Costs, benefits and consequences of lake restoration - Lake Hjälmaren as an example

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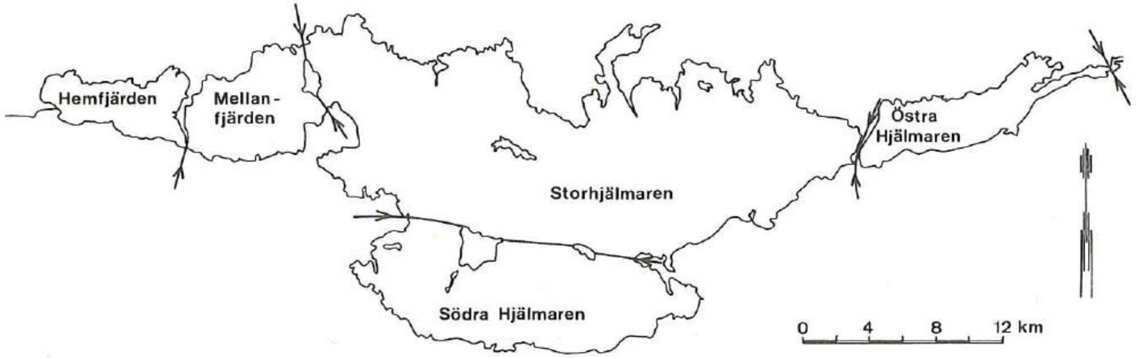
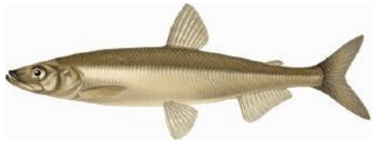
naturvatten

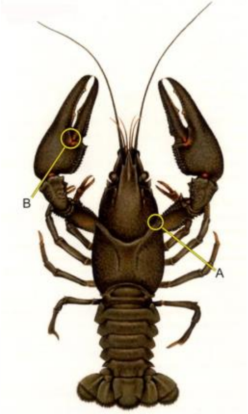
Lake characteristics

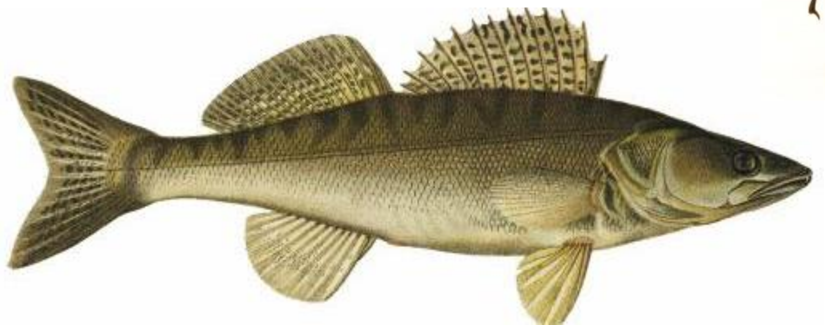


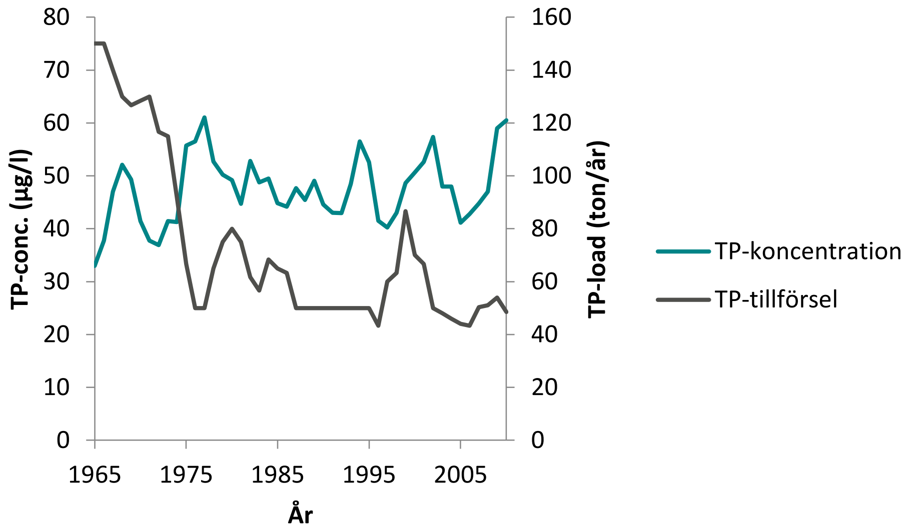
- Sweden's fourth largest lake (surface area≈500 km^2)
- Relatively high density of farming areas in the catchment. The lake was lowered by 2 m in the late 1800s to gain more arable land (200 km^2 of lake surface area was lost)
- Nutrient rich, TP≈40 µg/l, but difficult to establish ”natural” background levels in shallow lowland lakes, the environmental goal set to ≈20 µg/l
- Commercial fishing mainly, pikeperch and crayfish, smelt (nors) the dominating prey fish

