



Norwegian University
of Life Sciences



CERAD

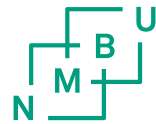
CENTRE FOR ENVIRONMENTAL RADIOACTIVITY



Norwegian
Meteorological
Institute



Statens strålevern
Norwegian Radiation Protection Authority



ICCE 2017, Oslo

Uranium -speciation, uptake and toxicity towards Atlantic Salmon (*Salmo salar*).

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in collaboration with

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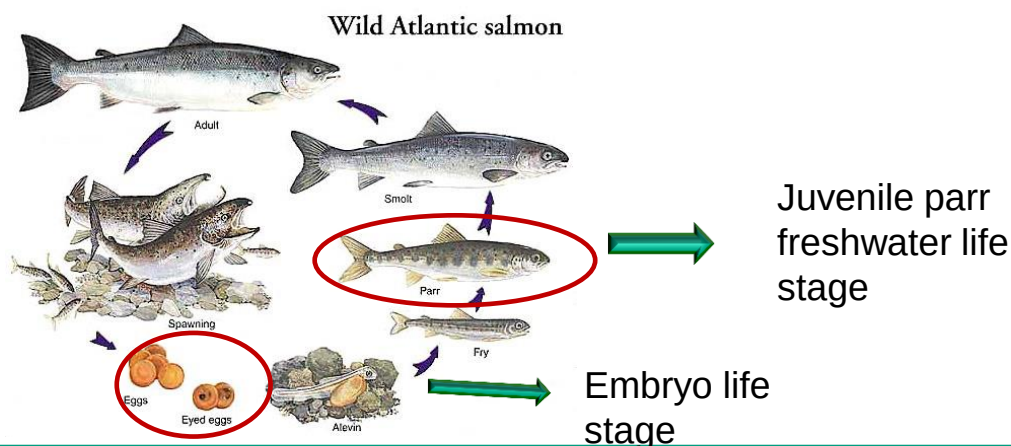
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Take home message

- Atlantic salmon – high commercial value, sensitive life stages
- Toxic effects of U is dependent upon speciation, uptake and lifestage
- Uranium is taken up from water in juveniles and into fish eggs
- Early developing embryos is more sensitive than juveniles
- Molecular responses are linked to adverse outcomes
- Uranium causing oxidative stress, is genotoxic and affecting the development.
- Uranium affects the gills and causing ionregulation problems in fish

Uranium effects in Atlantic salmon

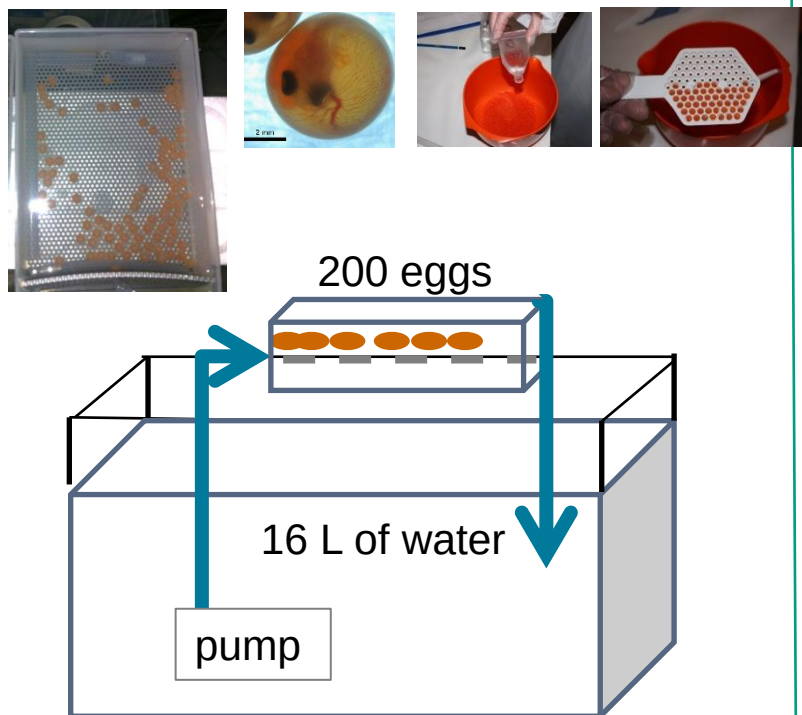
- Uptake of U in juveniles were determined at different water pH to determine impact of U speciation on bioavailability.
- U was determined in liver of juveniles and inside eggs to demonstrate transfer.
- Effects at individual level and changes in biomarker at molecular level were used to identify stress-responses induced in Atlantic salmon
-embryos and juveniles



