Gas supersaturation may cause effects on the biota comparable to acidification

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GAS SUPERSATURATION

BACKGROUND
MEASUREMENTS
CAUSES
BIOLOGICAL EFFECTS
CONCLUSIONS AND RELEVANCE

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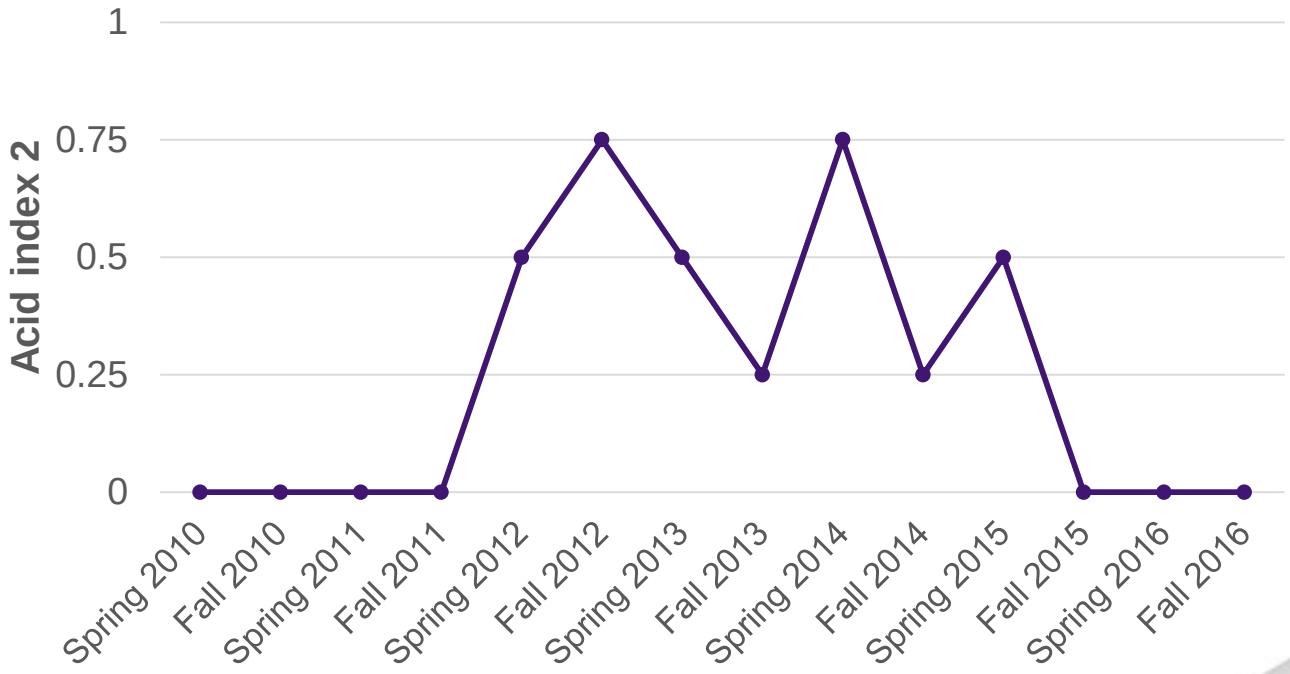
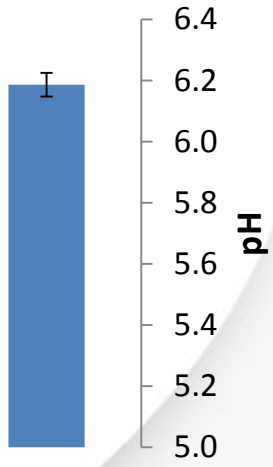
ACID INDEX 2 IN RIVER OTRA





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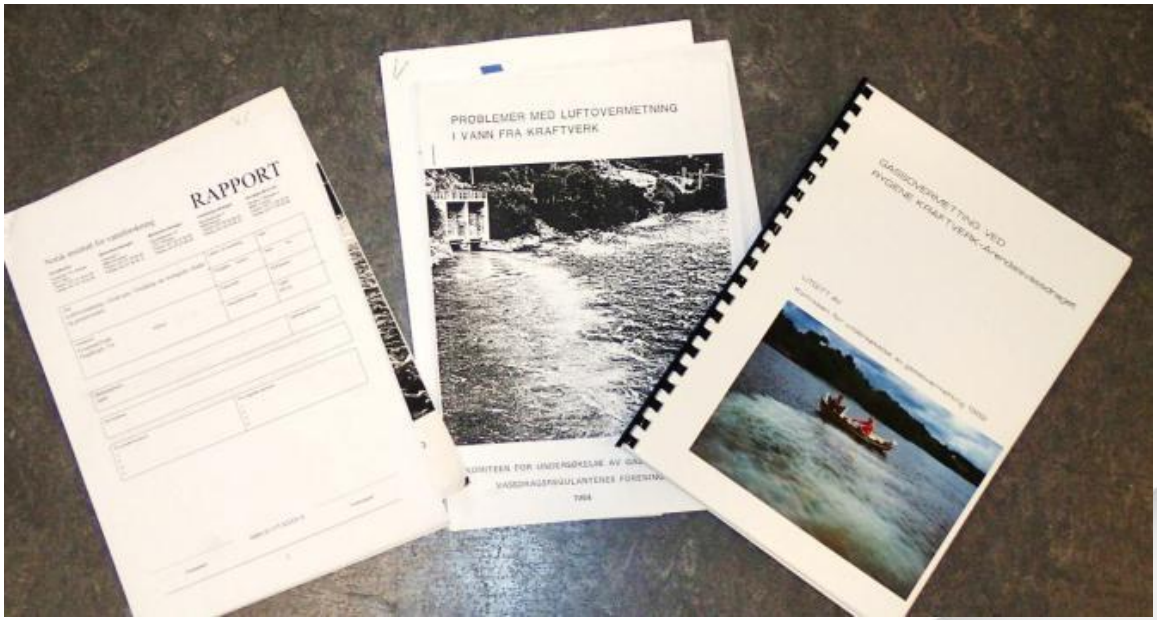
By Brokke power plant


Bekkeinntak på kraftverkstunneler
Sluttrapport fra Bekkeinntakkomiteen 1986
PROSJEKTANSVARLIG: VASSDRAGSREGULANTENES FORENING


RAPPORT
PROBLEMER MED LUFTOVERMETNING I VANN FRA KRAFTVERK

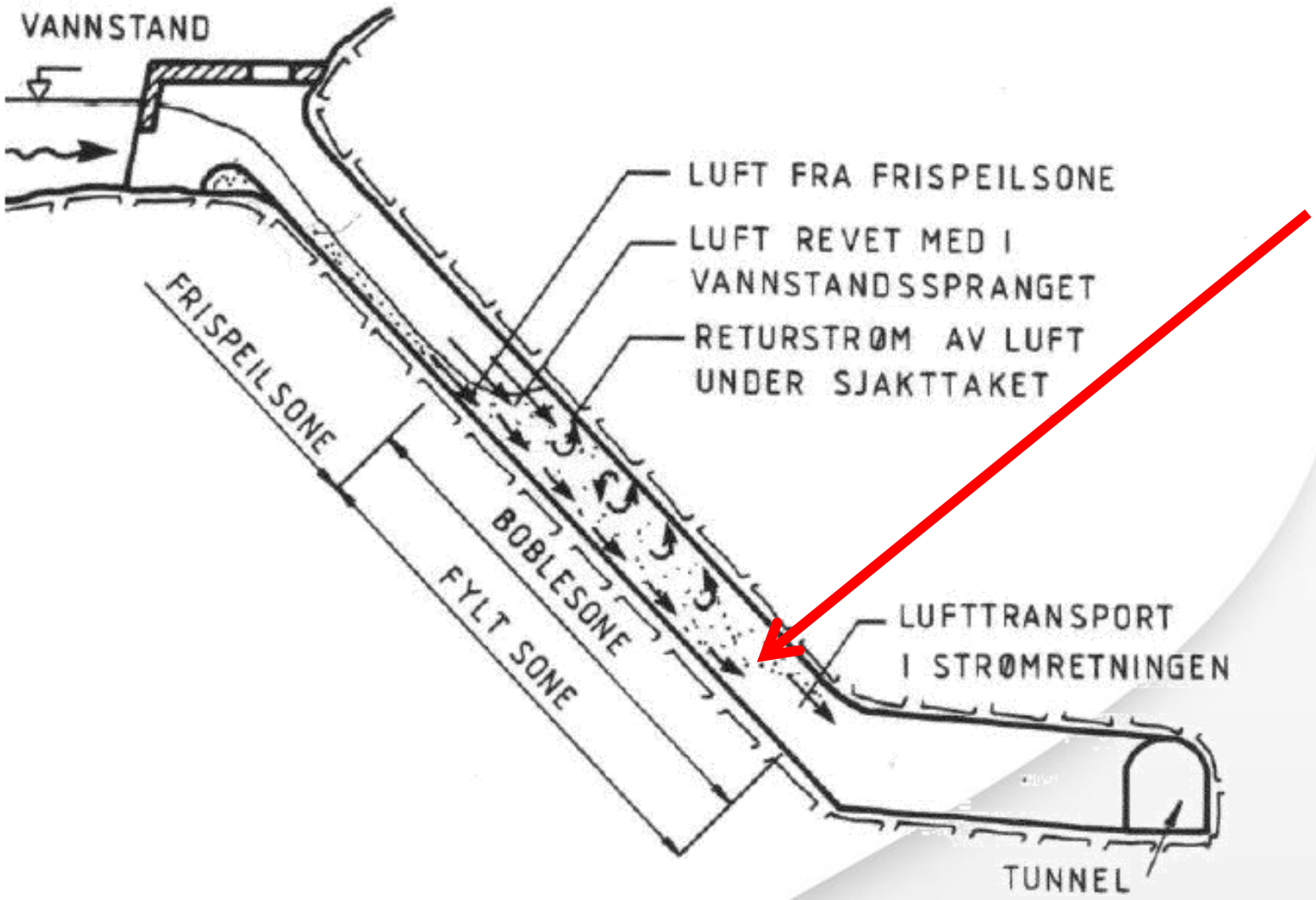
Gas supersaturation

Normal river water: 100 % Total Gas Pressure (TGP)

Carbonated bottle water: 120%-130% TGP

TGP may occur naturally: Water falls; temperature changes, photosynthesis

Man made: Gas + fluids + pressure + reduced pressure



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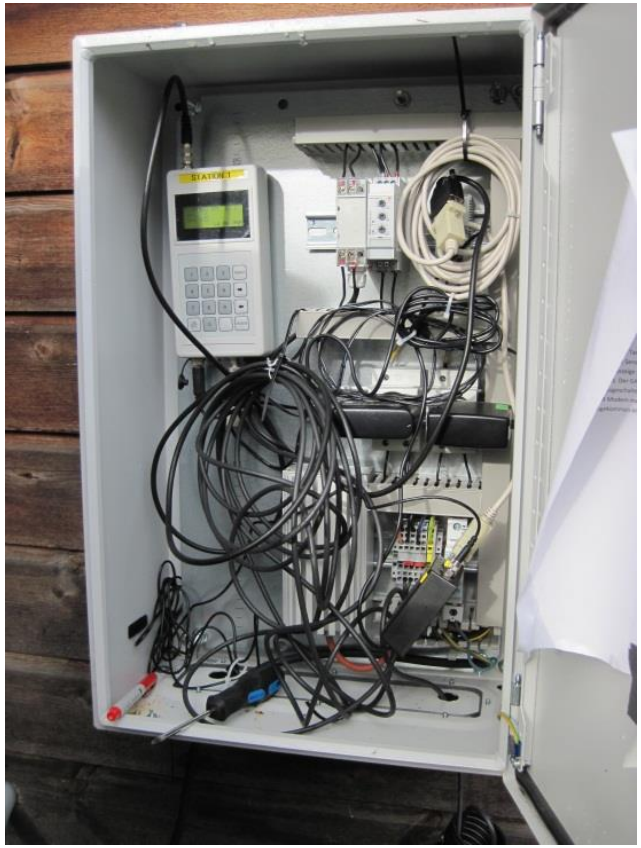
Lack of measuring equipment