T_w≈3,5 yr
D_m≈6 m
Secchi depth≈2m
Oxic bottom water

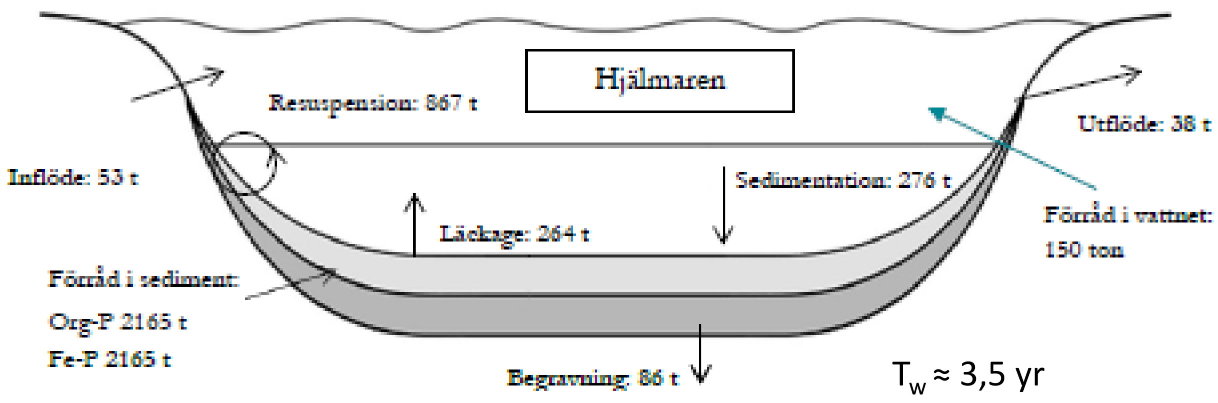


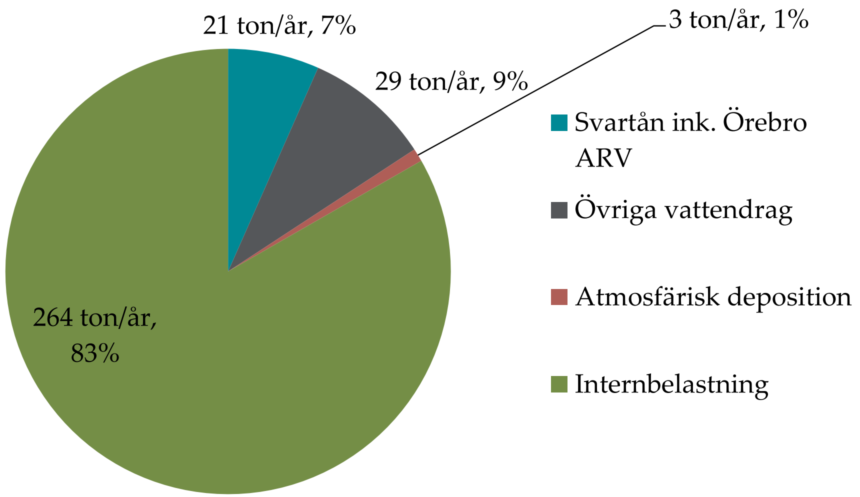






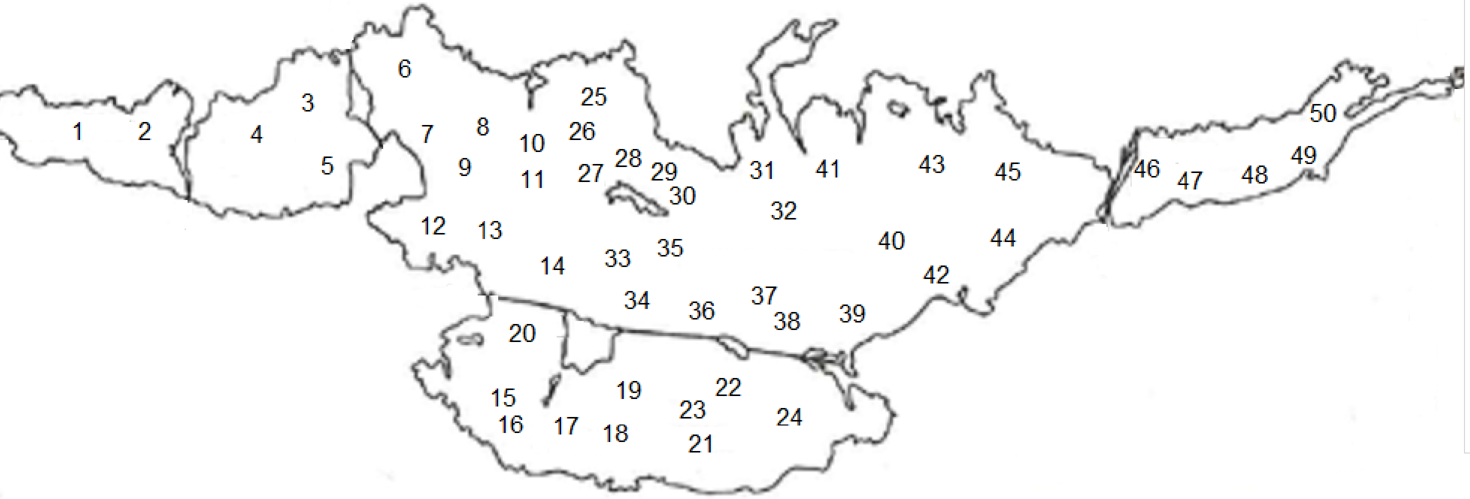
Drastic reduction in TP-load in the early 1970s mainly due to improved sewage treatment at Örebro municipality STP but no effect on the TP-concentration in the central basin. Data from Hjälmarens vattenvårdsförbund