Uranium model experiment with Atlantic salmon

Atlantic salmon embryos

Chronic exposure - 90 days at 6 °C (OECD 210)

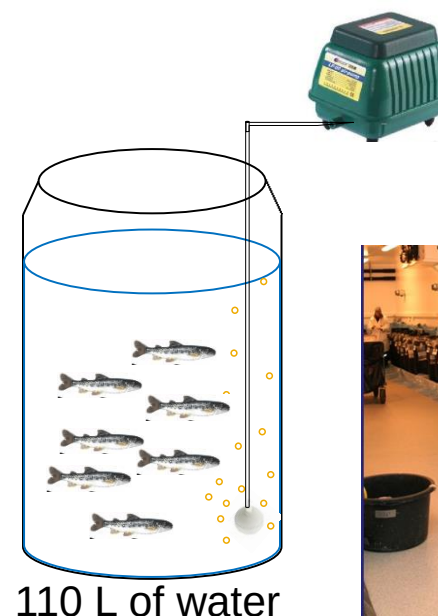


Atlantic salmon juvenile parr

Acute exposure- 96hrs (OECD 210)

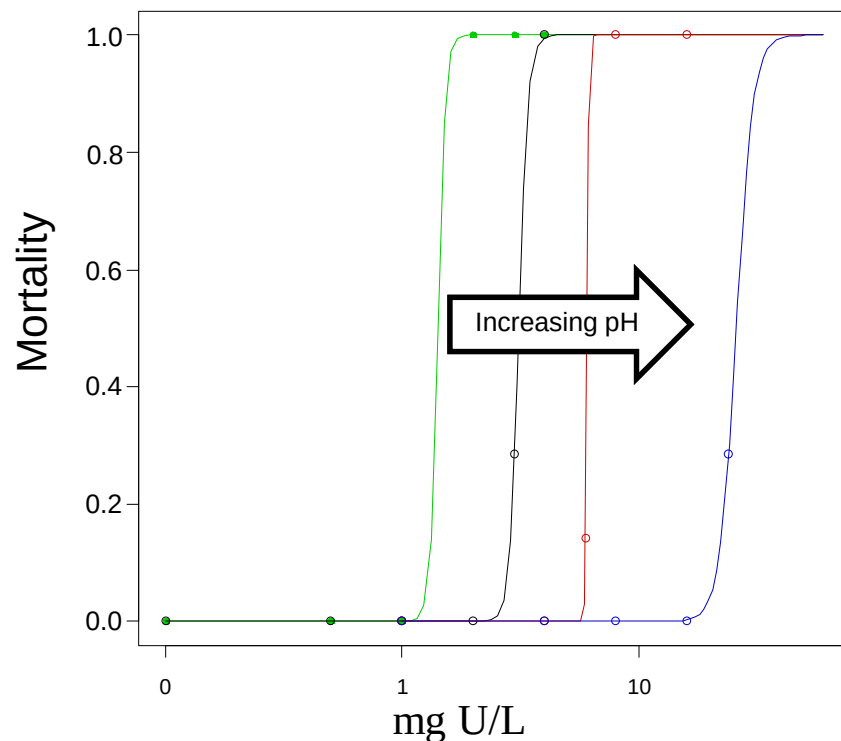


7 fish of 15.4 ± 0.8 g



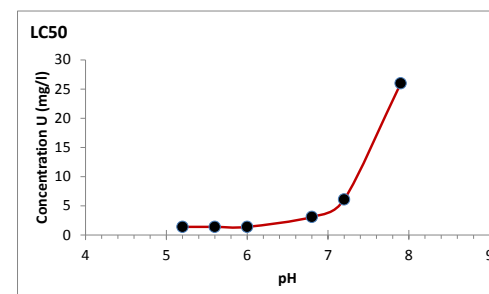
Water: US EPA very soft water, $\text{UO}_2(\text{NO}_3)_2 \times 6\text{H}_2\text{O}$ dissolved

