

## **Environmental influences on individual phenotypic traits in a wild Antarctic fur seal population**

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My research project looks at the influence of environmental variation on phenotypic traits using the Antarctic fur seal, *Arctocephalus gazella*, as a model system. At the time of application to the Antarctic Science International (ASI) Bursary, our project had investigated variation in growth and survival, movement behaviour, hormone levels, and gene expression in a population of fur seals breeding on Bird Island (South Georgia, sub-Antarctic) during two seasons of notably different environmental conditions. These analyses excluded, however, a key life-history trait known to be influenced by social and environmental variation – immunity. This was the topic of my extended research project with the ASI Bursary.

At the time of application, we had whole blood samples collected from 200 focal individuals; these encompassed 50 mother-pup pairs sampled during a breeding season of normal food availability and 50 mother-pup pairs sampled during a breeding season of comparatively low food availability. With the kind help of the ASI Bursary Grant, we used this material to assess nine innate and adaptive immune markers (bacterial killing assays (*E. coli* and *S. aureus*), hemagglutination, hemolysis, lysozyme, haptoglobin, neopterin, immunoglobulin G, and the innate/adaptive WBC ratio) as well as four oxidative stress markers (dROM, OXY, glutathione peroxidase, superoxide dismutase). The laboratory work was done in collaboration with Dr. Gábor Á. Czirják, head of the wildlife immunology lab at the Department of Wildlife Diseases at the Leibniz Institute for Zoo and Wildlife Research (IZW), and Dr. David Costantini, Professor of Ecophysiology at the Department of Ecological and Biological Sciences at Tuscia University.

The resulting data was analysed using generalized linear mixed models fitted in a Bayesian framework using Markov chain Monte Carlo methods in the R package MCMCglmm version 2.34. We included season (food availability), colony, body condition, baseline cortisol, and sex as predictor variables of the immune marker concentrations. The nine immune markers were then independently fitted as predictor variables of the four oxidative stress markers. Using this methodology, we can show that immune responses of pups are more responsive than adults to variation in food availability, and are modulated by cortisol and condition. Furthermore, immune investment is associated with oxidative stress in pups but not mothers. Our results suggest that early life stages show greater sensitivity to both extrinsic and intrinsic effectors, and that immunity may be a strong target for natural selection.

The resulting manuscript has been submitted and reviewed by *Communications Biology*. We are currently in the processes of revising the manuscript according to three helpful reviewer comments and will resubmit as soon as possible.

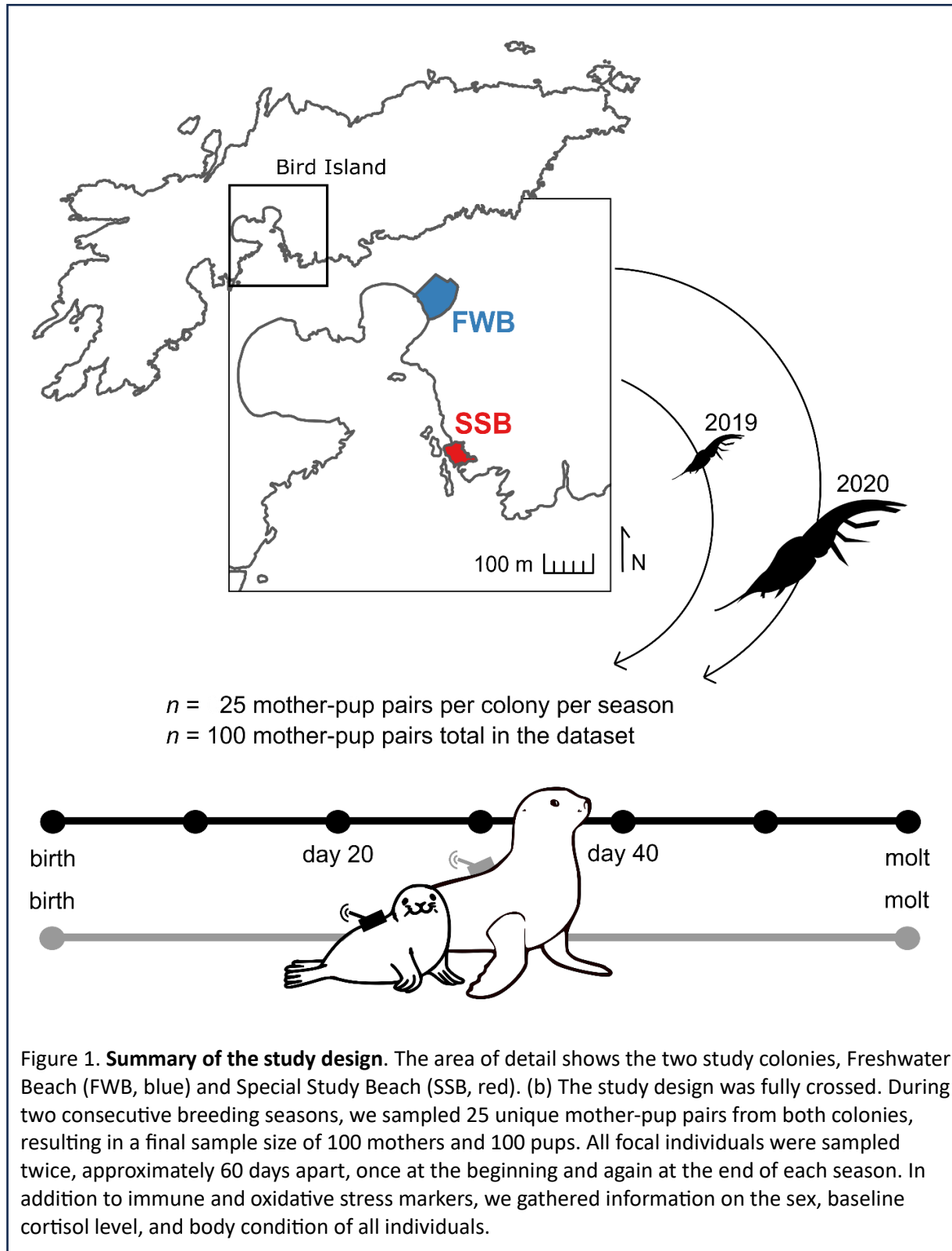




Figure 2. **Antarctic fur seal breeding beach.** Shown here is SSB, one of the two Antarctic fur seal breeding beaches from which individuals were randomly selected for collection of whole blood for the analysis of immune markers. The collection of biological material was carried out in collaboration with the British Antarctic Survey (BAS) on Bird Island, South Georgia in the sub-Antarctic. Sampling was carried under permits from the Government of South Georgia and the South Sandwich Islands (Wildlife and Protected Areas Ordinance (2011), RAP permit numbers 2018/ 024 and 2019/032). The samples were imported into the UK under permits from the Department for Environment, Food and Rural Affairs (Animal Health Act, import license number ITIMP18.1397) and from the Convention on International Trade in Endangered Species of Wild Fauna and Flora (import nos 578938/01-15 and 590196/01-18). All procedures used were approved by the BAS Animal Welfare and Ethics Review Body (AWERB applications 2018/1050 and 2019/1058). Photo by Rebecca Nagel.