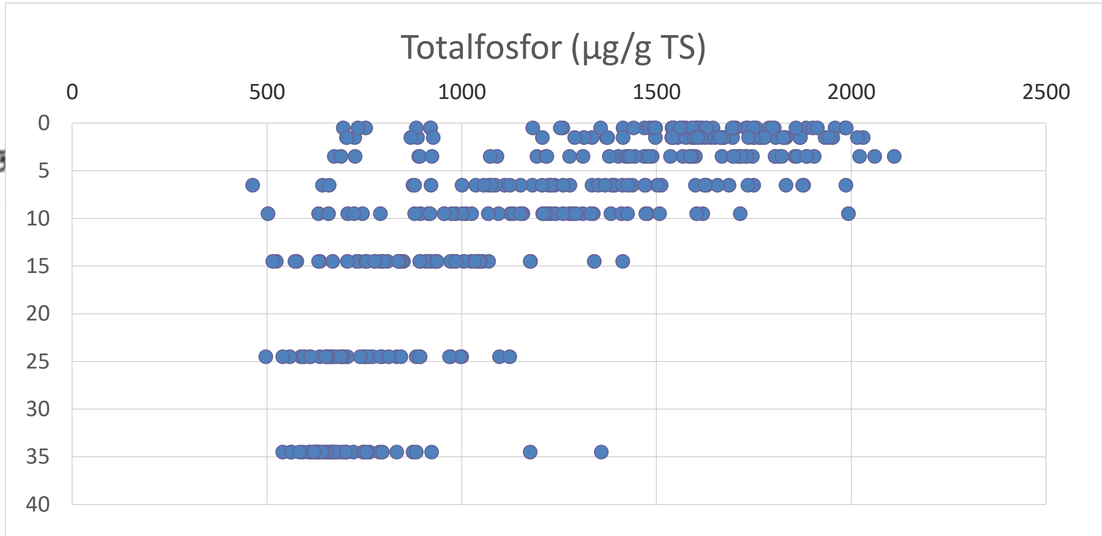


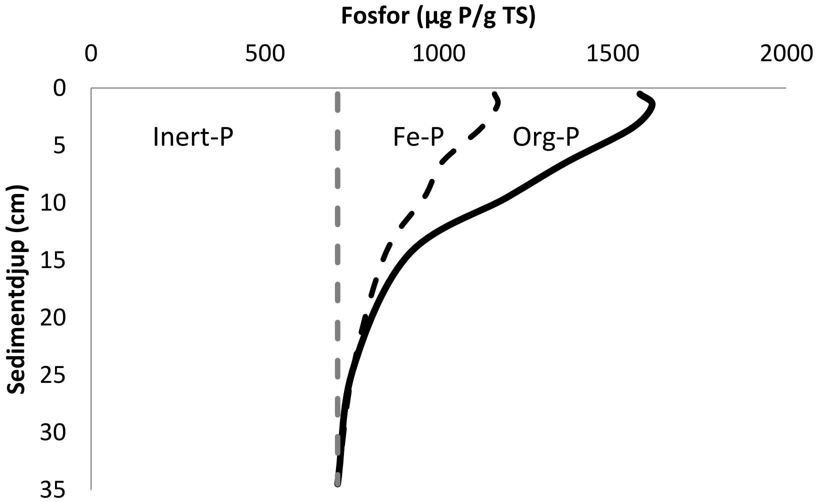


Model calculations suggest that internal loading is the dominant TP source (Malmaeus & Karlsson, 2015)

Mobile TP-content estimated to ~ 4 000 tonnes