Toxicity of U depend upon pH (H^+):

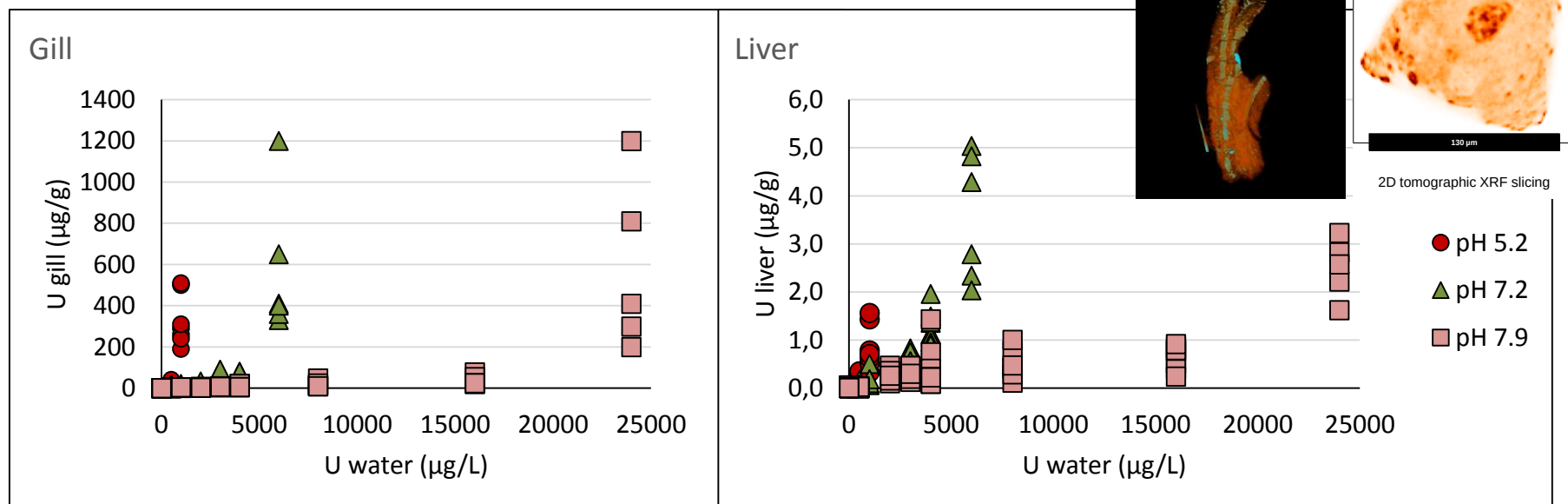


- pH 5.2, 5.6 and 6.0
- pH 6.8, Medium Na
- pH 7.3
- pH 7.9

pH	U LC ₅₀	
	mg/L	μM
5.2	1.4	6.0
5.6	1.4	6.0
6.0	1.4	6.0
6.8	3.1	13
7.3	6.1	27
7.8	26	109