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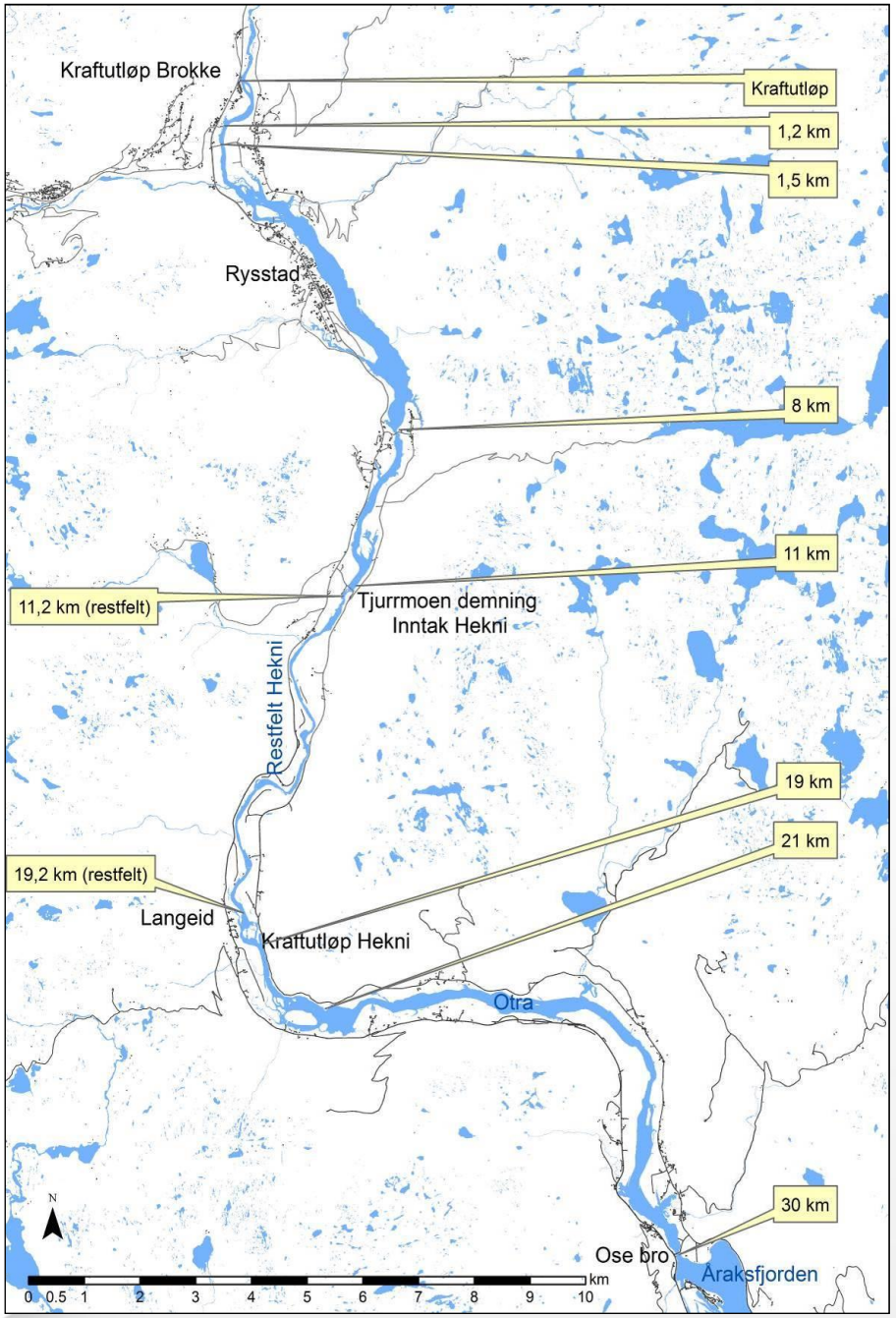
Gas saturation downstream from Brokke hydropower plant 2011-2016



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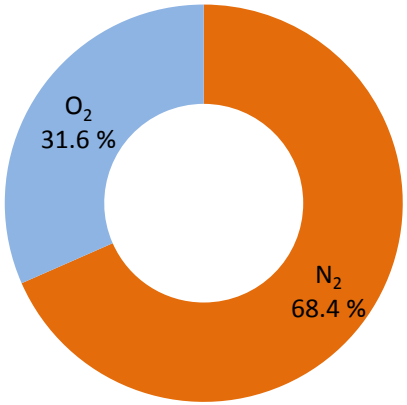
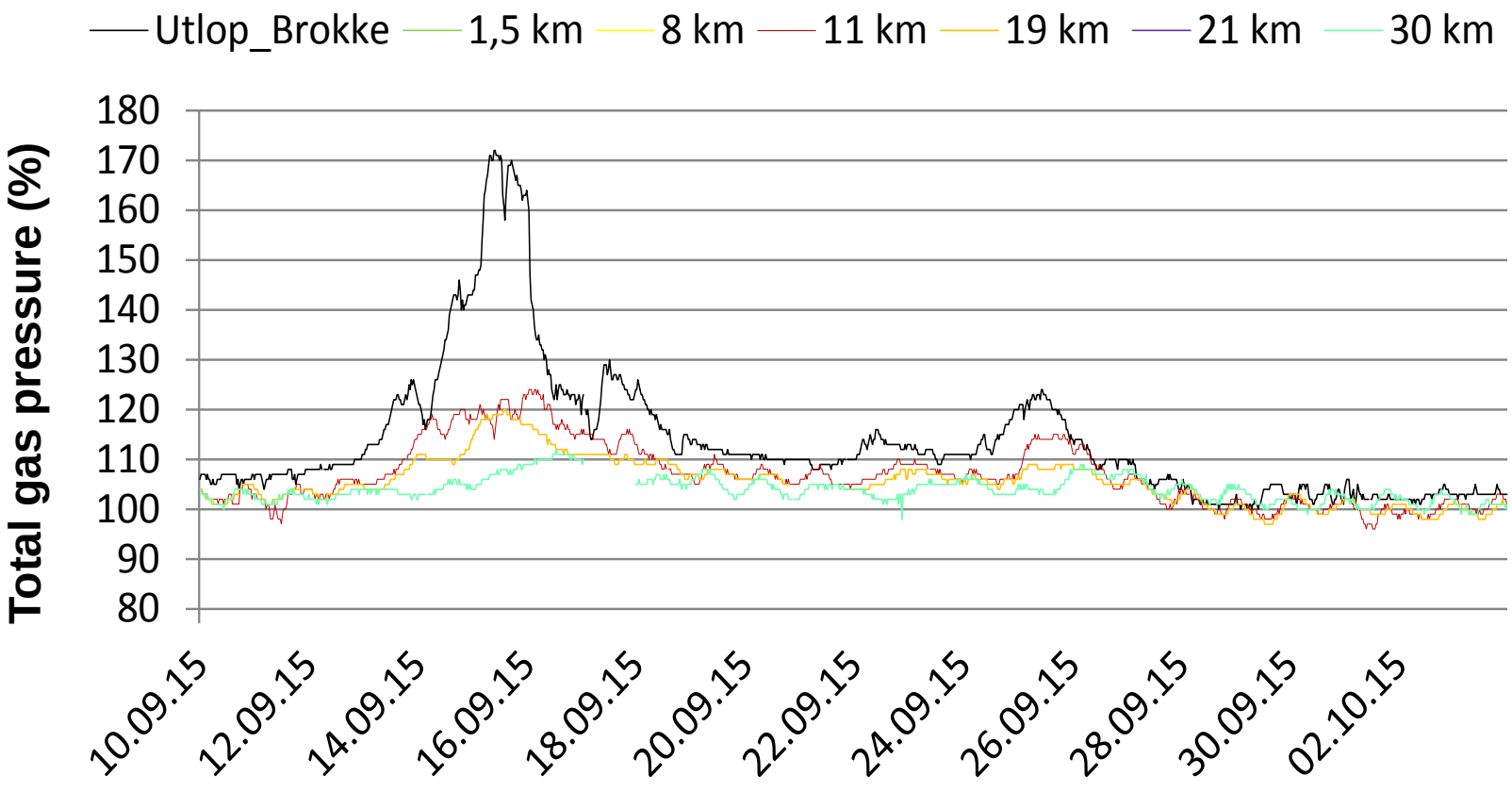
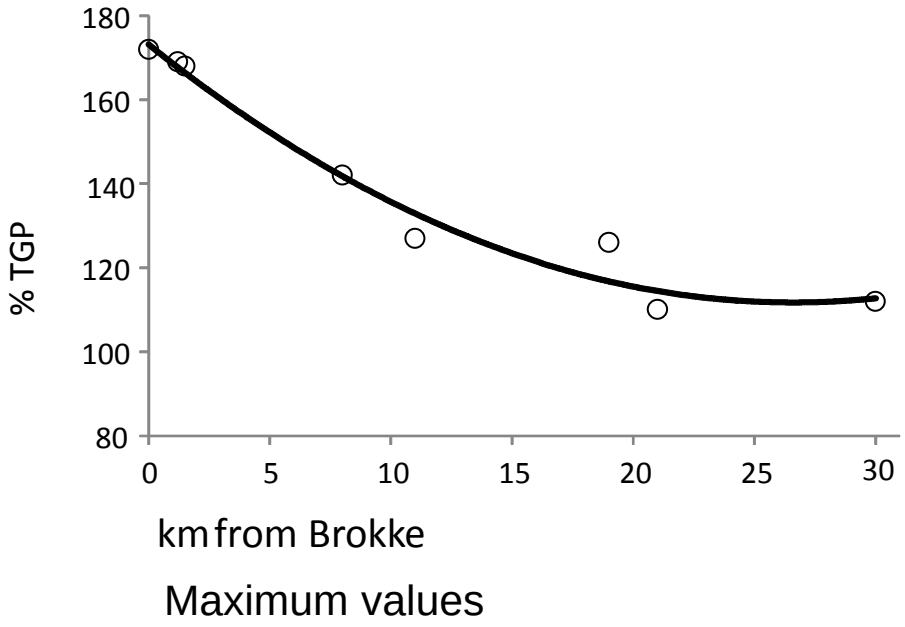
River Otra