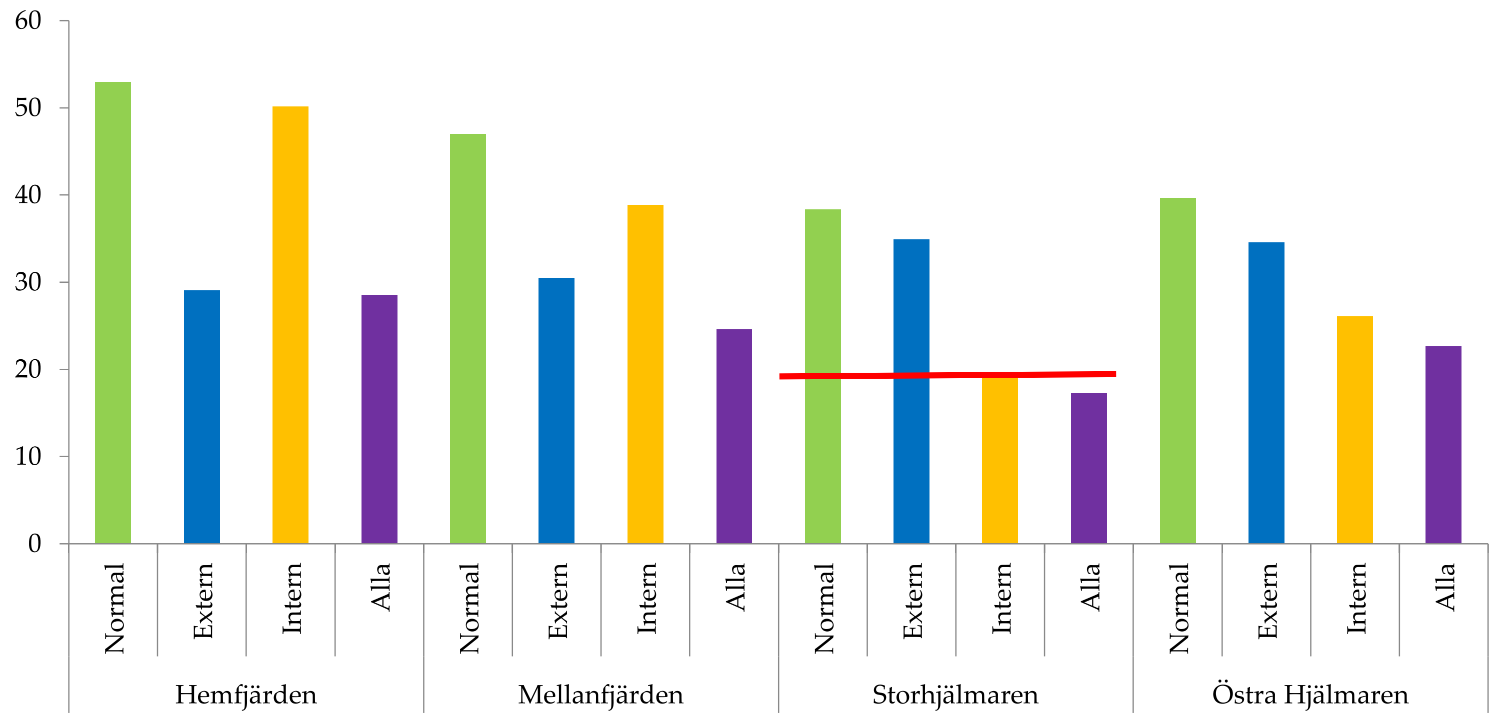






Malmaeus & Rydin, 2015

To achieve the environmental goal in the central basin ~ 50 % of the internal load has to be cut off ↔immobilise 2 000 tonnes Mob-P