U accumulation in fish, eg. gills and liver

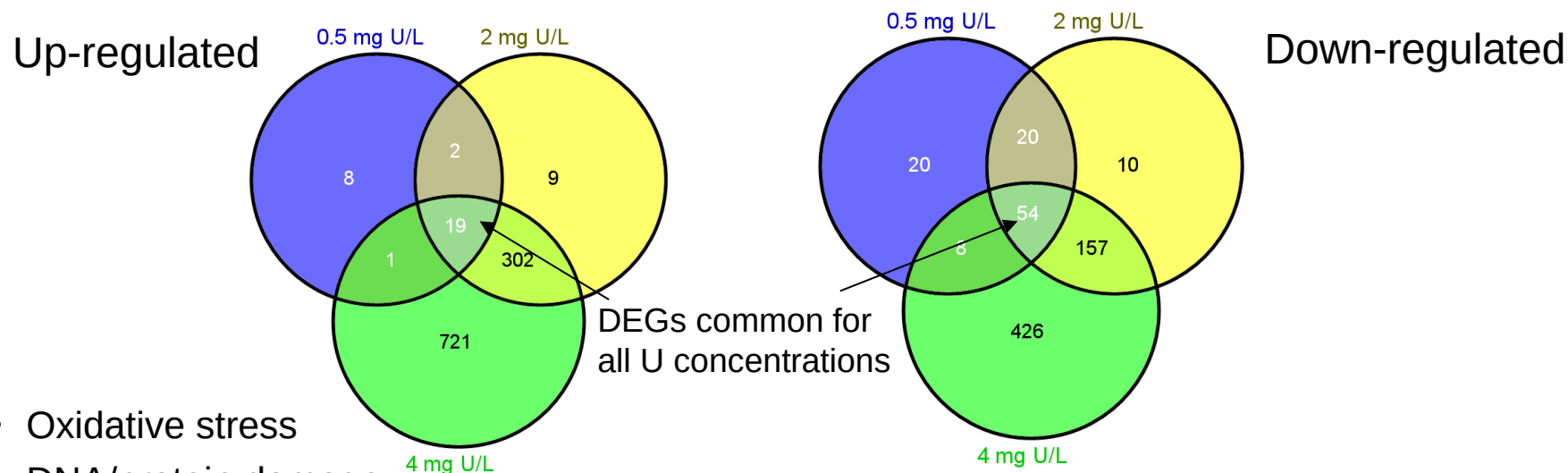


- U is taken up in gills. SR XRF imaging at Petra P06 demonstrate U distribution in gills of juveniles
- Uptake of U in gills and in liver also dependent upon pH and U concentration in water
- Similar trend in liver as in gills

Main modes of action identified due to differentially expressed genes (GO function and toxic pathways)

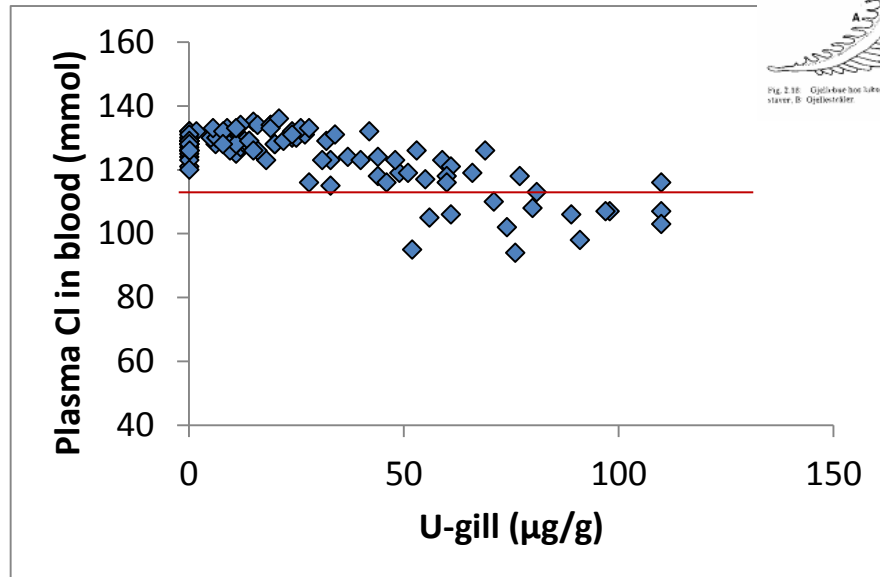


0.5 mg U/l water		2 mgU/l water		4 mg U/L	
9.6 µg U/g gill		20 µg U/g gill		138 µg U/g gill	
Up-regulated	Down-regulated	Up regulated	Down-regulated	Up regulated	Down-regulated
20	102	332	241	1043	645