O_2
31.6 %
N_2
68.4 %

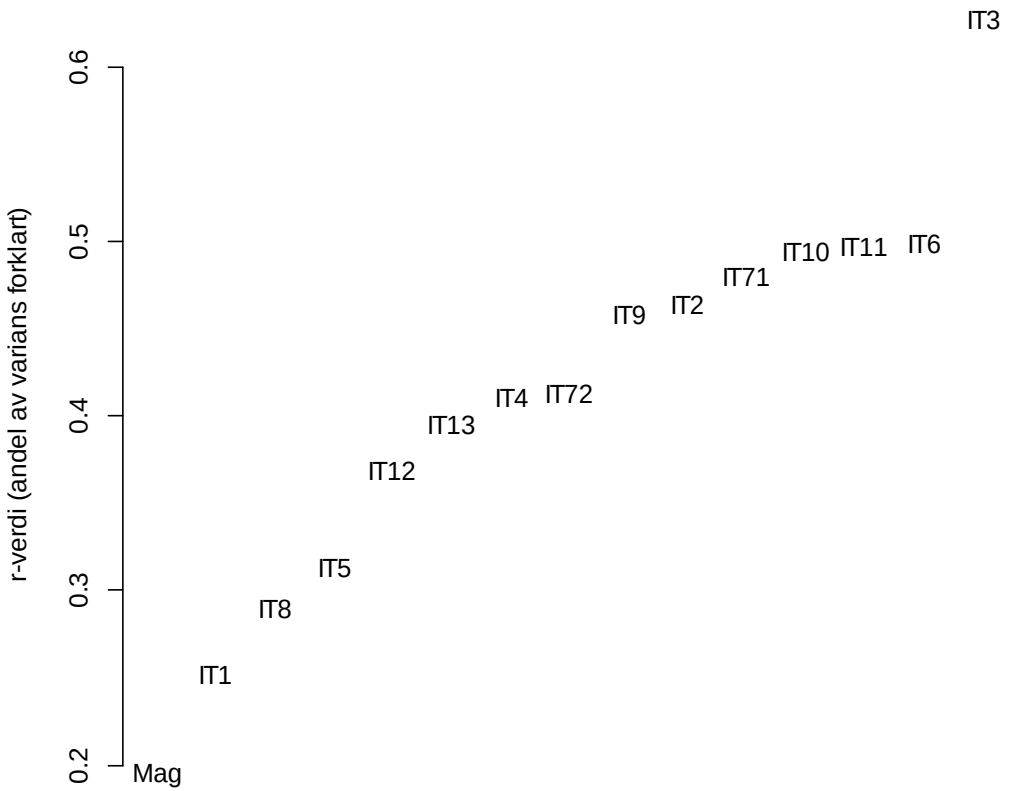

Utlop_Brokke
1,5 km
8 km
11 km
19 km
21 km
30 km
Total gas pressure (%)
180
170
160
150
140
130
120
110
100
90
80
10.09.15
12.09.15
14.09.15
16.09.15
18.09.15
20.09.15
22.09.15
24.09.15
26.09.15
28.09.15
30.09.15
02.10.15

Wave characteristics, aeration, dilution



Maximum values

Cause



Nr	
3	Ljosåni
6	Lisleå
11	Faråna
10	Havestøylani
71	Flossi
2	Hisa
9	Hylesdalsani
72	Flossi liten
4	Gjesløy
13	Myklevatnet
12	Kvernani
5	Skiptesbekken
8	Kvinnåni
1	Holsbekken

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Cause

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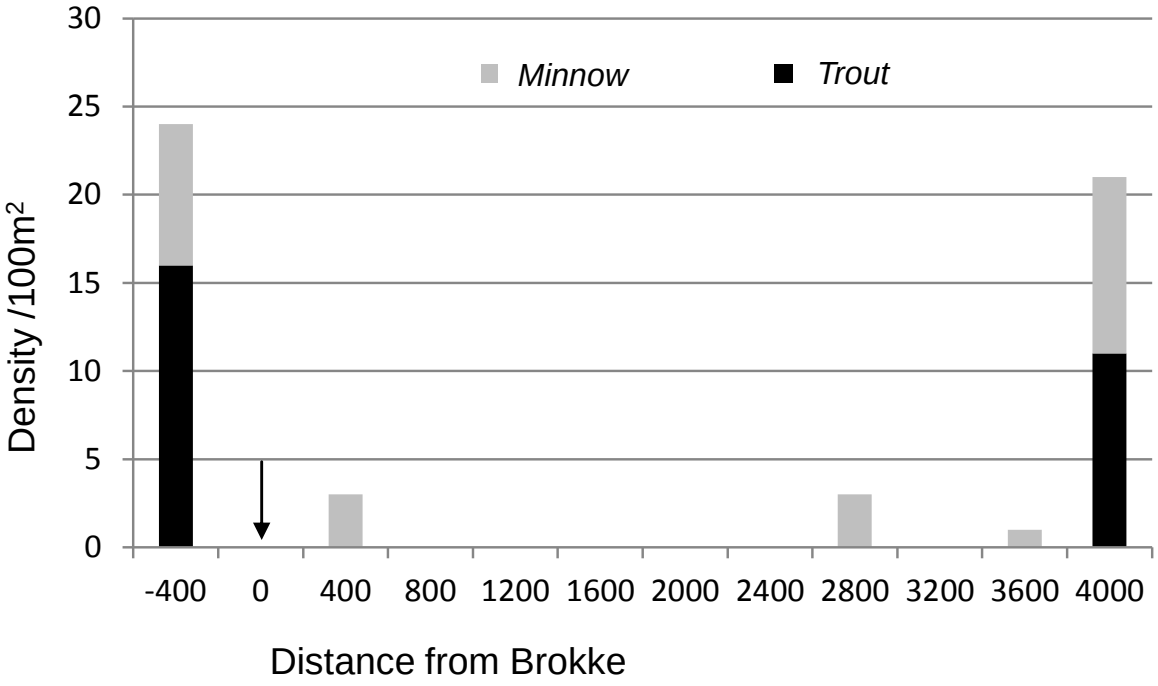
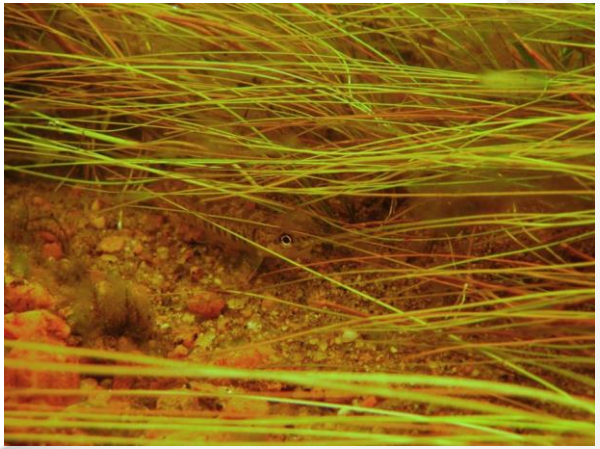
Effects on the biota

Electrofishing, Otra





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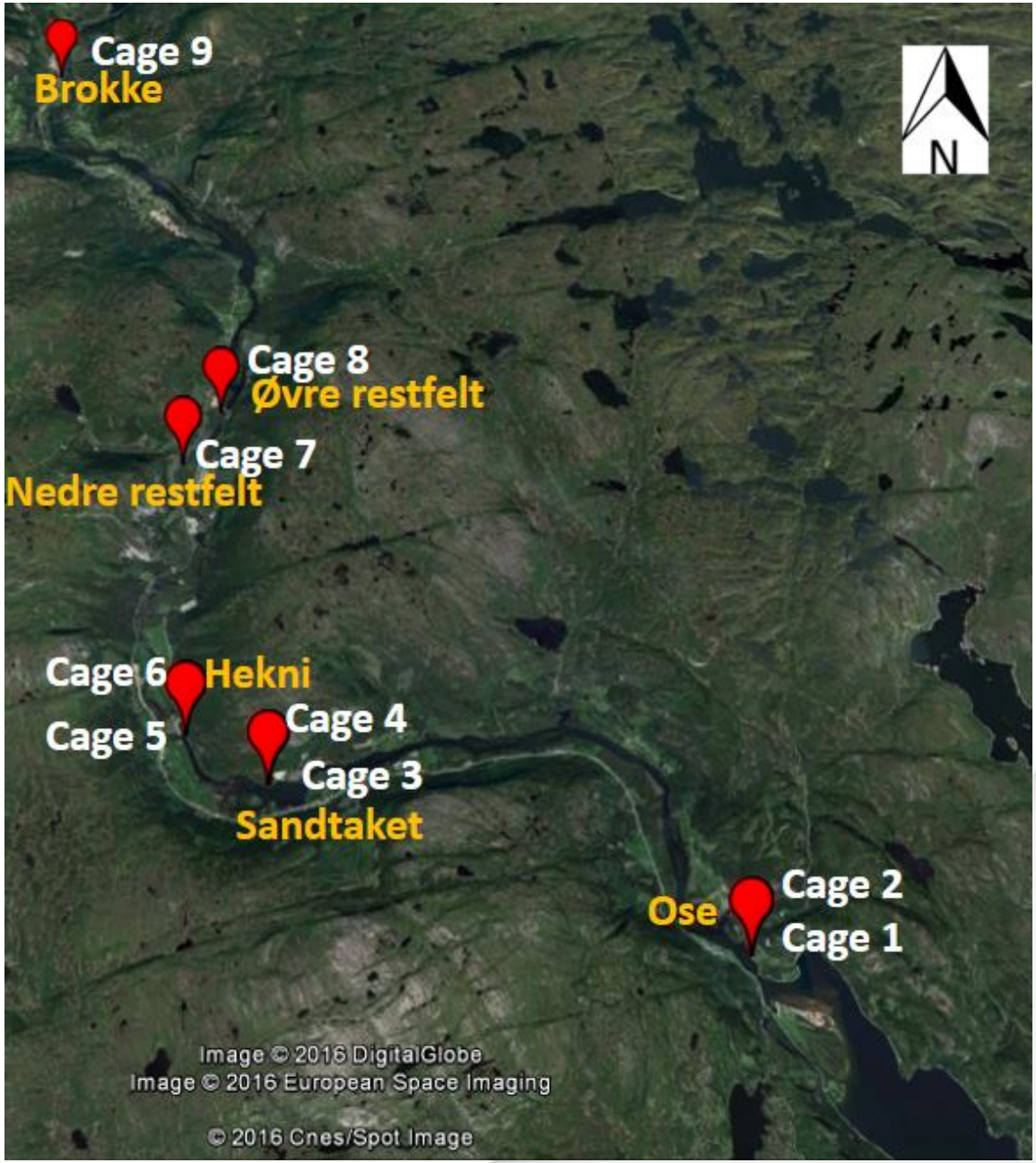
Cage experiments



