- Bobble chamber

EX. pH og CO_2 logging system



Eriksen rt al 1999

“Interface” of censors and GPS to data program and internet



NIVA

Controlled sampling

- Automatic sampling
- Different volumes
- Conservation
- Send samples to NIVA lab

Back to small scale – to sum up

Nb	Parameter	How often in practical life	Log or Lab	Comments
1	Biomass in each unit	Daily	Log	
2	% feed per day = SGR%	Daily	Log	
3	Oxygen (in and out that is drop in mg)	Daily	Log	
4	Watertemp	Daily	Log	
5	pH and or salinity / conductivity	Daily	Log	Low pH raw water or flood influenced raw-water needs closer attention
6	Water flow	Per week and per change	Instrument Manually	Minimum 10 litre vann/m^3 as a guideline for flow in circular units
7	Raw water quality	Each 14. day year around	Lab (NIVA WQ – package)	Important to specify the variations in the source that might influence your experiment
8	Control if fish has been exposed to metals (salmonides)	Before transfer to sea	Lab : Gill metal-concentration (µg Al/g gill dw) + DGT (Lab)	Can be done for the most relevant metals
9	Control of CO_2 -levels	Daily – variation with fish eating activity + natural CO_2 production from algea (raw water)	Lab Glass bottles leakage proof + bio-blokker Log if alk. is stable	Estimate from oxygen drop through fish tank – minor physiological effects from +10 mg L^{-1}
10	Control of NH_3/NH_4+	Daily to weekly depended on the intensiveness	Lab	
11	Fish tank water	Between groups with different raw - water quality and before / after change in conditions	Lab	

"Can you think of any others?"

NIVA

Thank you for the attention!