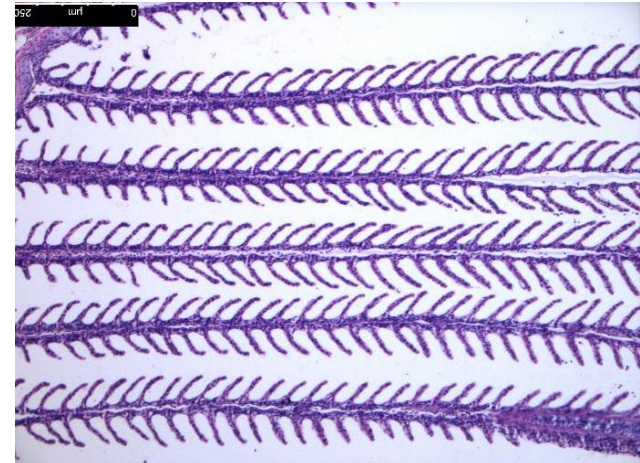


- Oxidative stress
- DNA/protein damage
- Mitochondrial disturbance (electron transport chain and membrane potential)
- Immune system
- Ion transport
- Metabolism

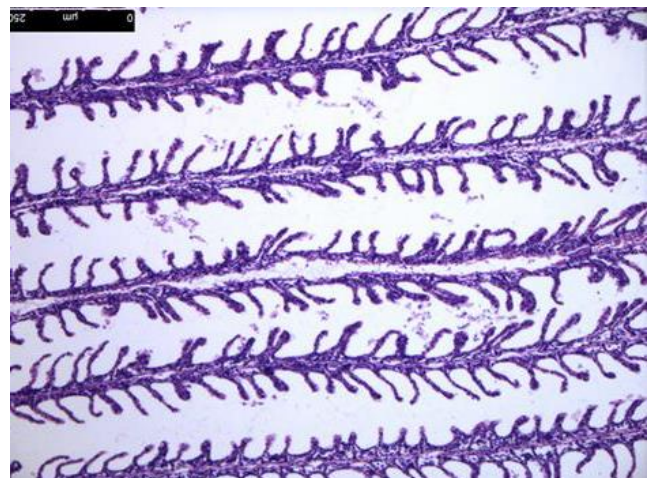
U causing pathological changes in gills



Control pH 5.5 (0.02 µg/g gill)

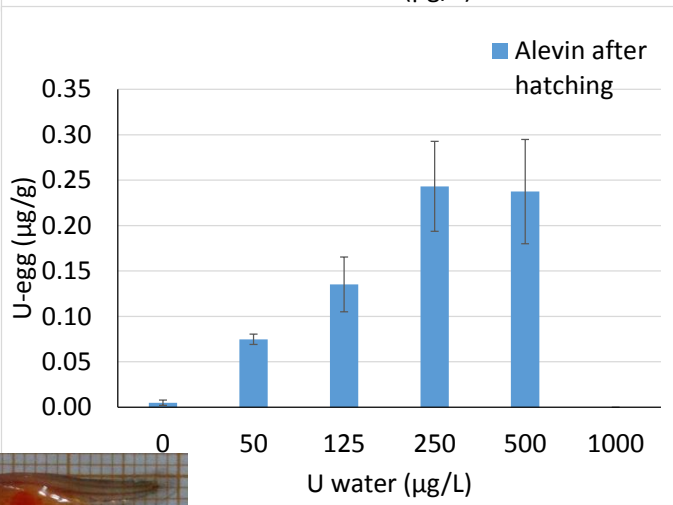
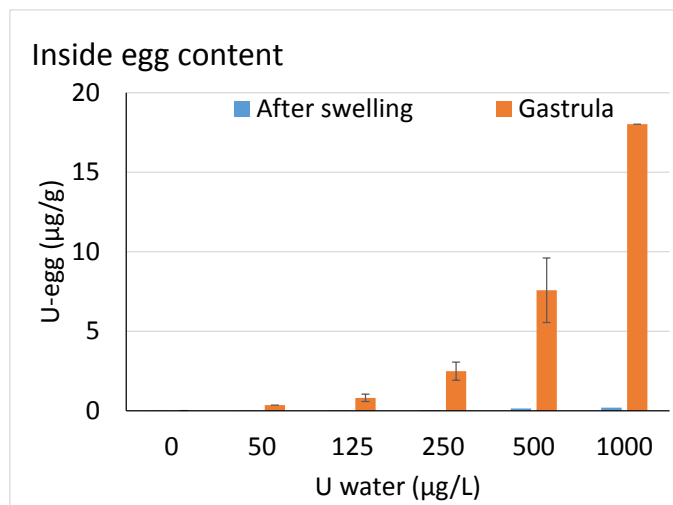
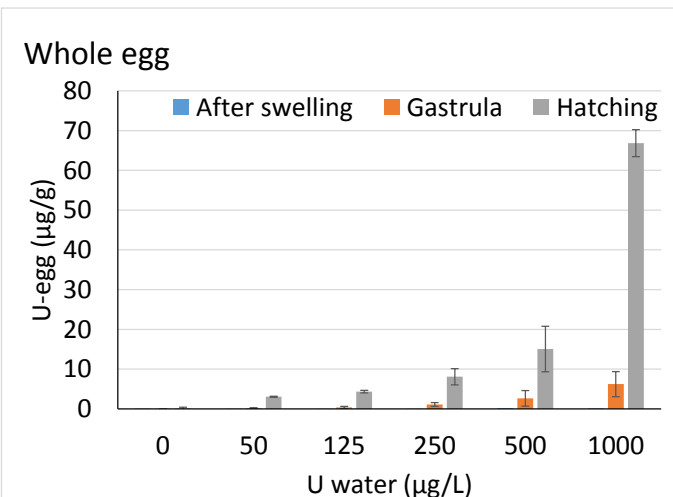