Malmaeus & Karlsson, 2015

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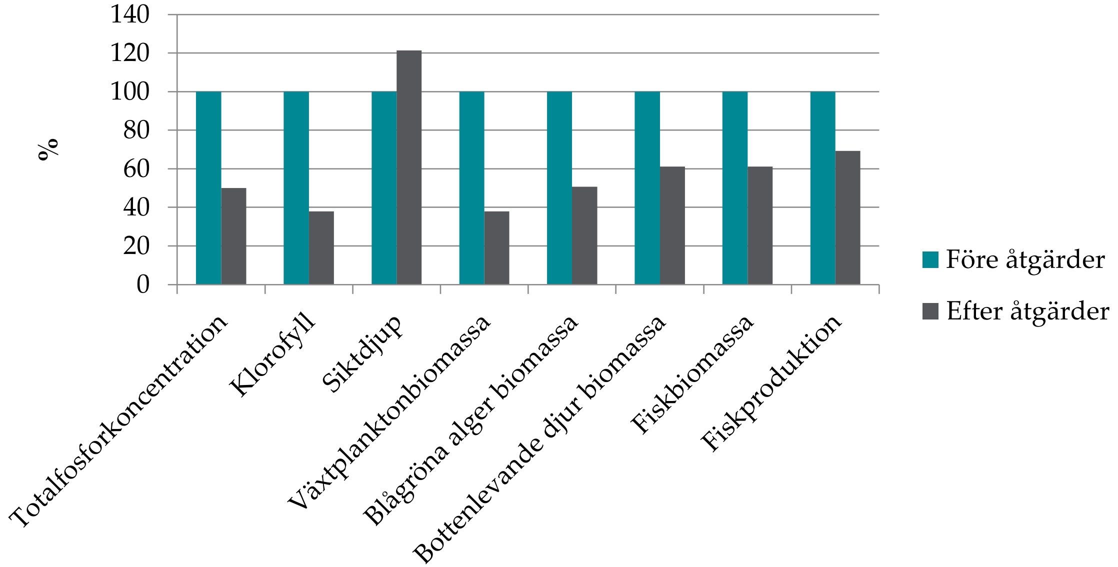
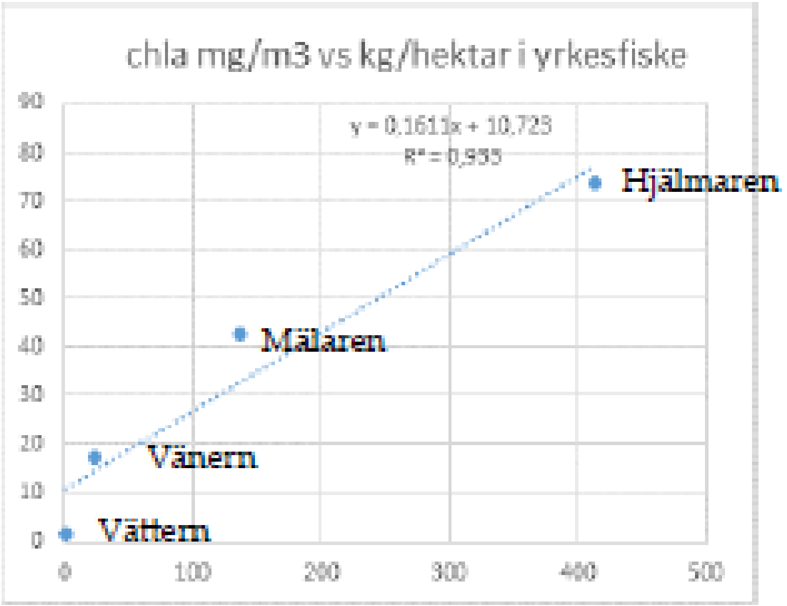
Effects of TP-reduction





Decreased Chl-levels (13→5µg/l) increased Secchi depth (2→2.5 m) decreased biomasses and production of various functional groups within the aquatic food web. Based on statistical relationships Peters et al., 1986; Downing et al., 1990; Sandström et al., 2016

