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Dioxins in Baltic herring and salmon: an inter-sectoral decision analysis for optimal management of the problem

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1. Introduction

Dioxin pollution to the Baltic Sea has been decreasing since 1970's, but high levels are still found from marine biota and sediment. Two commercially and culturally remarkable fish species, Baltic herring (*Clupea harengus membras*) and salmon (*Salmo salar*) provide a natural source of omega-3 fatty acids and vitamin D to the people living in the area. Unfortunately they also accumulate high levels of fat-soluble dioxins from their environment and food. Herring and salmon have a predator-prey relationship, creating a dependency between the dioxin concentrations of these two species. Owing to the dioxins, selling these fish species within the EU is partly restricted and the value of the catches low.

Dioxins are persistent organic pollutants originating mainly from atmospheric and riverine sources, the sea food being the main source to human in the Baltic Sea area. Although shown to be carcinogenic, high dietary exposure in infancy is typically associated with the enamel defects in teeth. The latest results also suggest early life exposures being associated with sperm quality in young adults. For this reason the estimate of tolerable weekly intake by the European Food Safety Authority was lowered in the end of year 2018.

2. Materials and methods

With a multi-disciplinary research team we constructed a Bayesian influence diagram (BID) to integrate social and ecological knowledge for evaluating alternative sectoral and inter-sectoral strategies to manage the dioxin problem of Baltic salmon and herring fisheries.

The BID consists of two key elements: 1) the ecosystem part, covering the dioxin concentrations in herring and salmon acknowledging their prey-predator linkage, and 2) the social part, covering the fish consumption of different groups in Finland, Sweden, Denmark and Estonia and the consequent health effects (Fig. 1). The impacts of nine decision options on these sub-models and further the whole model are evaluated by observing the resulting changes in the target variables of interest. The strategies are evaluated in the light of alternative criteria: 1) the dioxin concentrations of Baltic herring and salmon (ecosystem health), 2) the human consumption of Baltic salmon and herring, and the associated health risks and benefits (burden of disease), and 3) the commercial value of herring and salmon catches.

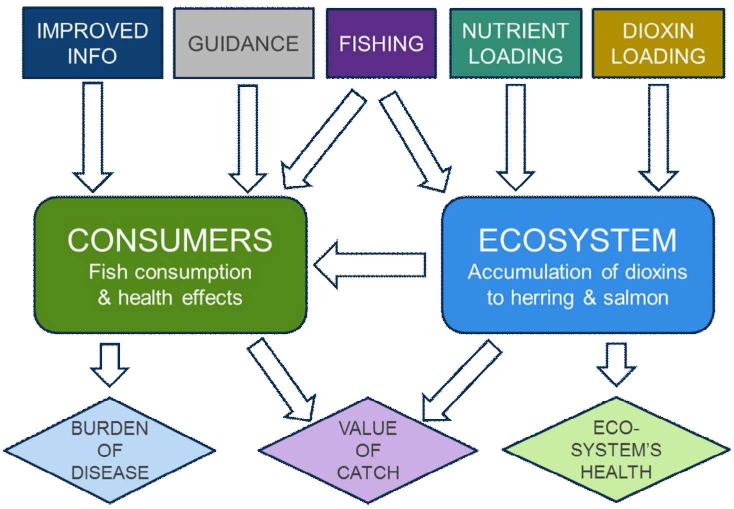

Figure 1: Key elements of the BID model. Rectangle-shaped nodes represent management decisions affecting the states of the ecosystem and consumer sub-models. The diamond-shaped nodes represent the assessment endpoints used.

3. Results and discussion: optimal management depends on the decision order, assessment endpoint and consumer group in focus

The relative utility reached with the analysed management actions, as well as their mutual ranking, varied depending on the order in which the decisions were taken. In some cases even the optimal decision concerning the implementation of a management action changed. For example, using dioxin concentrations in herring as the criteria, as the first action to take in the current situation, decreasing the productivity of the ecosystem by the nutrient abatement of 30% was recommended. Anyhow, as the last decision, the other decisions already being set to their optimal states, nutrient reduction did not produce any added value.

The optimal decisions varied depending on the decision-making criteria used, too. The decisions optimal to minimizing the dioxin concentrations in herring and salmon are not contradictory with those optimal to human health perspective, whereas the recommendations targeting to the increased human consumption of fish only, were contradictory.

From the human health perspective, optimal decisions as well as the utility reached with them, vary remarkably depending on the consumer group in focus (Fig. 2). As it is beneficiary for the elderly men - who in average do not get enough Omega-3 acids from the other sources – to eat more herring and salmon, promoting the eating of these fish species would be the most advantageous action to take. For the women in fertile age increasing the consumption of these fish species would not be only advantageous due to the risk to their potential offspring. For this reason the same action (meaning in this case that the information would not be targeted in a right way to the consumer group) produces strongly negative effect.

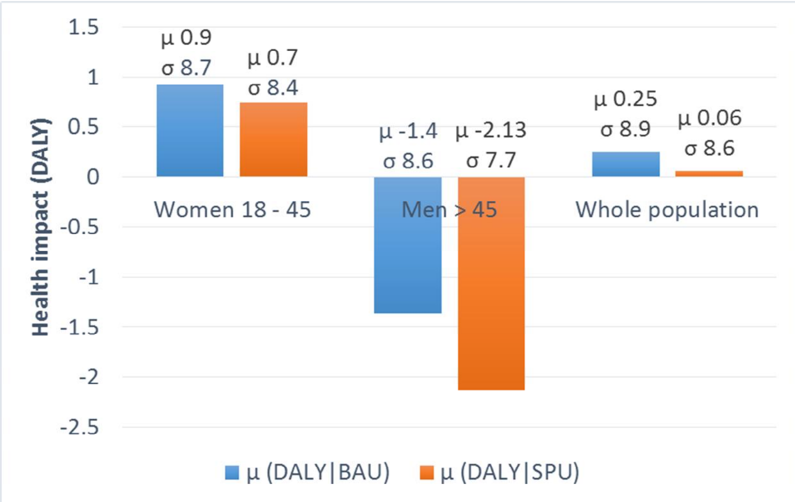

Figure 2: Burden of disease (in DALYs) caused by herring and salmon eating, calculated for women in fertile age, men over 45 years and the whole population in the business as usual situation (BAU) and with human-health-optimized decision strategy (SPU). DALY (Disability Adjusted Life Year), is a theoretical measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability. One (positive) DALY can be thought of as one lost year of "healthy" life.

Based on the analysis, the most robust single management actions (over the sectors and assessment endpoints) that can be recommended are: 1) developing products and markets to promote the use of smaller fish in human diet (herring <17 cm and salmon 40-80 cm); 2) developing information sharing, targeting the right information to right consumer groups; 3) further reductions of the dioxin emissions to the ecosystem.

The usefulness of fisheries management to reduce dioxins was found uncertain and, if being the only strategy adopted, even negative. However, fisheries management decisions should not be made based on the dioxin concentrations only, but also the ecological sustainability of the stocks have to be considered.

4. Conclusions

The results demonstrate the requirement to understand the effects of management measures in a holistic way: managing only one species or policy domain may not be effective, and may also have unanticipated systemic effects in the ecosystem. In general, optimal management depends on the assessment criteria used, as well as the order in which the decisions are made. Unsynchronized management decisions in different sectors may decrease each other’s effectiveness. The results thus suggest that communication and collaboration between the public health, environmental and fisheries sectors is needed. Informing the right target groups in the right way would lead to best benefits from the viewpoint of all management decisions, which would imply creating an informative link between the sectors, too.