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Associations between egg quality, abiotic factors and female traits: insights from a 40-year-long Baltic herring monitoring program

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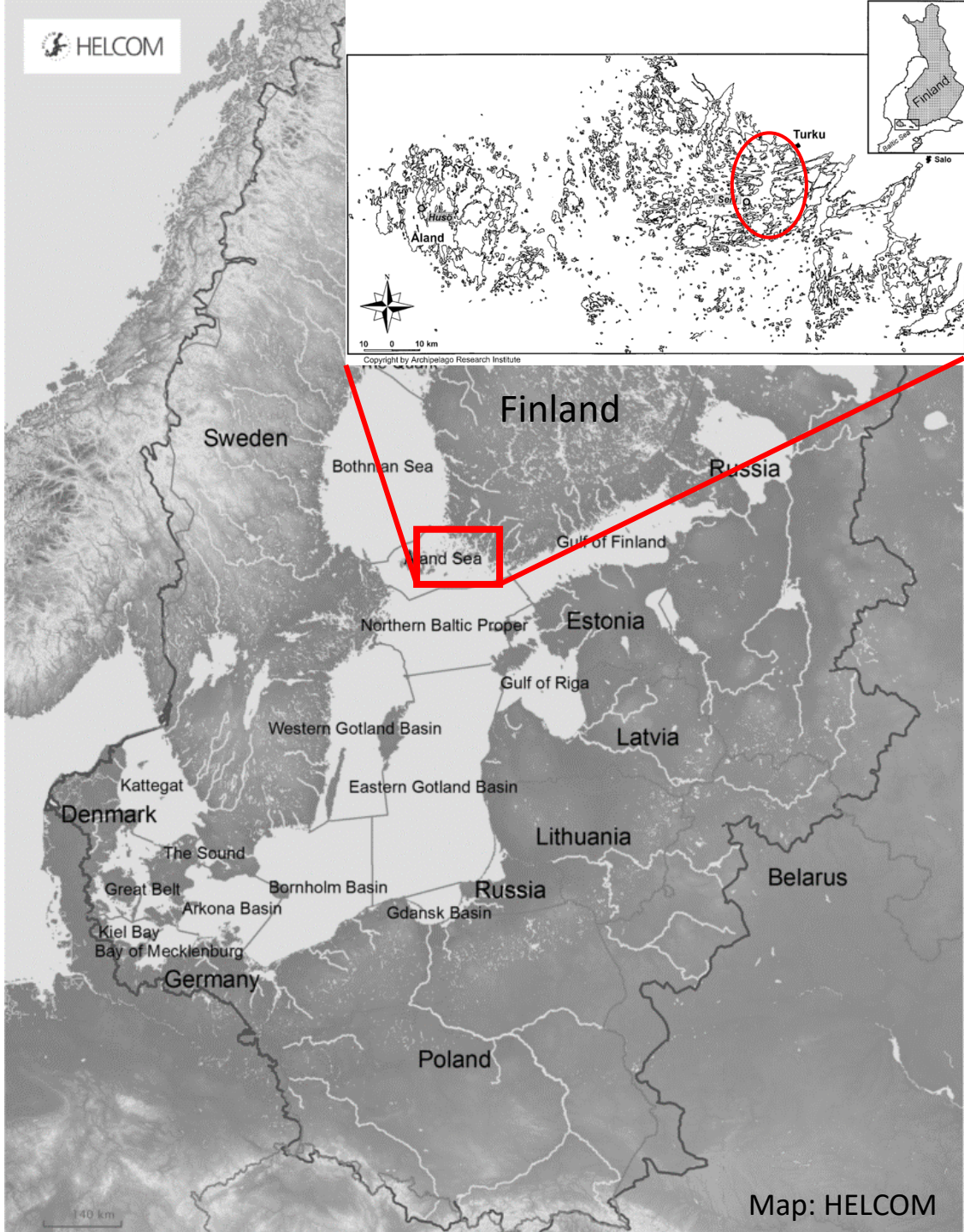
Baltic herring monitoring in the northern Baltic Sea