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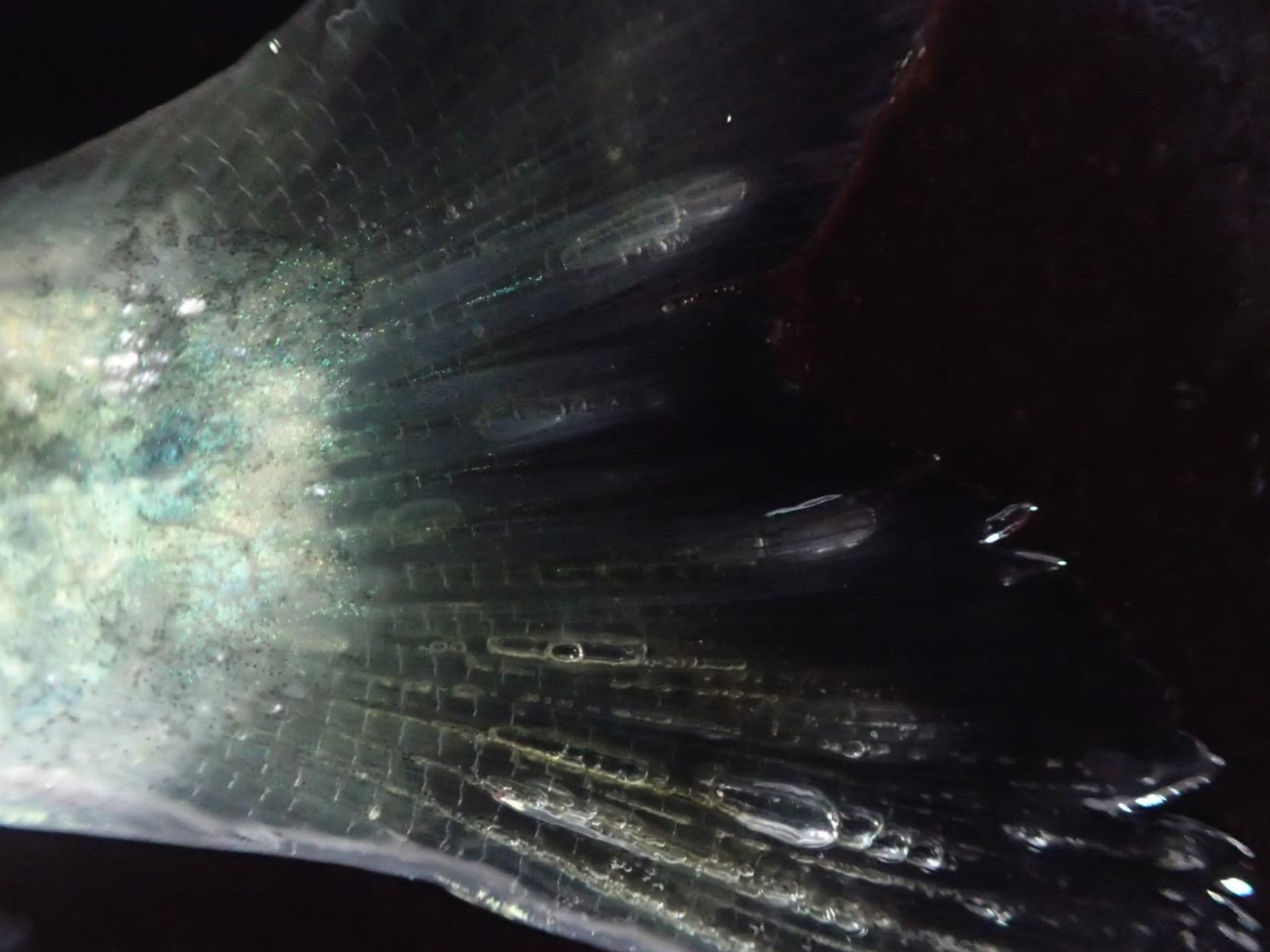
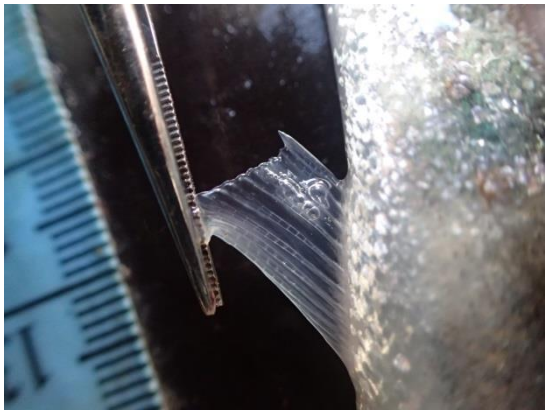
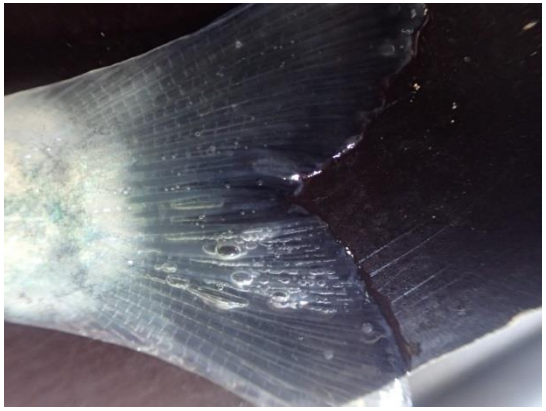
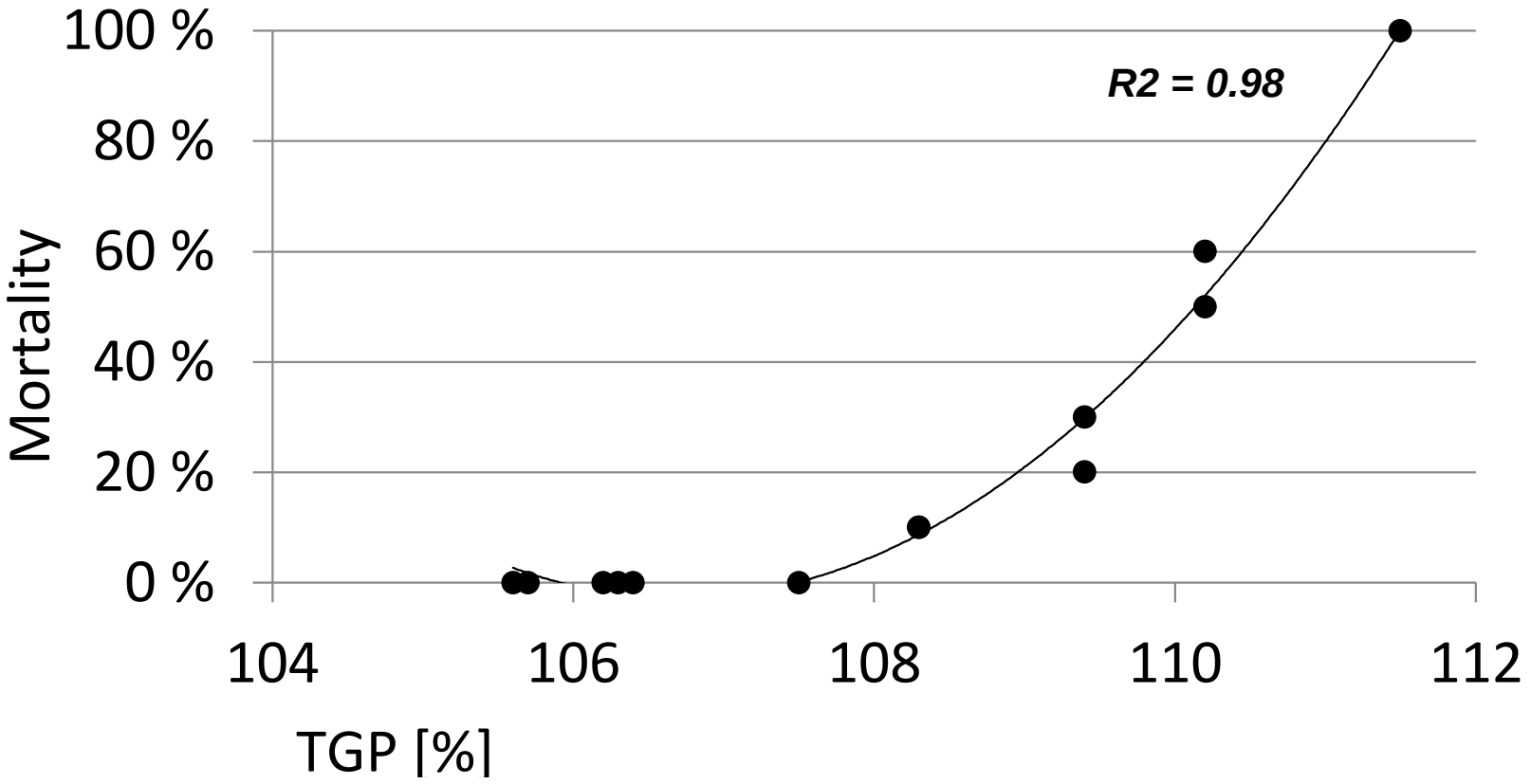
Right gill arch 1 = metal analysis
Left gill arch 2 = histology
Right gills = check for gas bubbles
Fins = bubbles
Blood = Plasma cortisol

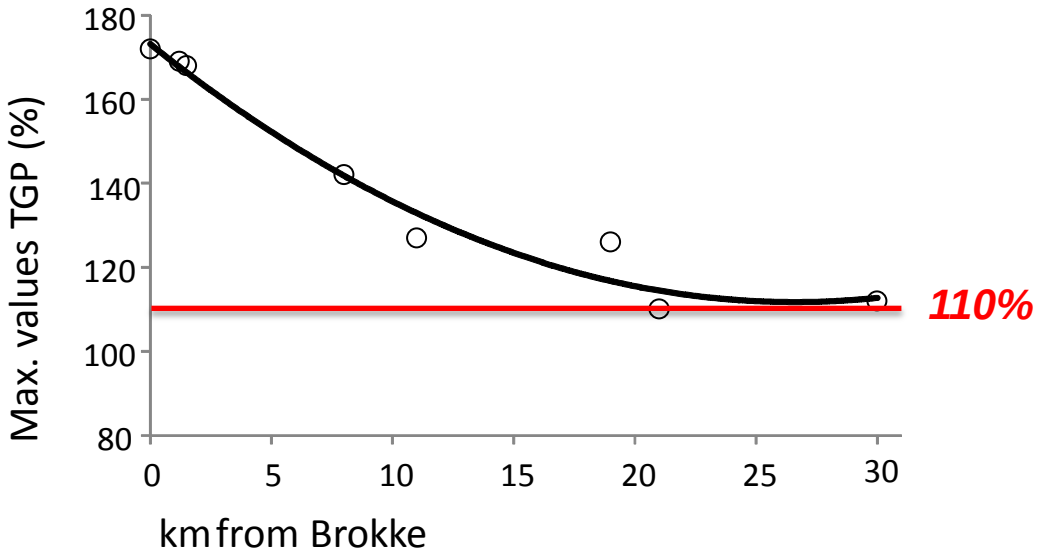







100 %
80 %
60 %
40 %
20 %
0 %
Mortality
R2 = 0.98
104
106
108
110
112
TGP [%]

