OUTSIDE JEB

This is your salmon on acid

AQUATIC ACIDIFICATION

Like high school sweethearts, rising atmospheric carbon dioxide levels and the acidity of Earth's surface waters go hand-in-hand. And just as the chemistry in puppy love is beautifully simple, so too is aquatic acidification – one carbon dioxide molecule combines with one water molecule and a proton is freed. Sadly, this is where our love story ends because the more that protons are freed, the more acidic the water becomes, and the more it affects creatures that live and breathe the life aquatic. Indeed, aquatic acidification is linked to a variety of sub-lethal effects in marine fishes that raise concern for the long-term impact of climate change on oceanic ecosystems. But little is known about effects on freshwater fish and of the consequences of growing up in acidified water. So, Colin Brauner at the University of British Columbia, Canada, and a team of Canadian collaborators decided to test how current and projected carbon dioxide levels affect developing pink salmon. Among all the species of Pacific salmon, pinks are the youngest when they migrate to the open ocean from their freshwater nurseries, so any developmental effects caused by acidification of their natal environment could have a profound impact on their survival during the critical life history stage of seawater transition.

Brauner's team, headed by Michelle Ou, began their acid test by dividing salmon embryos into three freshwater groups that varied in carbon dioxide content from present day levels to predicted end-of-century levels. They then reared the fish in these conditions for 10 weeks – to an age when natural populations begin swimming out to sea – and compared several growth parameters to see how the fish measured up to each other. In all categories, fry from the highest carbon dioxide exposure group fell short, meaning that growth was impaired in the salmon that developed in acidified freshwater. This stunted growth could have dire consequences for the young fish because runts are easy targets for predators and less competitive for food.

The team then compared the olfactory responses of the salmon raised in different levels of carbon dioxide. First, they tested the aversion response of the fish to an alarm cue (made from their ground-up salmon siblings…ew!). They added the alarm cue to one side of a split aquarium, leaving the other side clean, and then measured how much time each fish spent swimming on either side. Compared with fish raised in present-day levels of carbon dioxide, fish raised at elevated carbon dioxide levels spent nearly double the time in the side of the aquarium with the alarm cue, meaning their aversion response was blunted. Next, the team placed microelectrodes in the noses of the fish so that they could quantify how well the fish smelled different chemicals. The team presented these wired-up fish with isolated amino acids – chemicals that are used by adult fish for homing back to their natal streams to spawn – and again found a blunted response in the salmon reared in elevated carbon dioxide water compared with those reared in present-day conditions. Together, these experiments show that developing in freshwater with elevated carbon dioxide levels can impair the ability of salmon fry to respond to important olfactory cues in their environment.

Stunted and blunted, aquatic acidification is of clear concern for freshwater fish.

10.1242/jeb.112623

Ou, M., Hamilton, T. J., Eom, J., Lyall, E. M., Gallup, J., Jiang, A., Lee, J., Close, D. A., Yun, S.-S. and Brauner, C. J. (2015). Responses of pink salmon to CO_2-induced aquatic acidification. *Nature Clim. Change* doi:10.1038/nclimate2694.

Sarah Alderman
University of Guelph
alderman@uoguelph.ca

A head for sex

SELF-FERTILIZATION

We all have different ideas of the meaning of trauma. For example, I'm untroubled by spiders, while my daughter shrieks at the mere thought of them. But what about a syringe full of sperm shot into your head? Traumatic enough for me and I'd assume for most people. However, as shown by Steven Ramm and colleagues in a recent issue of *Proceedings of the Royal Society*, one organism's trauma may be another's only shot at family life.

Macrostomum hystrix is a tiny flatworm with a positively bizarre sex life. In contrast to humans with two separate sexes, these worms are simultaneous hermaphrodites, meaning that they are both male and female at the same time. As a consequence, while it takes two humans to tangle, these worms can go it alone and self-fertilize. Although this, in itself, is not unusual, where it gets strange is the manner in which self-fertilization occurs. What Ramm and his colleagues discovered is that *M. hystrix* worms accomplish this trick by injecting sperm from their needle-like penises into their own heads! And the more sperm they inject, the more offspring they produce. Why the head? Simple: because of anatomical constraints, that's the easiest spot to reach.

Unsurprisingly, hypodermic self-fertilization – also known as traumatic insemination – is not the best reproductive choice for these worms. In previous studies, the team found that offspring produced by selfing

Outside JEB is a monthly feature that reports the most exciting developments in experimental biology. Articles that have been selected and written by a team of active research scientists highlight the papers that JEB readers can't afford to miss.

survived less well and were less fecund than offspring produced by outcrossing. So given these costs, why do they bother? In short, because they must.

Selfing solves a crucial problem for *M. hystrix* by assuring reproduction when opportunities to outcross are limited. Most plants can get by on this approach, as do a sizable fraction of animals, so why not? For a start, selfing animals entirely dispense with the risks and hassle of finding a mate. Additionally, their offspring are 100% their own. But selfing incurs serious costs, in particular the risk of inbreeding depression in offspring. Because of this cost, worms are quite reluctant to self-fertilize, waiting more than 50% longer than when they are given the chance to outcross. But a worm's life is short; when the team separated them from their potential mating partners, they went straight for their own heads.

Although peculiar, and even a little amusing, the behaviour of these worms makes perfect sense. Some reproduction is clearly better than the trauma of none, but what remains unclear is the cost to the worms themselves: you can imagine that traumatic self-insemination may do a worm about as much good as a hole in the head. Also, do they live shorter lives than outcrossed worms? And can they continue feeding as efficiently? The answers to these questions remain unsolved, so there is still much to learn about these interesting little creatures.

10.1242/jeb.112599

Ramm, S. J., Poirier, M. and Scharer, L. (2015). Hypodermic self-insemination as a reproductive insurance strategy. *Proc. R. Soc. B.* **282**, 20150660.