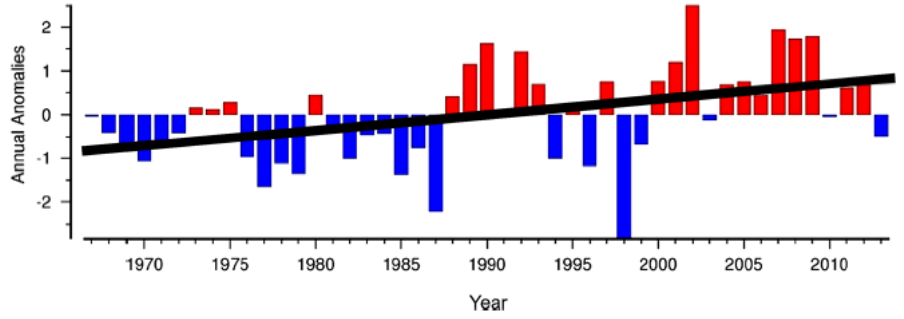
- Traits of spring-spawning Baltic herring (*Clupea harengus*) population monitored annually since 1984 in the Archipelago Sea
  - Length, weight, age, maturity and sex determined from ca. 42 000 fish in total/~1000 fish annually
  - Muscle and ovarian lipid content, fatty acid composition, and ovarian thyroid hormones T4 (thyroxine) and T3 (triiodothyronine) concentrations from subsets
  - Fish from commercial/research trap nets
- Main overwintering/feeding grounds of the spawning herring presumed to be located in the Bothnian Sea



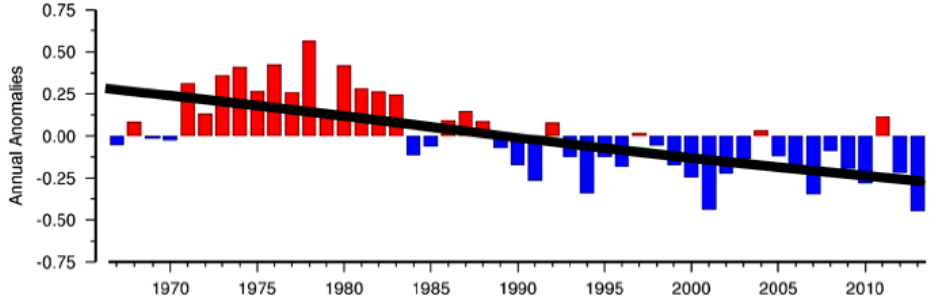
Monitoring period includes variable and shifting environmental conditions

- Warming and highly fluctuating temperature
  - Mean ~1.5-2.0 °C overall increase in surface water temperature
- Low and temporally changing salinity
  - Mean salinity level of surface water ~6.7 PSU in late 1970s, then decreased and finally stabilized to present level in early 90's (~6.0 PSU)

Summertime surface water temperature at 0-20 m in the spawning area



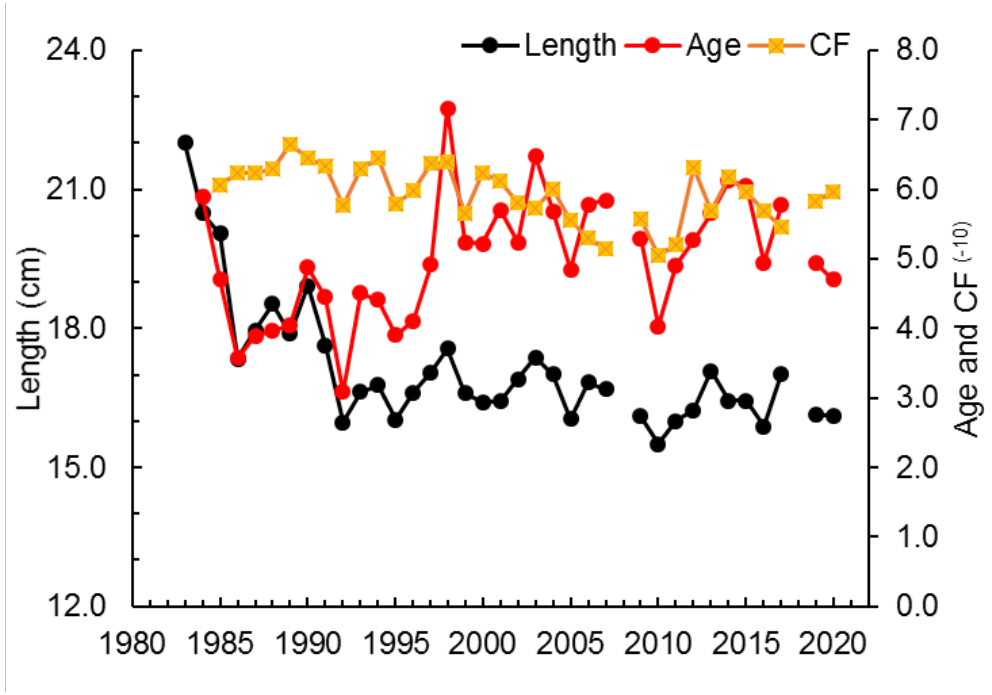
Summertime surface water salinity at 0-20 m