LD50 = 110% gas supersaturation



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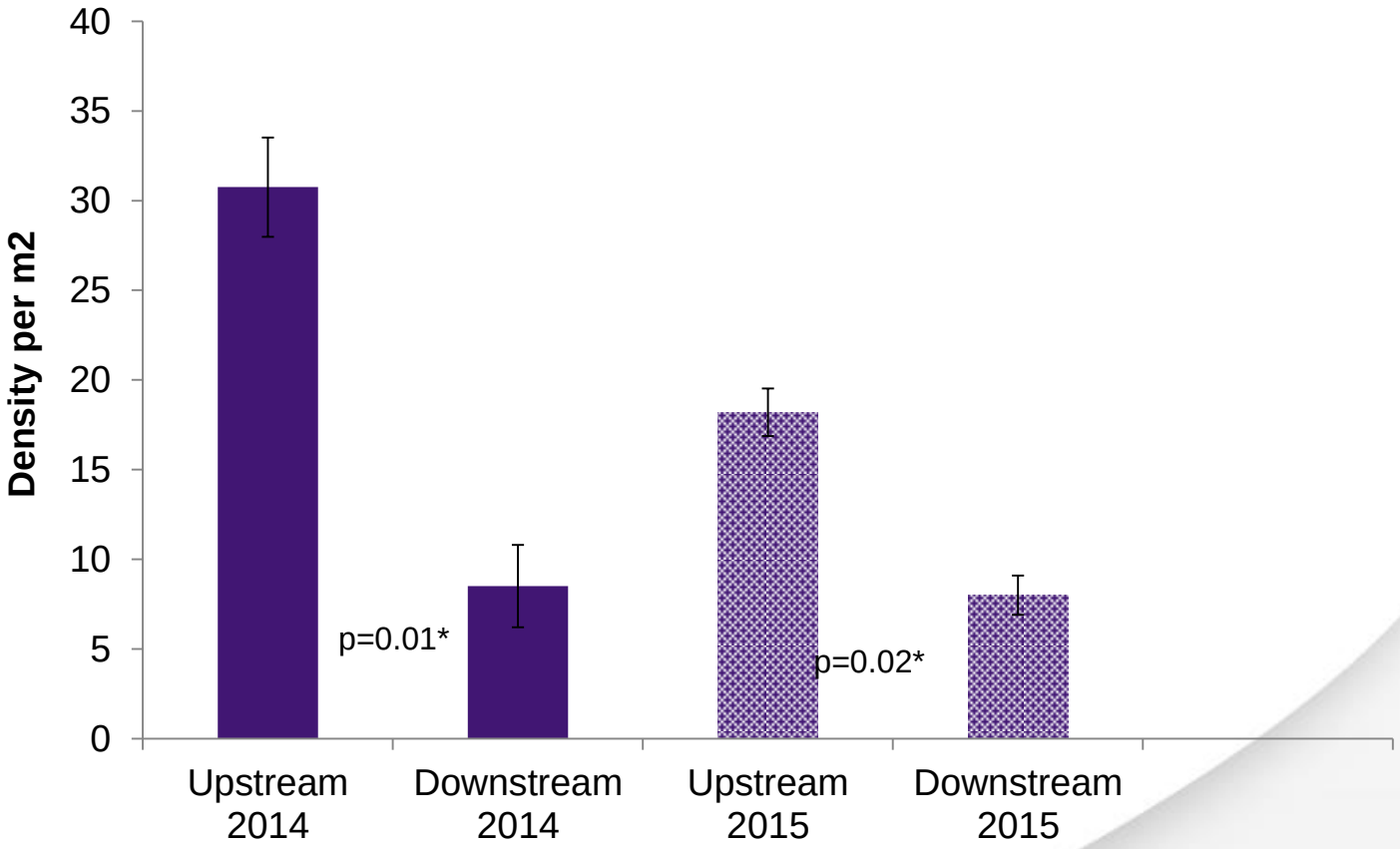
Effects on benthic invertebrates

Density of invertebrates



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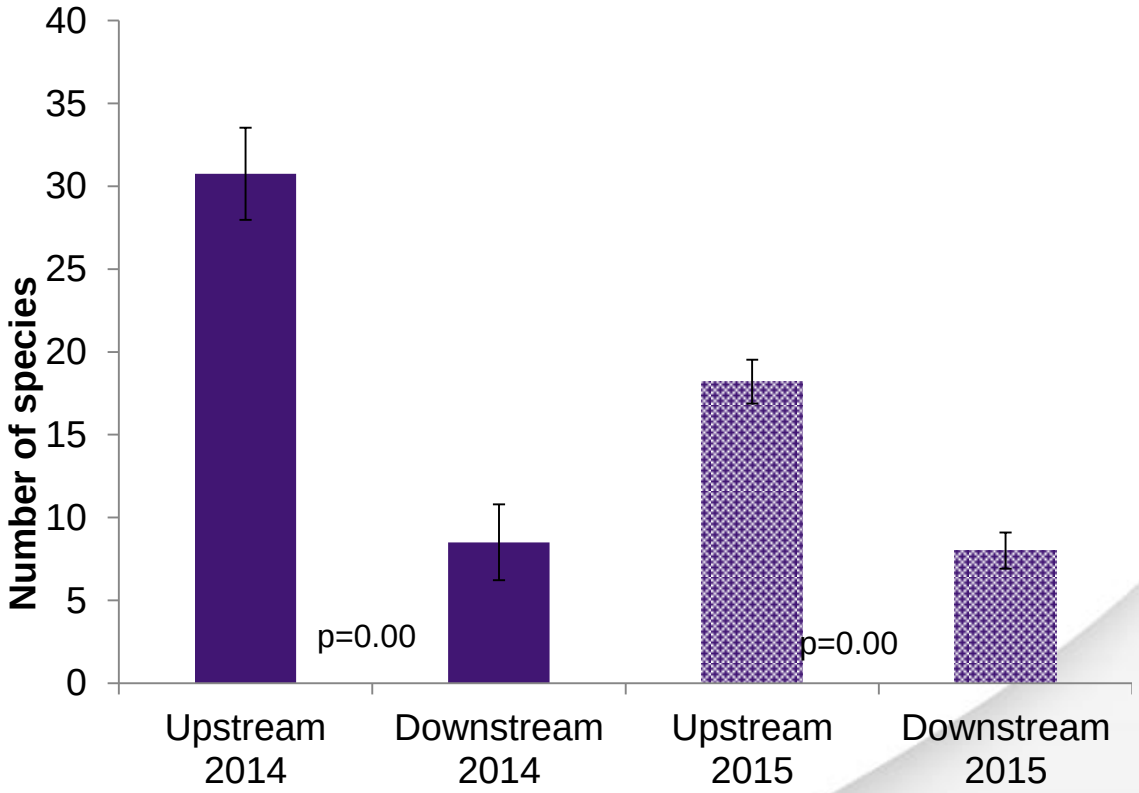
Diversity of invertebrates



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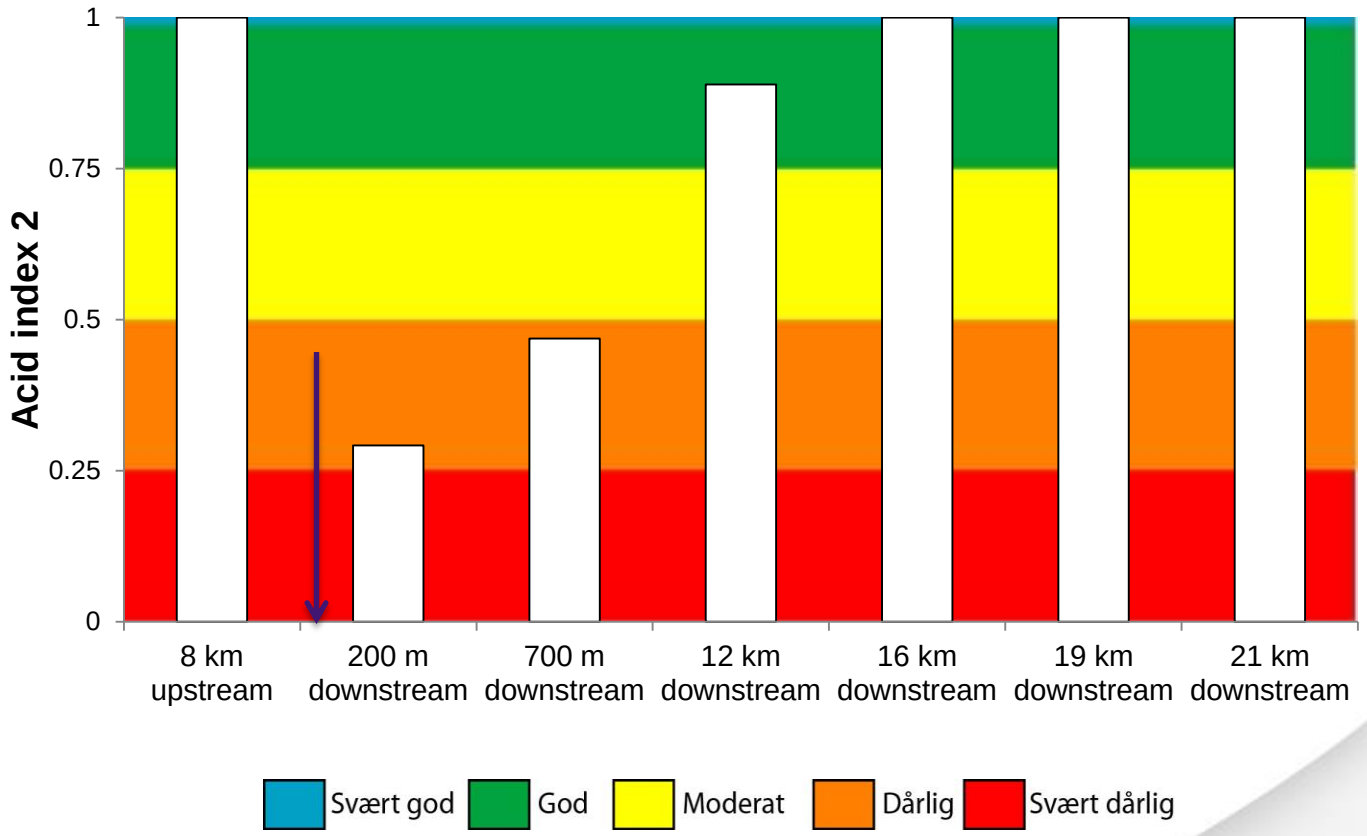
Average acidification index 2010-2015



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Fauna dominated by digging taxa

200 m upstream		700 m downstream		11 km downstream	
Taxon	**No./m²**	**Taxon**	**No./m²**	**Taxon**	**No./m²**
Chironomidae	6896	Nematoda	1513	Chironomidae	6299
Oligochaeta	1407	Oligochaeta	1299	Oligochaeta	842
Acari	1103	Acari	235	Nematoda	188
Oxyethira sp.	776	Chironomidae	145	Acari	168
Nematoda	458	Apatania sp.	51	Oxyethira sp.	84
Simuliidae	318	A. borealis	23	Ostracoda	64
Oecetis testacea	305	Simuliidae	13	Leptophlebia marginata	23
Lepidostoma hirtum	302	Tipula sp.	8	Pisidium sp.	22
Leuctra fusca/digitata	283	Nemoura cinerea	7	Empididae indet.	19
Pisidium sp.	240	Collembola	7	Simuliidae	15
Radix balthica	220	Empididae indet.	6	Apatania sp.	14
Amphinemura borealis	199	Pisidium sp.	6	Leuctra hippopus	13

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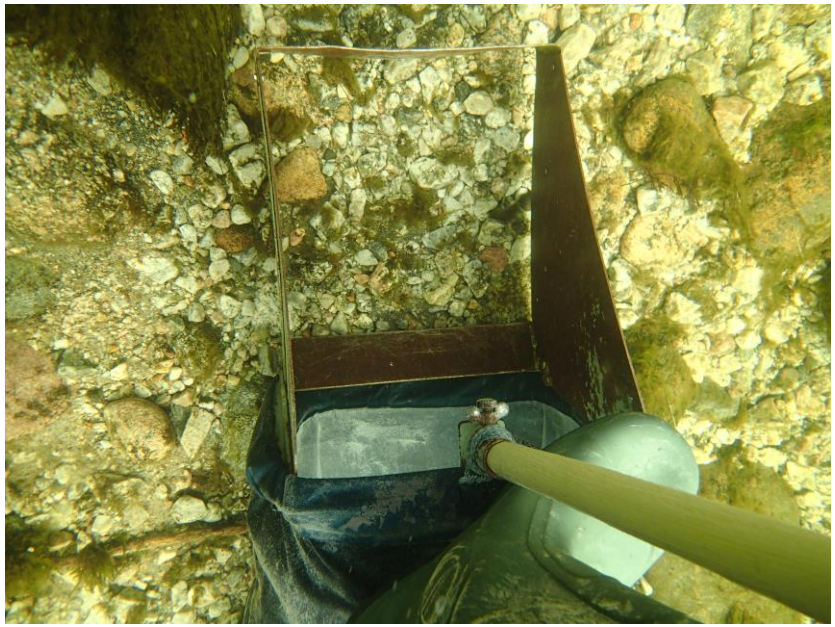
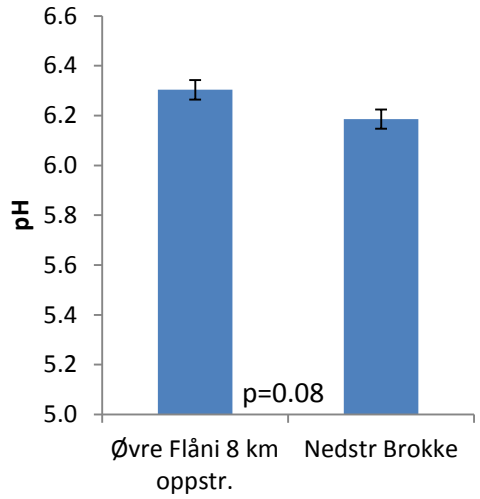
Possible causes