1 mgU/L at pH 5.5 (328 µg/g gill)

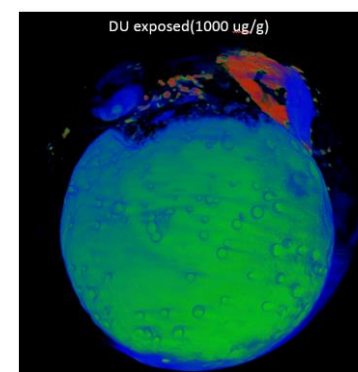
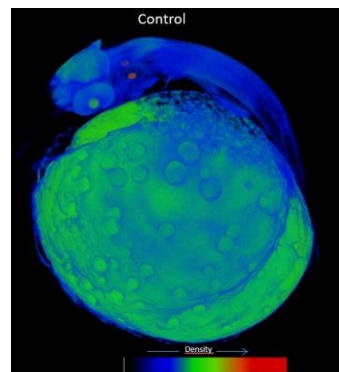


- Uranium exposure affecting the gills and causing ion regulation problems
- Effects correlate with U-gill concentration independent upon water concentration

U is taken up in eggs

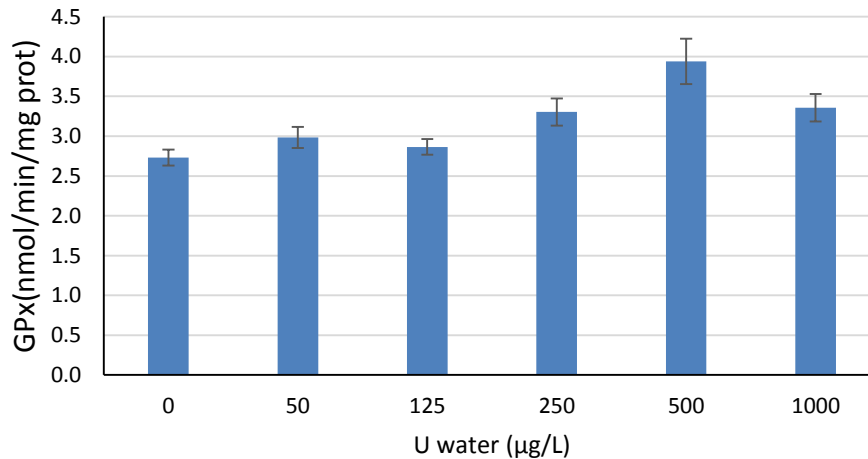


- U is taken up inside egg and concentration increase with time and is present in alvin after hatching
- Nano-CT identify the U distribution in eggs