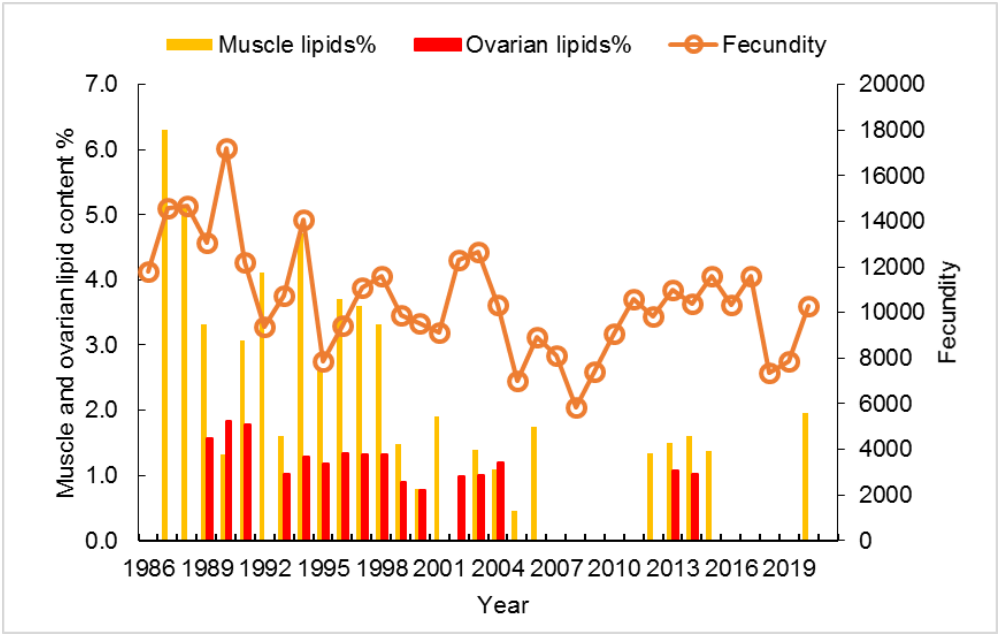


Mäkinen et al. (2017)

Changes in population traits

- Mean length of population decreased from 21 cm to 16 cm due to reduction of their growth rate
- Slight increase in mean age
- Decrease in Fulton's condition factor (CF)
- Amount of lipids decreased both in ovarian and muscle tissues
  - Female length show no association with amount of ovarian lipids → follows general pattern found in many other fish species
- Decrease in fecundity





Lipid content associated with winter temperature and salinity

- Decreased lipid content associated with increasing winter temperature and decreased salinity
  - Presumed effects via e.g. increased energy expenditure
  - Role of food resources obvious, but data is lacking from feeding grounds