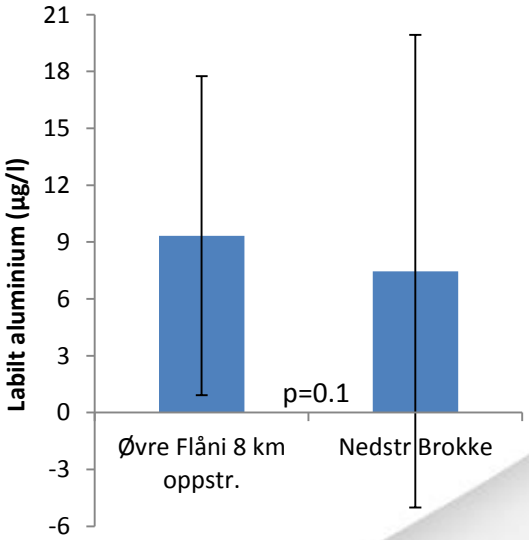
- Substrat



Possible causes

- Substrat
- Water chemistry/ organic load





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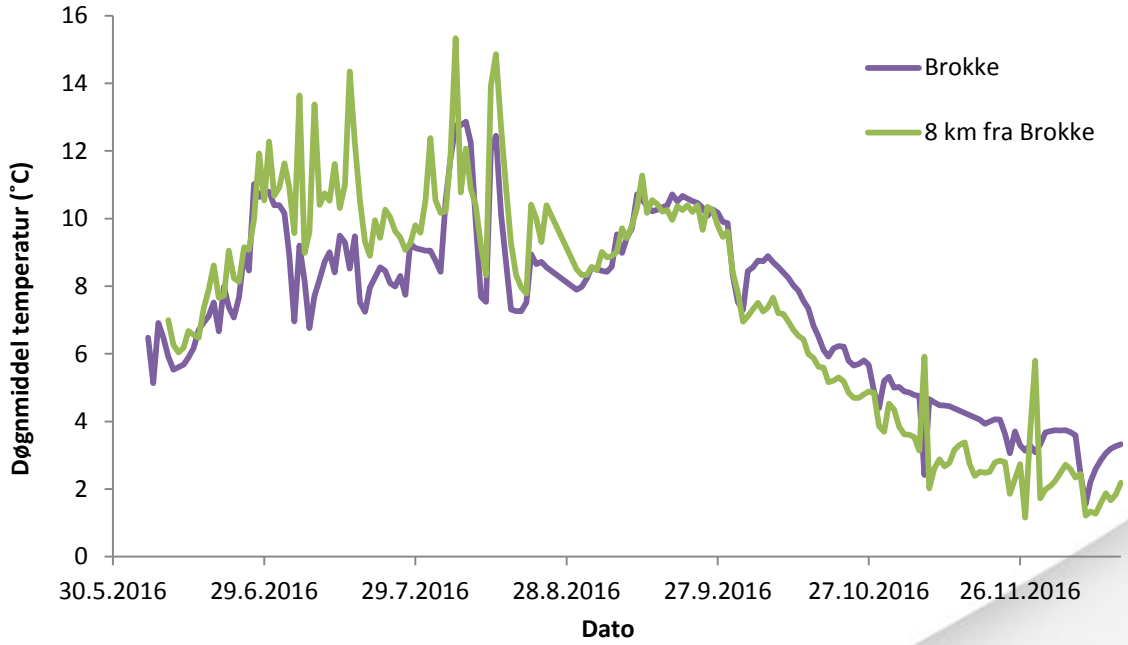
Possible causes

- Substrat
- Water chemistry/ organic load
- Temperature



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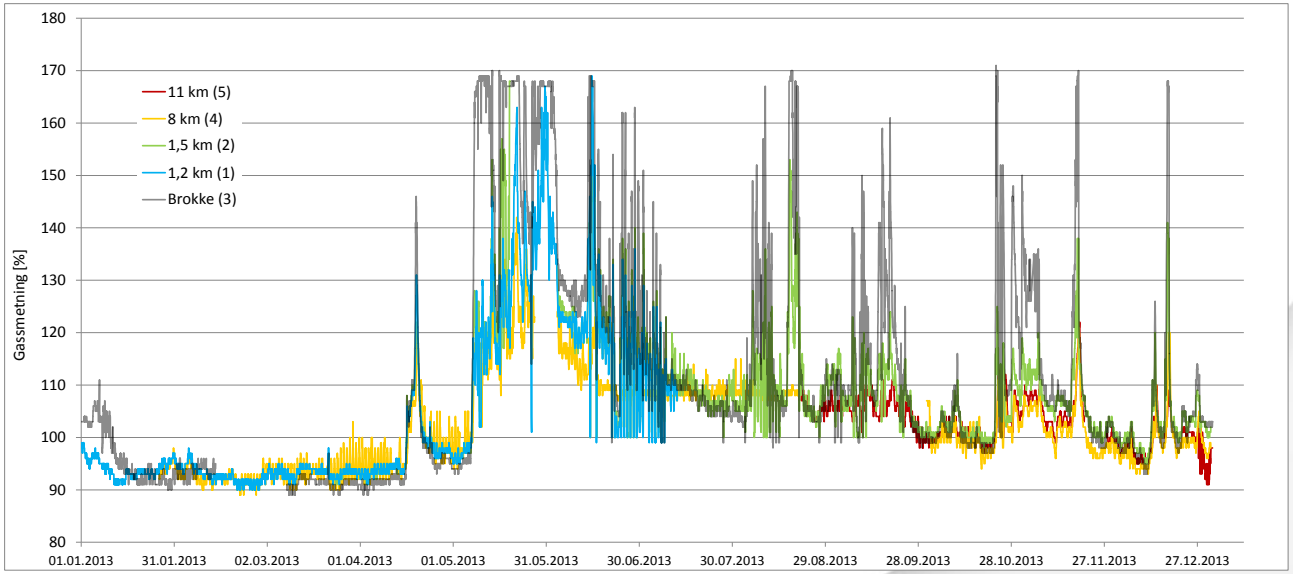
Possible causes

- Substrat
- Water chemistry/ organic load
- Temperature
- Gas supersaturation



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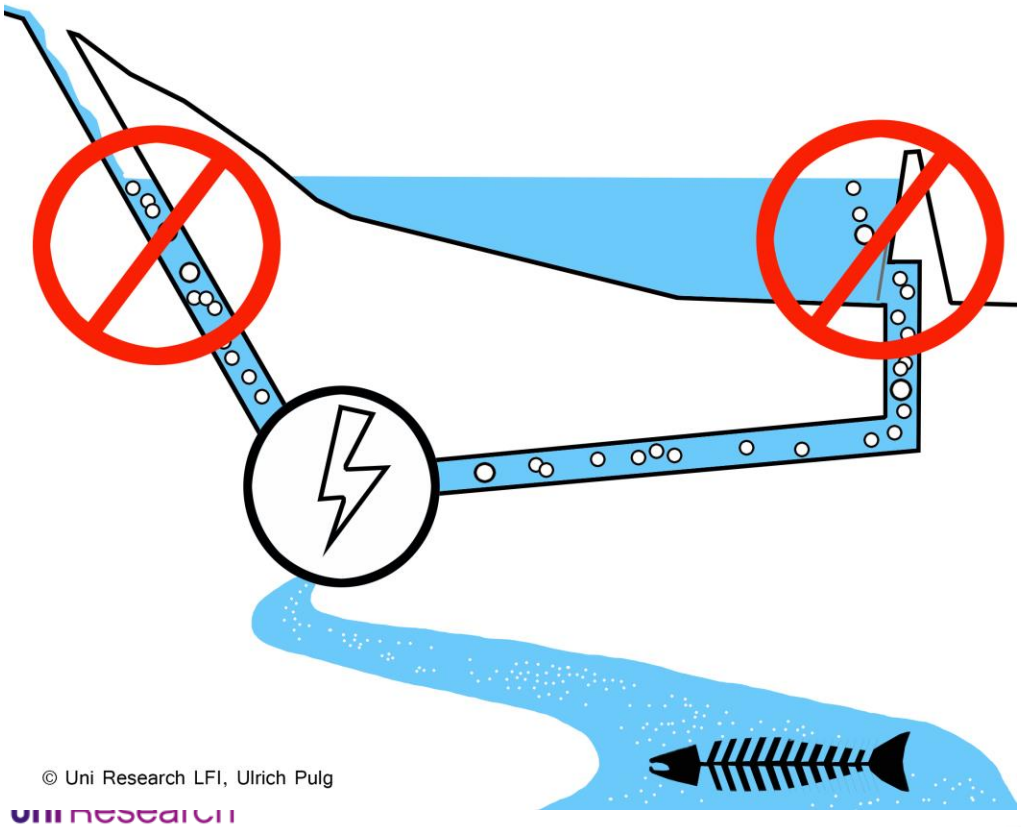
Summary Otra (2011-2016)

110% for > 20 km
100-110% for >30 km
4 km without fish
12 km increased fish mortality
8 km influence on invertebrates



Conclusions

- **Supersaturation may severely influence the the biota**

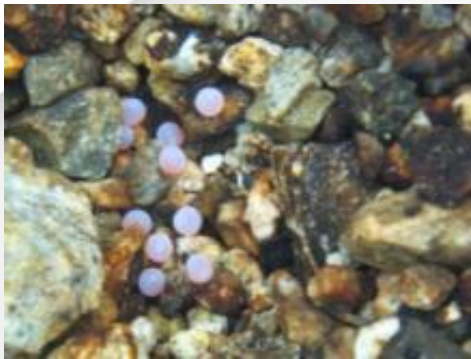
Lack of knowledge

- Occurrence of supersaturation elsewhere
- Effects on benthic animals and zooplankton
- Sub-lethal doses and avoidance behaviour of fish
- *No regulations or awareness exists*