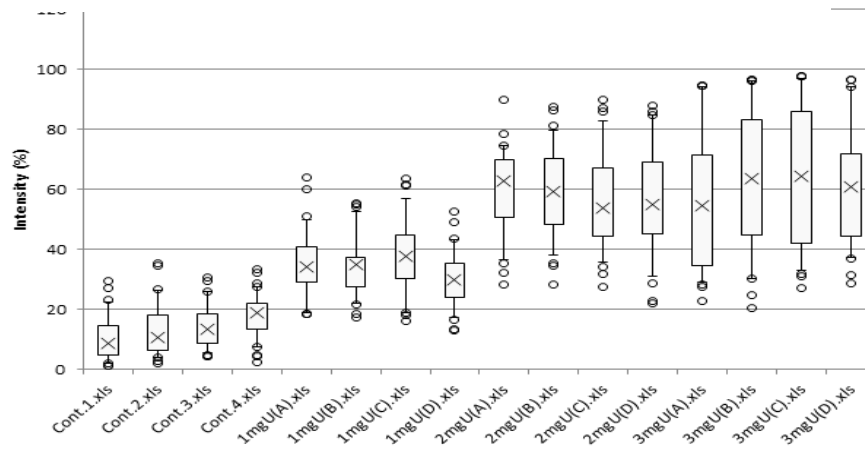
Mechanism of U toxicity in embryo

GPx



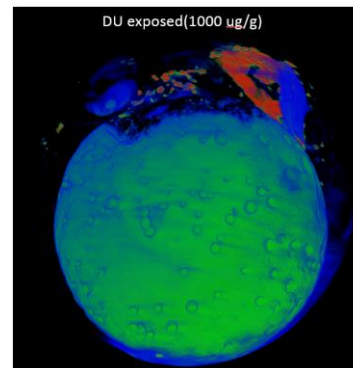
- Change in ROS enzymes activity indicate that U induce ROS
- Comet assay indicate that U is genotoxic

Comet assay-embryos

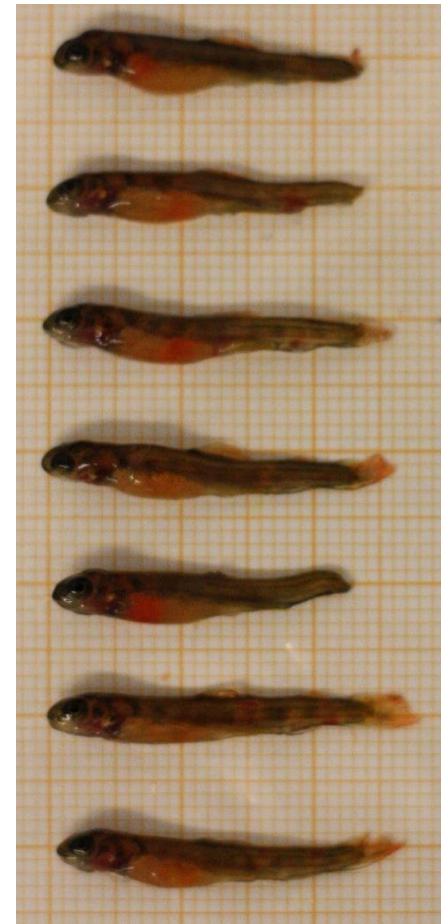


U toxicity - embryo development

- U affecting the development of eggs:
 - 100% mortality observed at 1000 $\mu\text{g U/L}$
 - Earlier hatching of eggs observed at 500 $\mu\text{g U/L}$
 - Tailfin deformities



500 $\mu\text{g/L}$



Conclusion

- pH and U concentration are factors influencing the U bioavailability
- The uptake of U in tissues correlate with U toxicity
- Embryos were more sensitive when exposed to U than juveniles
- Uranium causing oxidative stress and is genotoxic, and affecting the development of embryos and causing acute ionregulation failure at high concentration in juveniles
- Responses at the molecular level are linked to pathological changes/ adverse outcome: ionregulation failure, development, mortality

Challenges:

- Extrapolation of results from lab to the field.
- Field experiments are essential- should insert clean fish in contaminated water.