

Quantifying long-term changes in southern right whales' behavioural response to kelp gull micropredation using a latent covariate Markov model

Kelp gulls (*Larus dominicanus*) feed on the skin and blubber of southern right whales (*Eubalaena australis*) off Península Valdés, Argentina. Attacks are mainly targeted to mother-calf pairs, and they have increased over time. Studies have shown that whales spend more time in energy-demanding behaviours and less time resting in response to kelp gull attacks. These effects on whales' behaviour could have important conservation implications, given that Península Valdés is a breeding ground with low food availability, where mothers rely mainly on stored energy to sustain lactation. However, short-term studies suggest that whales have learned new ways to cope with attacks, so we aimed to quantify these changes using behaviour and attacks data spanning 24 years. In 1995 and from 2004 to 2018 we visually followed mother-calf pairs, recording their behaviour every 5 minutes (classified as rest, slow travel or high energy behaviours) and the number of kelp gull attacks they received in every interval. We modelled the whales' behaviour assuming a Markov process where transition probabilities are functions of a latent covariate that represents their disturbance state, which increases when whales are attacked and decreases when they are not, bounded between 0 and 1. Model parameters were allowed to vary among years with a temporal correlation structure. For every year we computed the steady state distribution of the Markov chain fixing the latent covariate at the least and most disturbed values, 0 and 1, and used those distributions as a proxy for the potential effect of kelp gull attacks on whales' behaviour. In 1995 attacks would have decreased the whales' rest frequency from 0.49 (undisturbed) to 0.19 (disturbed), while the high energy behaviours frequency would have increased from 0.17 to 0.57. Between years 2010 and 2018 attacks caused smaller changes in behaviour: rest frequency would have decreased from 0.45 to 0.22, and high energy behaviours would have increased from 0.14 to 0.40. In addition, the time to return to pre-attack behaviour was longer in 1995. Our results suggest that kelp gull micropredation still affects whales' behaviour, but currently, they invest less energy to avoid it than they did in 1995.