Relevance for ICP waters

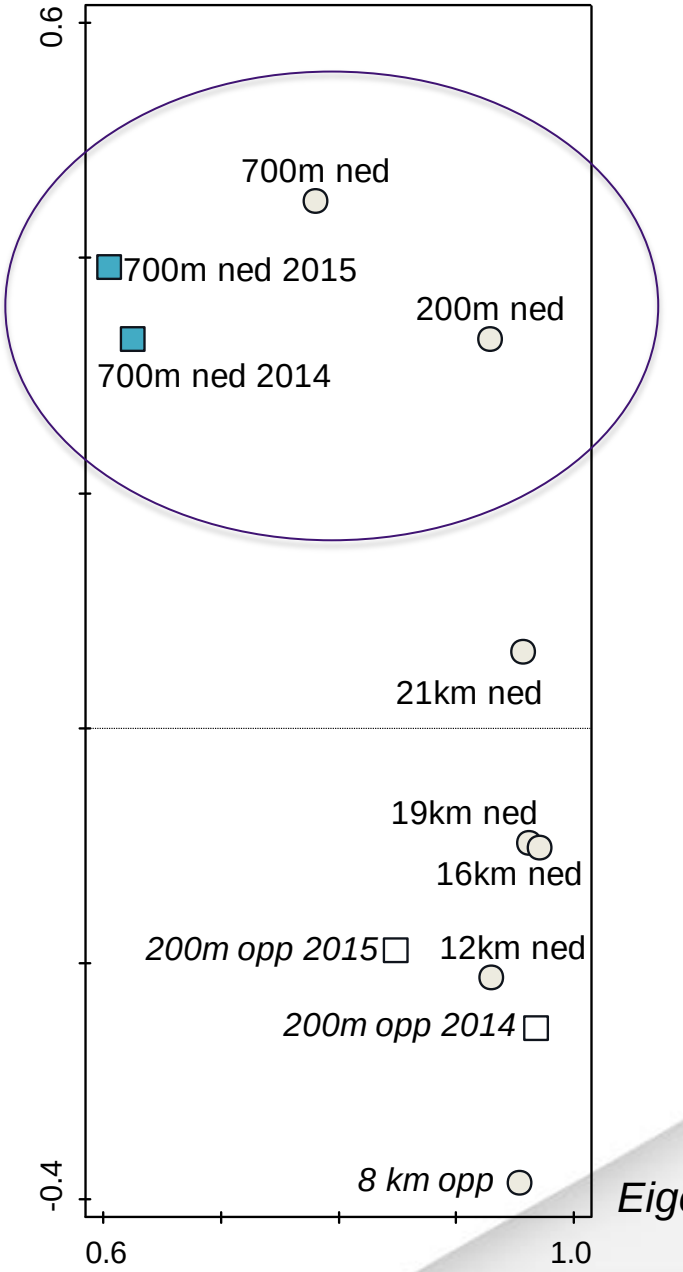
- Biota may indicate acidification when the cause is supersaturation
- May occur downstream from dams and power plant outlets, also downstream of falls?






Thanks for your attention!

Species composition



Eigenvalues: 0.77/ 0.08

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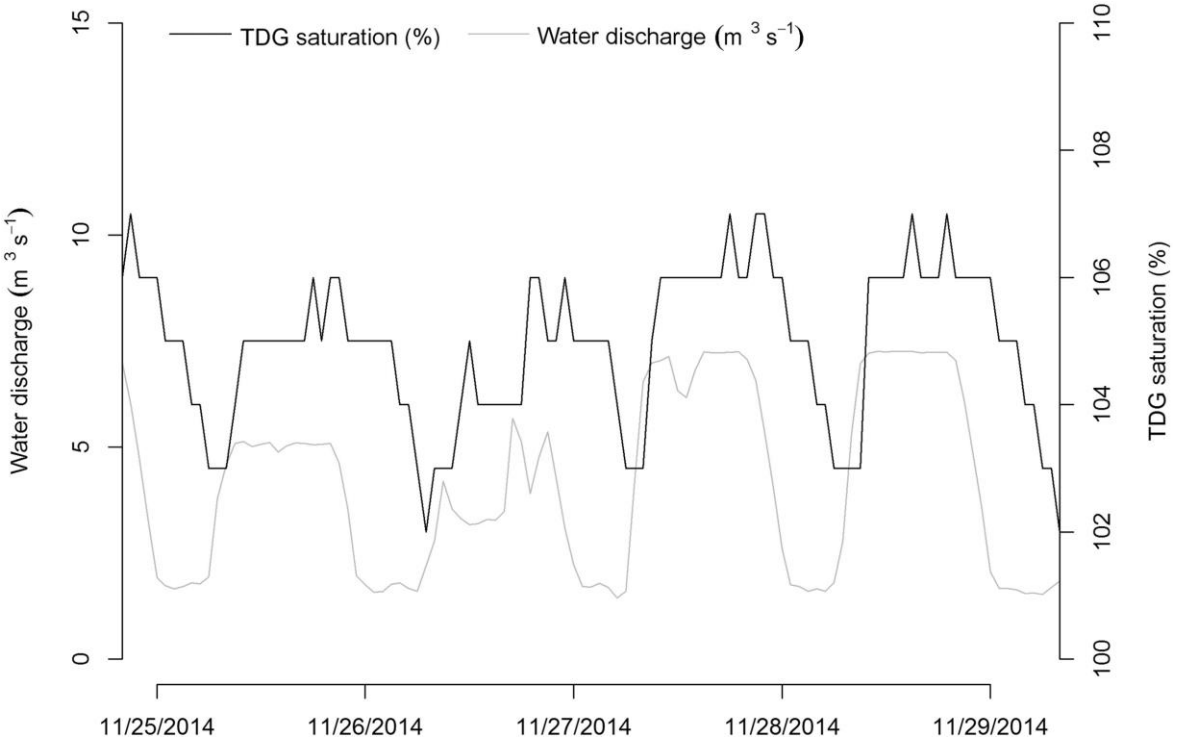
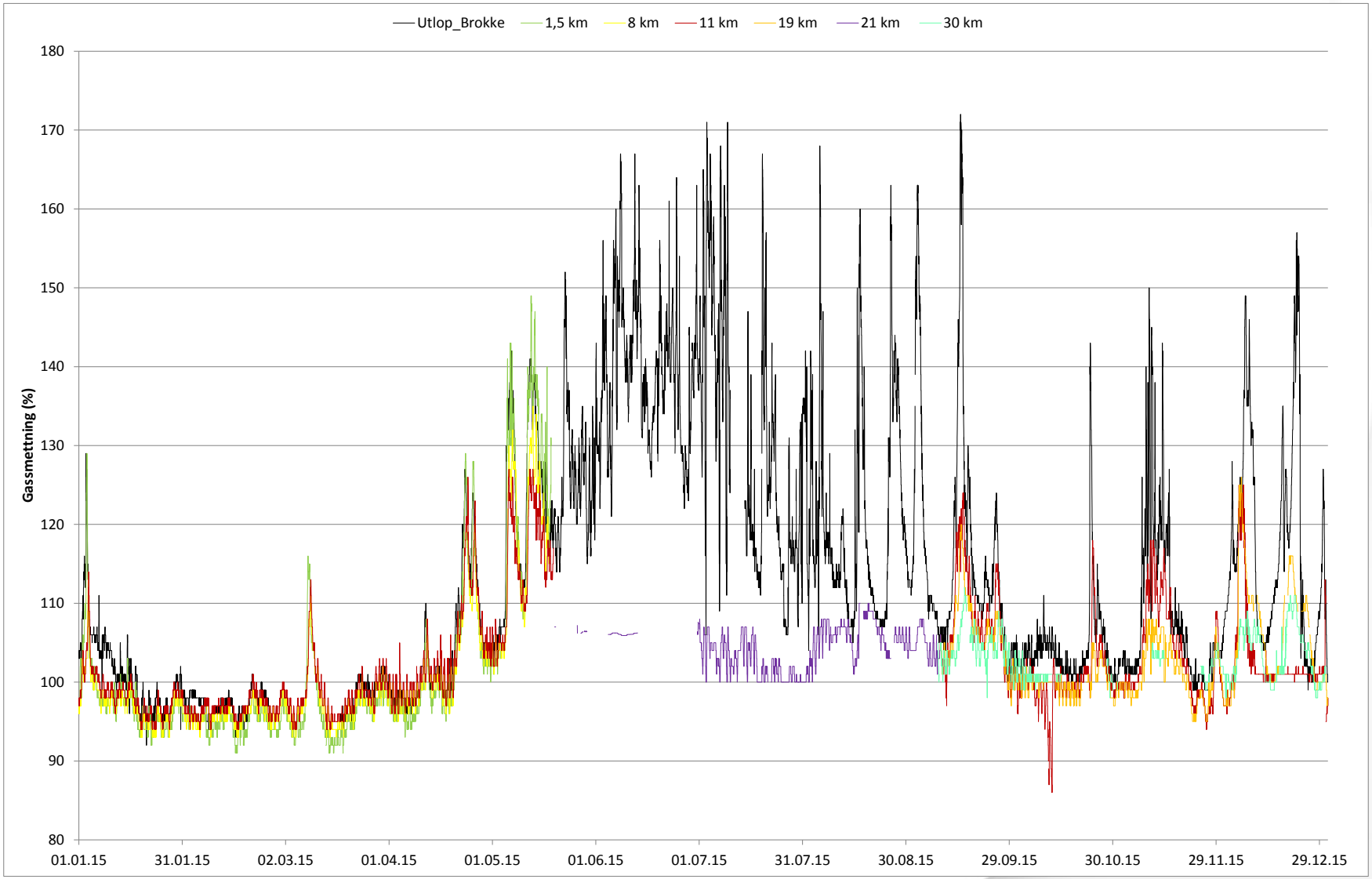


Pulg, Vollset, Velle, Stranzl. (2016). First observations of saturopeaking: Characteristics and implications. *Science of the Total Environment* 573: 1615-1621



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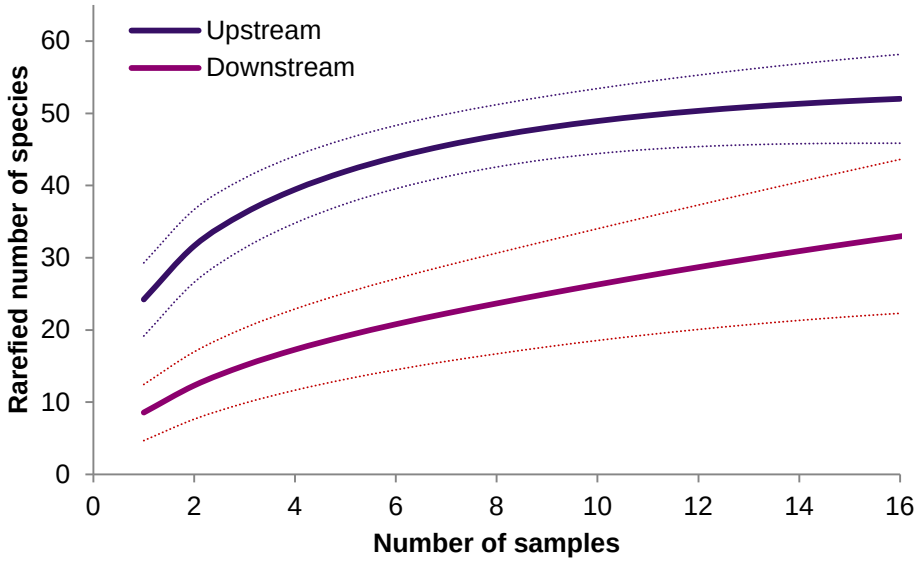
Accumulation curves for species richness



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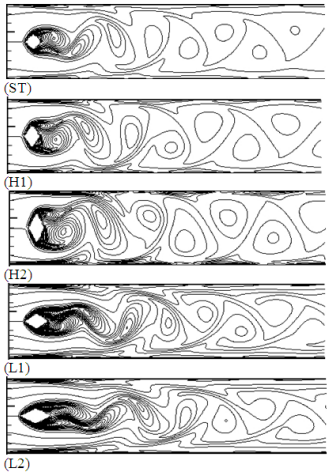
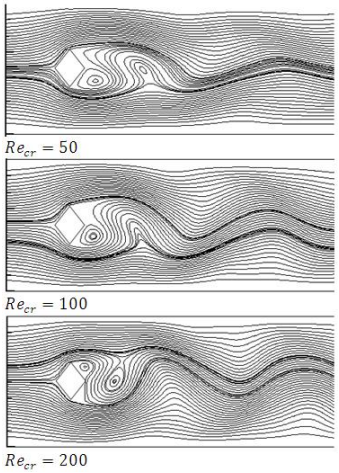
Low Pressure / Variable Pressure Zones in Rivers

Mitigation measure: Pressure Variability due to form drag?

