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Eight decades of changes in herring reproductive investment: effects of fishing, environment, and conspecific density

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Abstract
Reproductive investment is a central trait for population dynamics and productivity. Commercial-scale fishing is a major driver affecting population structure, dynamics, and adaptation of life-history and behavioural traits. Theory predicts an increase in reproductive investment in response to an elevated mortality, and fishing has the capacity to induce evolutionary changes in this trait. In this study, we investigate the contribution of environment, fishing pressure, and intra-specific competition to variation in the reproductive investment of the Norwegian spring-spawning herring (*Clupea harengus*), a stock that has been fished for centuries, and monitored for decades. Growth rate (measured as mean age-at-length), sea surface temperature, and fishing pressure had a positive impact on reproductive investment. Fish with a higher post-spawning weight had a lower reproductive investment in the largest length-class. This non-intuitive result reflects the trade-off between growth and reproduction, as, among the large fish, the fast-growing individuals invested less in reproduction and were in better condition after spawning than slow-growers. After accounting for the main environmental variables and fishing pressure, we discovered a weak, but significant positive temporal trend in the reproductive investment, suggesting fisheries-induced evolutionary adaptation of reproductive investment in the Norwegian spring-spawning herring.

Keywords:
Harvesting, climate, Norwegian spring-spawning herring, *Clupea harengus*, density-dependence, trade-offs, fisheries-induced evolution

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