Reducing the nutrient levels may lead to smaller catches of pikeperch. Example from the four large lakes of Sweden. From Sandström et al., 2016

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Investigated mitigative actions

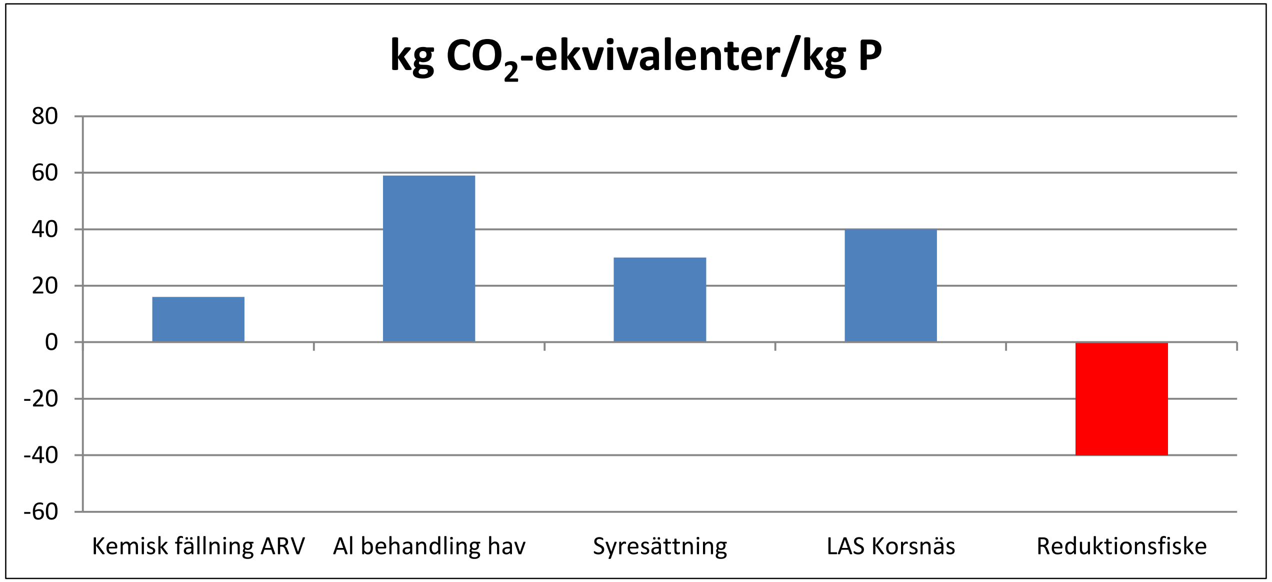
- Aluminum treatment
- Conventional dredging
- Low-flow dredging
- Reduction fishery

Other not evaluated measures

- Oxygenation/enhanced mixing
- Hypolimnetic withdrawal
- Mussel cultivation (*Dreissena Polymorpha*)
- Precipitation with other agents
    - iron
    - calcium
    - Phoslock

Life cycle assessment (LCA)

- assess environmental impacts associated with all the stages of a product’s or process life stages
- compare the climate impact (CO_2-emissions) for the investigated P-removing techniques, taking into account raw materials, production, transports, operation and maintenance of these.
- functional unit the removal of 1 kg mobile phosphorus



Example from Gävle, Bothnian Sea, Karlsson et al., 2012

Aluminum treatment

- By far, the most accurate estimations compared to the other investigated measures
- Dosage, 200 km^2, 50 g Al/m^2 → 100 000 tonnes Al-salt

↔ 100 years consumption of the same chemical at Örebro municipal STP

- Costs, 500-600 MSEK in total,~500 SEK/kg Mob-P
- CO_2-emissions (mainly from production of chemicals) 75 000 tonnes ↔ 5 % of Örebro County yearly emissions
- Low risk for toxic effects from Al in Lake Hjälmaren

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Conventional dredging

- Simply removing the top 10 cm of the sediment pack from accumulation areas for cohesive fine matter. Bring it ashore , dewater, stabilise and dump on a landfill would generate approximately 20 Mm^3 of dredged material ~ 50 times more than the new harbour under construction in Gothenburg
- Costs (uncertain) ≈ 2 BSEK (assuming no costs for handling hazardous substances), 1 000 SEK/ kg Mob-P
- CO_2-emissions same order of magnitude as Al-treatment
- Dredged matter could possibly be utilized as a fertilizer/ soil improver