Form drag: Form drag occurs because localized flow separation can create a high pressure upstream from an object and a low pressure downstream in the objects wake (Wohl, 2015). The resulting pressure-gradient force oposes flow and creates viscos energy losses downstream of the object (Tritton, 1988; Roberson & Crowe, 1993).





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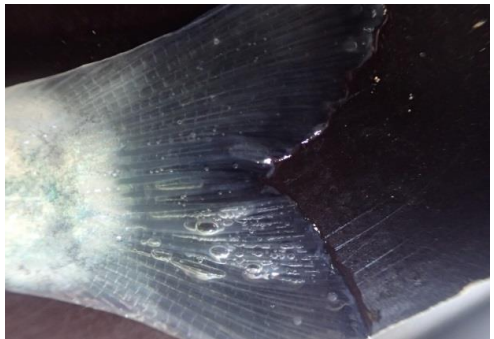
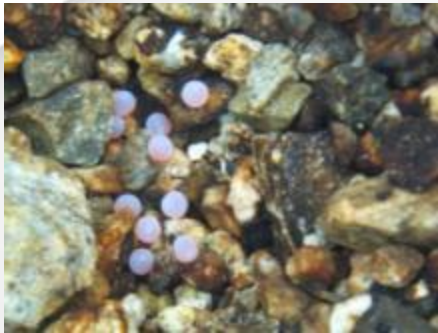
Biological effects from gas supersaturation

Fish

- Gas bubble desease
- Depending on species, life stage and depth
- Fish in hatcheries have increased mortality from 102-103 %
- Fish in rivers experience acute death from 110 %
- Immune system and behaviour influenced below 110%

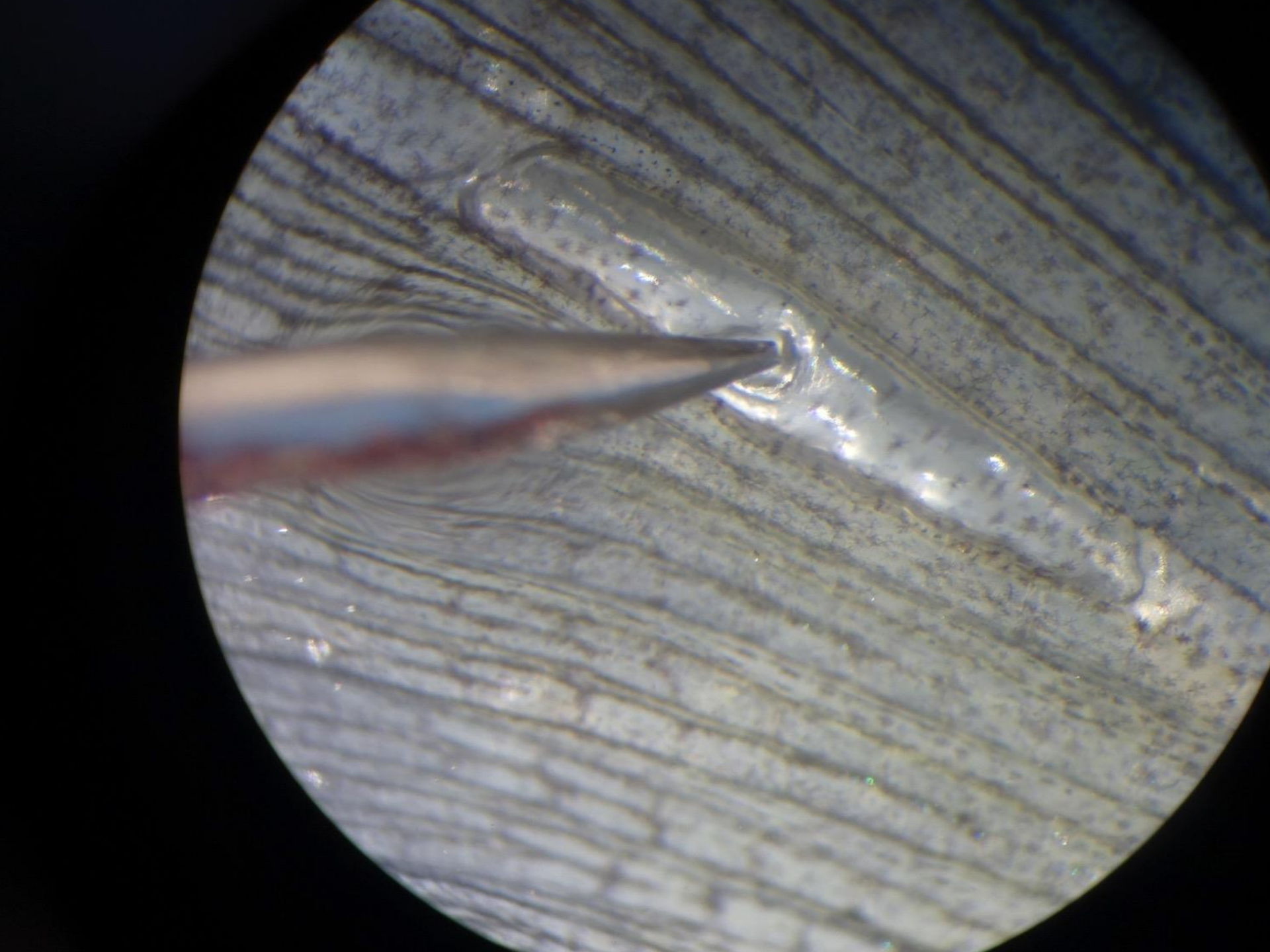




Biological effects from gas supersaturation

Other groups

- Bullfrog 120% (*Rana catesbeiana*, Colt et al. 1984)
- Zooplankton 115% (*Daphnia magma*, (Nebeker et al. 1975).
- Crayfish: 120%-127% (*Orconectes limosus*, Nebeker et al. 1976)
- Stoneflies: 130% (*Acroneuria californica, A. pacifica, Pteronarcys californica*)
- Aquatic plants: no data– buoyancy effects? CO2- boost?



Tiltak mot gassovermetning

- Gjøre noe med kilden; Vanskelig å isolere hvilke inntak til Brokke som bidrar mest til overmetningen
- Opprettholde loggestasjoner som beskriver situasjonen med fravær/forekomst av gassovermetning – bestemme influensområde (rom & tid)
- Hvordan responderer fisk og bunndyr på eksponeringen – unnviklsesatferd?
- Kartlegge influensområdet nedstrøms Tjurrmodammen dvs. hvilke deler av blekas nåværende utbredelsesområde er påvirket – 2 km - 12 km
- Miljøbasert kjøring av Hekni dvs. planlegg stans i Hekni i perioder uten gassovermetning slik at restfeltet ikke får overmettet vann (Uni kan utrede når det er gassovermetning og anbefale konkrete kjøreregler)- allerede innført?
- Tiltak med å lufte ut gassovermettet. Mulighet for utgassing på fallstrekningen nedstrøms Brokke. Uni anbefaler dette og kan sammenfatte eksisterende data fra mange vassdrag og fra litteratur for å bestemme potensialet.

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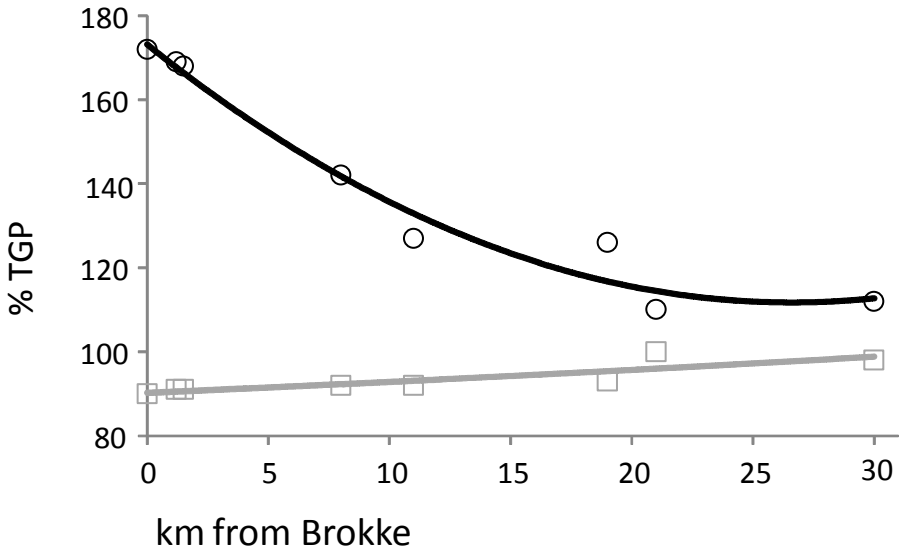
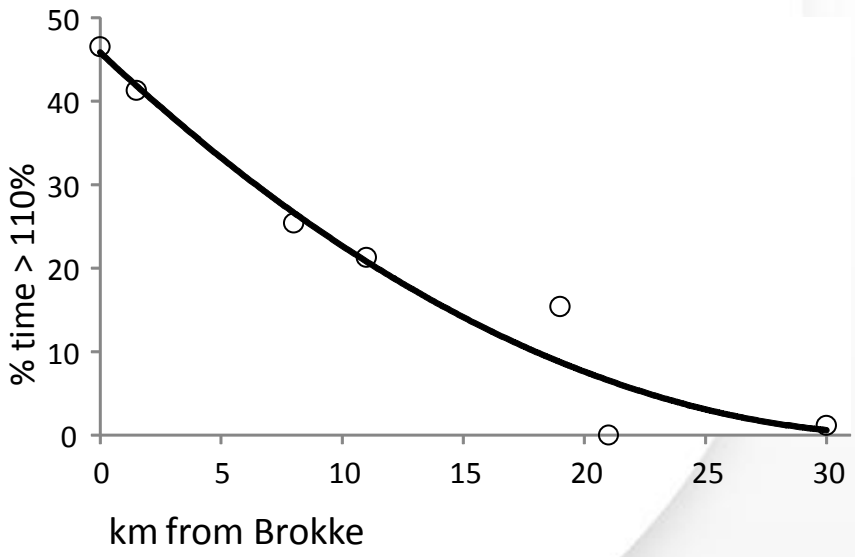
Wave characteristics, aeration, dilution





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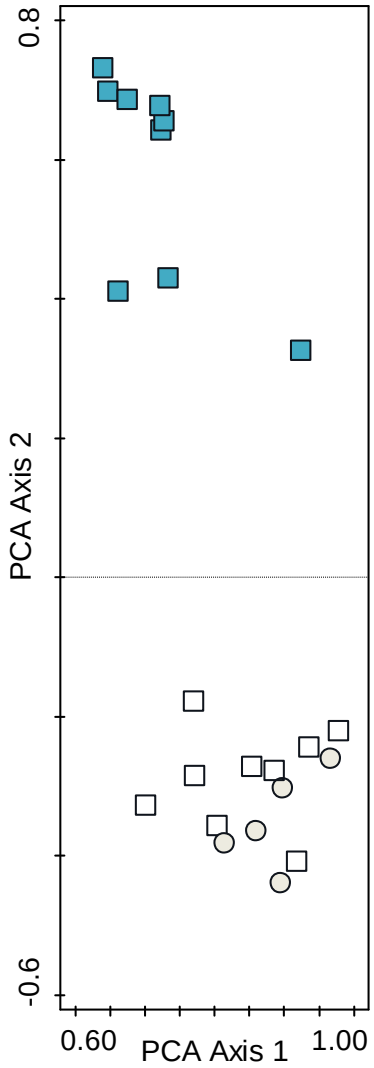

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