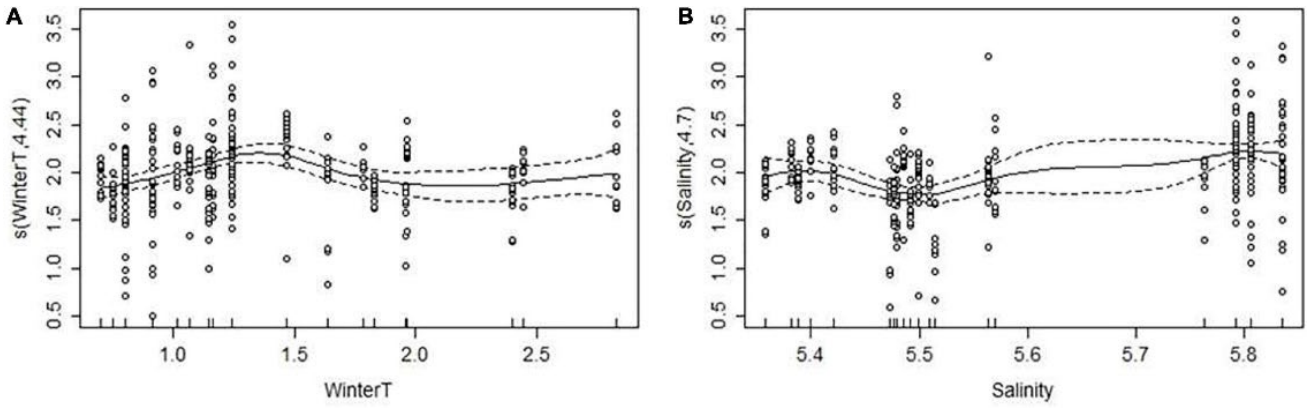


Figure. Generalized additive mixed model (GAMM) plots showing the partial effects of selected explanatory variables on log-transformed content of lipids in the eggs (µg/egg) (Rajasilta et al. 2021).

Variation in ovarian thyroid hormone levels

- Thyroid hormones (THs, T4 & T3) play a central role e.g. in the mobilization of lipids
- THs analysis using nano-LC-MS/MS (Ruuskanen et al. 2018*)
- THs levels show high variation between individuals
- Mean concentration of ovarian T3 varied between 21-51 pg mg^{-1} DW in 1990-2019. Among-year variation significant ($p<0.01$, n=75). Highest mean concentrations in 1990.

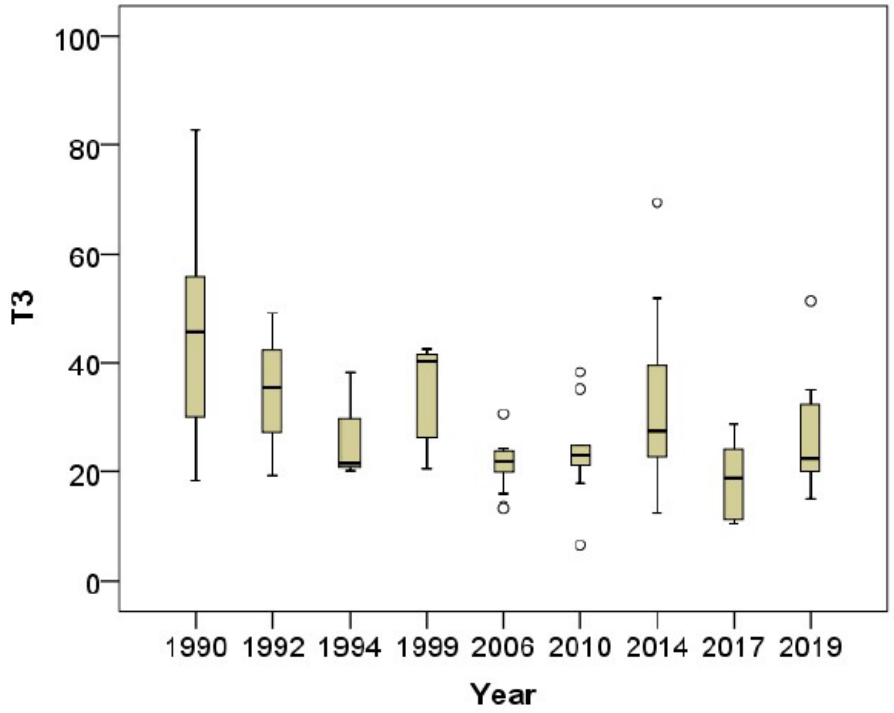


Figure. Box-plots showing mean concentration of triiodothyronine (T3, pg mg^{-1} DW) in ovarian tissue of spawning Baltic herring in 1990–2019.