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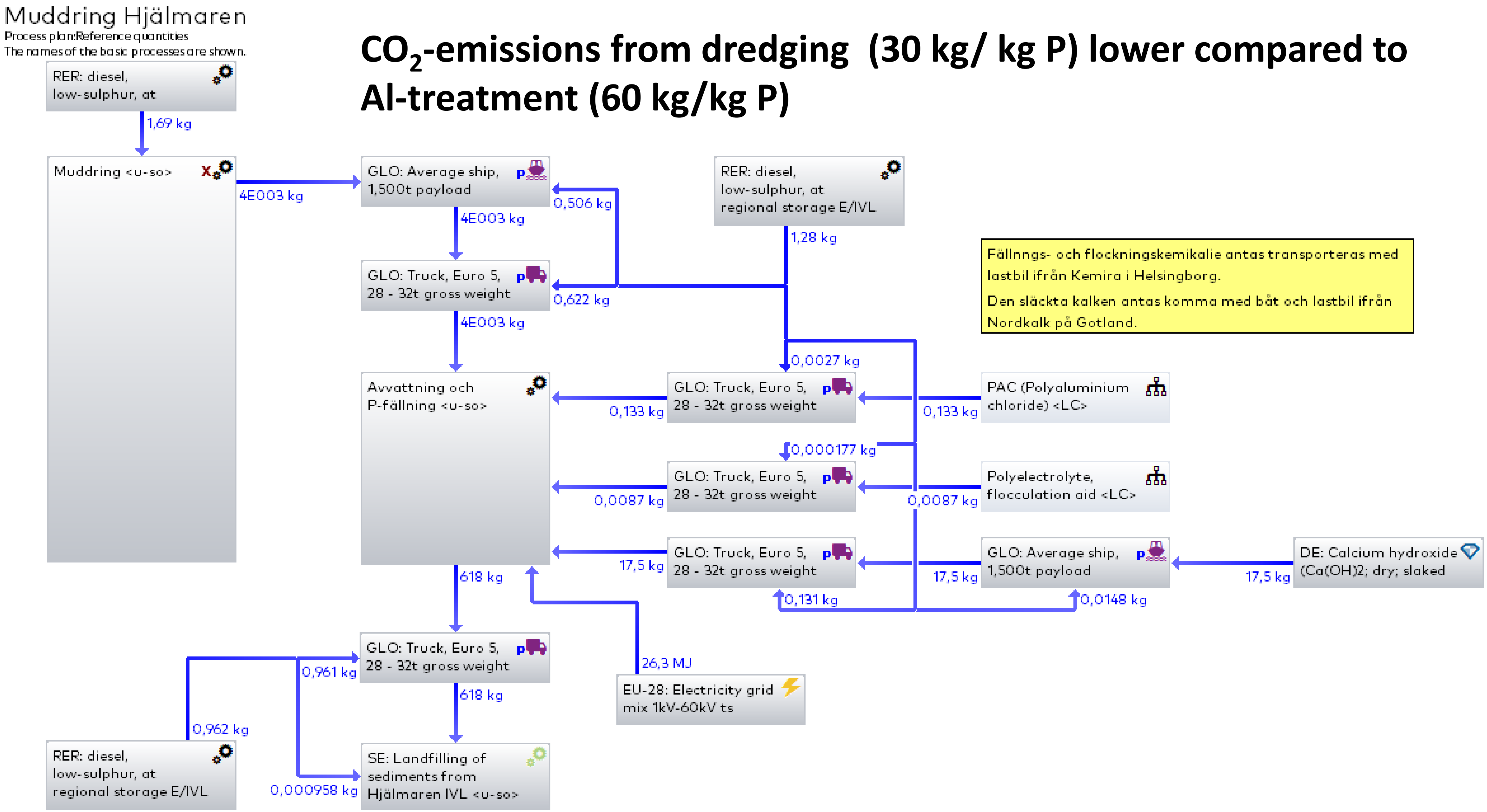
CO_2-emissions from dredging (30 kg/ kg P) lower compared to Al-treatment (60 kg/kg P)



Low-flow dredging

- Only tested on a small scale
- Less resource demanding compared to conventional dredging. Possible utilization of dredged material directly on farmland if suitable conditions
- The recently undertaken operation in **Lake Ralången** will be used for further analysis

