How does pollution impact sperm quality?

Supervised by Becky Cramer, Natural History Museum
Preferred background of candidates: Biology
Number of available projects: 1 project with space for 1 – 2 students
Preferred project period: within 15 June – 30 Aug

The Natural History Museum (NHM) sperm collection houses over 12,000 samples from more than 600 species of bird sperm preserved in formalin, with most samples collected from relatively pristine habitats. However, a subset of 60 samples from the tree swallow (*Tachycineta bicolor*) were collected from Hamilton Harbor, Canada, which has been heavily polluted with polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and heavy metals due to industrial uses as well as urban development (Canada, 2021). The tree swallow is known to be sensitive to pollutants, for example, with reduced hatching success being linked to the environmental levels of persistent organic pollutants in a different study region (Custer *et al.*, 2014). In this project, you will quantify and compare the proportion of abnormal sperm cells from tree swallow samples collected in Hamilton Harbor and in a less-polluted site, to evaluate how pollution impacts sperm normality.

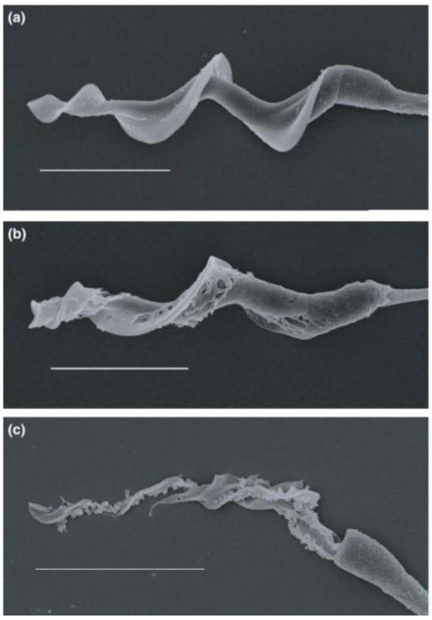

Figure 1. Images from scanning electron microscopy showing a) normal and b,c) damaged sperm acrosomes from reed bunting *Emberiza schoeniclus* (a,b) and chaffinch *Fringilla coelebs* (c). Figure taken from (Støstad *et al.*, 2019).

Previous work indicates that sperm, and particularly the sperm acrosome (which is the focus of this project) are susceptible to environmental damage. The acrosome is an organelle at the tip of the cell, which contains enzymes for dissolving the membranes around the egg. It therefore serves a very important function in the steps immediately before fertilization. In songbirds, the acrosome has a shape different from almost all other taxonomic groups known. The acrosome has a wide membrane that wraps around it in a helical fashion (Fig 1a). The acrosome appears to be particularly susceptible to damage, especially for species with relatively long sperm, like the tree swallow (Støstad *et al.*, 2019). Previous research shows that sperm from the Chernobyl nuclear fallout zone show higher levels of abnormality than do sperm from unpolluted areas (Hermosell *et al.*, 2013), while pollution by heavy metals did not cause higher abnormality rates in two Chinese populations of tree sparrow (*Passer montanus*) (Yang *et al.*, 2020). The effects of persistent organic pollutants, such as the PCBs and PAHs common in Hamilton Harbor, on bird sperm has not been studied, so this study will provide novel insights on the impacts of these pollutants. However, persistent organic pollutants are known to affect the proportion of sperm cells with normal morphology in mammals (Louis *et al.*, 2015), so they are likely to have an effect in birds also.

Persistent organic pollutants often can be volatilized and redistributed around the globe due to changing temperatures (Hung *et al.*, 2022), making it particularly timely to understand how these chemicals impact wildlife. In addition, pollution is more likely to impact human communities that are otherwise disadvantaged due to race and/or socioeconomic status (Mohai & Saha, 2015). Better understanding the myriad impacts of different pollutants on wildlife may help us understand and mitigate potential impacts on disadvantaged human communities.

Outline of project work and deliverables

The majority of the time (about 5 weeks) will be spent taking images of sperm cells and scoring which cells are normal vs. abnormal, after proper blinding of the images to avoid biases. In the final week, we will collate the collected data and analyze it. One student can likely image and score 40 males over the five weeks, which may be sufficient to publish in a peer reviewed journal as a brief note. With two students, we may be able to complete full scoring of all samples in the collection, making the dataset almost certainly publishable.

Interdisciplinary nature of learning outcomes

- **Data management, reproducibility, quality control, and analysis.** You will be taking images of many sperm cells and scoring them for normality. This data will need to be kept organized so the data can be linked to male identity and sampling locality. You will learn how to keep the data organized and reproducible—an important goal in the era of open data sharing in science. We will use standard statistical tools to check how representative our measurements of sperm abnormality are for individual males and for species using resampling analyses. The final comparison will use linear mixed models in R. Depending on your level of comfort in R, we will work together on these analyses.
- **Bird physiology and ecotoxicology.** Depending on your interests, you will have opportunity to read in the primary literature about relevant bird physiology and ecotoxicology.
- **Sperm cell function and spermatogenesis**. While you don't need a complete understanding of how sperm cells form in order to do this project, having a basic understanding of spermatogenesis will enrich your experience. I'll give you a brief introduction to spermatogenesis at the start of the project, and guide you to primary literature sources if you're interested in delving more deeply.
- **Microscopy.** This project will involve substantial amounts of time at the light microscope, so you will become proficient with using the Leica software suite. We may also use ImageJ for down-stream image processing and annotation.
- **Museums.** While it won't be a primary focus of this project, you will gain some insights into the use and structure of museum databases as we choose samples and update the database with the images you've taken.

Citations

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