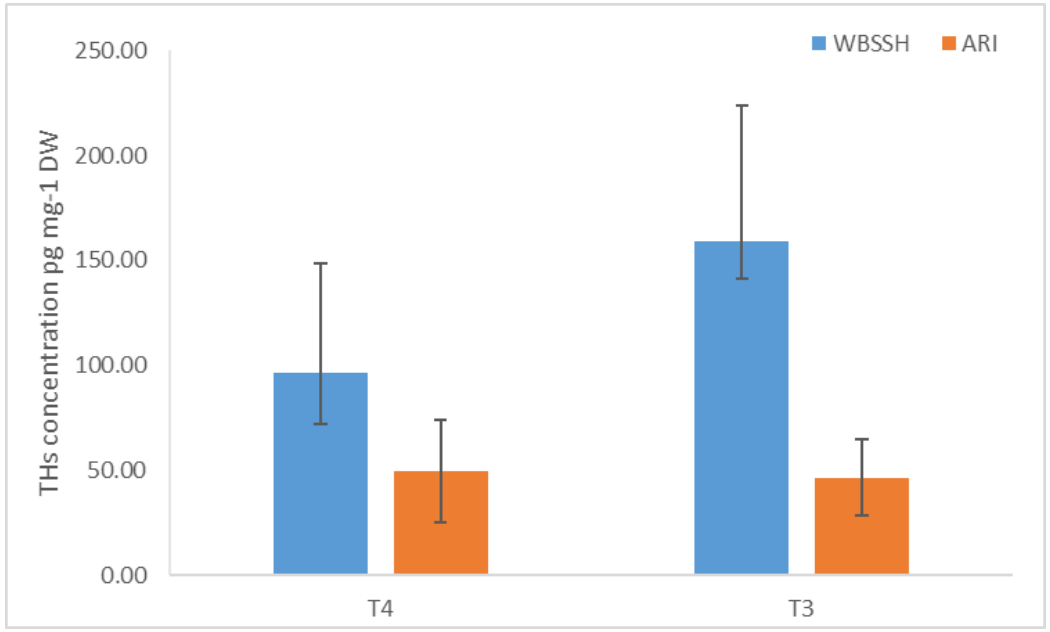
*Ruuskanen, S., Hsu, B. Y., Heinonen, A., Vainio, M., Darras, V. M., Sarraude, T., & Rokka, A. (2018). A new method for measuring thyroid hormones using nano-LC-MS/MS. J. Chromatography B, 1093, 24-30

THs levels associated with temperature and salinity

- THs concentrations in 1990-2019 also associated negatively with winter temperature and positively with salinity
  - THs levels lower after mild winters
- Some maternal traits and composition of eggs linked with embryonic survival (Laine & Rajasilta, 1999)
- → Effects of incubation temperature on the relationships between maternal traits, egg quality and larval traits studied experimentally in 2020-21
  - See posters W6-P1 & W6-P2
- Initial analyses in 2021 also with western Baltic spring-spawning herring (WBSSH), indicate significant differences in ovarian THs concentrations

	THs	***T3***	***n***
	r_S	r_S	
Salinity	0.58; $p < 0.001$	0.45; $p < 0.001$	75
Winter T	−0.35; $p < 0.01$	−0.39; $p < 0.01$	75

n = number of females analyzed; p = risk level.



Thank you!

Referenced studies:

- Mäkinen, K., Rajasilta, M., Ruuskanen, S., Lauerma, A., Karpela, T., Sahlsten, J. Effects of incubation temperature and maternal phenotype on Baltic herring (*Clupea harengus membras*) eggs and larvae: an experimental study. *Manuscript.*
- Rajasilta, M., Mäkinen, K., Ruuskanen, S., Hänninen, J., Laine, P. (2021) Long-term data reveal the associations of the egg quality with abiotic factors and female traits in the Baltic herring under variable environmental conditions. *Frontiers in Marine Science; Marine Fisheries, Aquaculture and Living Resources. Doi: https://doi.org/10.3389/fmars.2021.698480*

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