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Reduction fishery

- Standing stock of fish biomass ˜ 10 000 tonnes, fish yield ˜2 000 tonnes/yr
- Fishing the yield would remove 20 tonnes Mob-P yr
- Cost 1 500- 2 000 SEK/kg TP
- Positive impact on CO_2-emissions if catch converted to biogas 2 000 tonnes fish would ”save” 800 tonnes of CO_2
- Negative impact reducing the stock of prey fish would possibly affect the biomass of predatory fish, e.g., pikeperch negatively
- Less potential compared to precipitation or dredging but could on the other hand continue for many years

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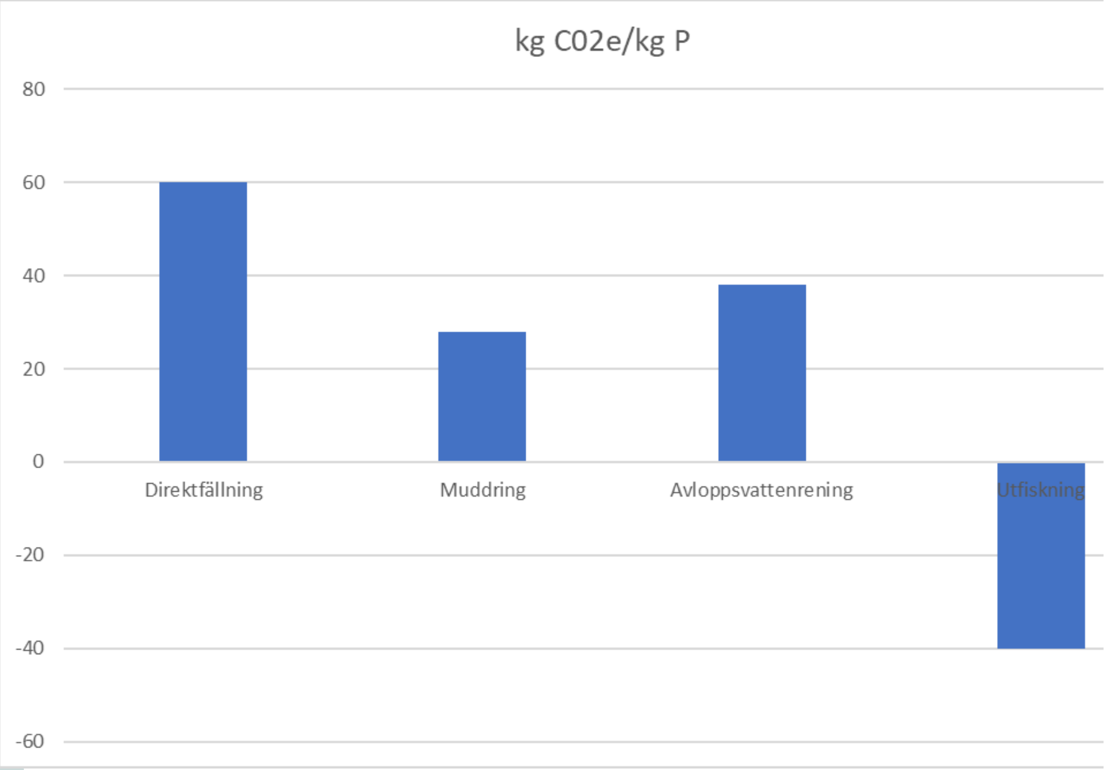
Summary

	Reduction fishery	Aluminium treatment	Low-flow dredging	Conventional dredging
Coast/ kg P (SEK)	1 500–2 000	500	unclear	1 000 (uncertain)
Positive side effects	The catch may be used as food, feed or for production of biogas		Fertilizer on surrounding farming areas	
Negative side effects	Declining stocks of predatory fish	Resource demanding, CO_2-emissions from production of chemicals		Resource demanding, CO_2-emissions from dredging operation



Concluding remarks

- To combat internal loading in a large water area like Lake Hjälmaren is not an easy task
- The environmental risks associated with e.g., dredging (turbidity) and Al-treatment (toxicity) are small and manageable

- **but**

- The benefit (less eutrophication) has to be weighed against the use of resources, the climate impact and the possible reduction in commercially and for recreational purposes important fish species
- Various reactions among stakeholders

Hjälmaren: Dyrt och miljömässigt tveksamt att minska fosforn:
"Inget som gör att man ropar hej, det här gör vi"

Nerikes Allehanda
14 maj 2019

- The IVL-report C381 can be downloaded from www.ivl.se

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