Daniel E. Rozen
University of Leiden
d.e.rozen@biology.leidenuniv.nl

Dateless bees wear better perfume

Attracting a mate is an expensive endeavour – there are dances to learn, the right outfits to wear and an entire array of vocalizations to perfect. Because males are usually the sex that does the searching, most scientists have focused on the costs that they bear. But in a few species conditions can arise that cause females to invest in finding a mate. In these situations, females have to balance several costs: the potential cost of not producing any offspring if she fails to find a mate, the cost of mating itself and the cost of signalling to attract a mate.

To best balance these costs, theory predicts that females should increase their signalling effort the longer that they spend without a mate, as the potential cost of failing to find a mate increases. Leigh Simmons, a researcher from the University of Western Australia, decided to test this hypothesis using the solitary ground-nesting Dawson's bee. As males only search for females immediately after the females emerge as adults, females who get left out during the first pass must find ways later to attract the attention of males by using a particular blend of chemicals found on their cuticles that function as a pheromone perfume. Would females that had failed to mate the first time round invest more in the chemical composition of their cuticle chemicals to attract a male on the rebound?

First, Simmons nabbed 50 female bees right as they emerged from their burrows. He froze one set immediately, then isolated another set in a sort of bee nunnery away from males for a day and then froze them. Finally, he unleashed the remaining females to a group of male bees, allowing some to mate and perform their post-copulatory courtship behaviour, while others only mated (to isolate the effects of insemination on cuticle chemistry); and a final group was allowed to mate and nest after. This gave him five groups across which to compare the composition of their cuticle covering: one that was young and unmated, another that was older and unmated, one that had mated but not had post-copulatory courtship, one that had mated and had post-copulatory courtship, and one that was allowed to have all the normal mating behaviours and then nest afterwards. Simmons then used hexane to dissolve the chemicals from the cuticle of each bee before using gas chromatography to identify and quantify each chemical.

He found a total of 21 compounds that dissolved out of the female bees' cuticles, and the composition of the cuticle chemicals extracted from the female bees that had been unmated for a day had altered significantly. Meanwhile, the cuticle components of the bees that had mated (either with or without post-copulatory courtship) were more like those of the freshly emerged bees, and the chemical composition of the nesting bees' cuticles differed from that of all of the other groups. So, the unmated female bees had altered the composition of their cuticle chemicals, while mated female bees did not.

Not a lot is known about the costs of pheromone signalling or the mechanisms by which females can change their signalling, but in desperate times, it seems that at least female Dawson's bees break out their best perfume to find that lucky guy.

10.1242/jeb.112607

Simmons, L. (2015). Sexual signalling by females: do unmated females increase their signalling effort? *Biol. Lett.* **11**, 20150073.

Katie Marshall
University of British Columbia
kmarshall@zoology.ubc.ca

Journal of Experimental Biology (2015) 218, 2984-2986

Slow-growing fish have the fastest declines

Our world is currently in the midst of a mass extinction, with species declining and disappearing at alarming rates. However, not all are faring so poorly. While many populations and species are disappearing, others are maintaining their numbers, or even becoming more abundant, and a critical question is why: why are some species and populations more vulnerable to decline and extinction than others?

Many researchers have identified that body size predicts vulnerability to population decline and species extinction. Populations and species with larger individuals are more likely to decline and go extinct than those with smaller individuals. However, this relationship between body size and population decline and extinction is probably because larger animals tend to have other life-history traits – like lower rates of reproduction, slower growth rates and delayed sexual maturity – which make them less able to recover when the mortality rate increases. There is a great deal of variation in life-history traits, even within animals of a given body size. Thus, although body size may provide a reliable rule-of-thumb for predicting vulnerability to decline and extinction, it is only a rough measure.

Maria José Juan-Jordá, from the Universidade da Coruña, Spain, and Simon Fraser University, Canada, with collaborators from both universities, as well as the European Commission Joint Research Center, Italy, decided to tackle the challenge of identifying whether other life-history traits, such as growth rate, can better predict vulnerability to decline and extinction than body size alone. The researchers focused on the Scombrid fishes, which are the tunas, mackerels and bonitos. Because tunas and their relatives are important commercial food fishes, most species have faced high mortality as a result of fishing pressure at some point. Life-history data are also available for most fishes in this family, so the researchers were able to select species with known life-history traits and only included species that have declined when faced with fishing pressure. The team was then able to control for fishing pressure, and use general and logistic linear models to determine whether traits related to body size or traits related to the speed of life (i.e. growth rate, age-at-maturity, longevity) better predicted the extent of the species' decline, and the probability of overfishing.

Analysing the results of their calculations, Juan-Jordá and colleagues found that the models that included both growth rate and fishing pressure best predicted the extent of a species' decline and whether a species was considered overfished; models that included only fishing pressure were less reliable. The models that included body size and fishing pressure were the least able to accurately predict the extent of species decline and overfishing. Thus, the researchers demonstrated that life-history traits related to the speed of life, such as growth rate, are better at predicting whether a species will decline and become overfished than body size.

The researchers also identified that tunas, mackerels and bonitos from higher latitudes have declined more dramatically than fish from lower latitudes. For fish, water temperature is tightly linked to growth rate, with fish growing and maturing more slowly in cold water. Thus, this study both identifies a global pattern in fisheries population declines and offers an underlying explanation. Across broad global scales, the slower-growing fish at higher latitudes decline faster when faced with fishing pressure.

10.1242/jeb.112615

Juan-Jordá, M. J., Mosqueira, I., Freire, J. and Dulvy, N. K. (2015). Population declines of tuna and relatives depend on their speed of life. *Proc. R. Soc. B* **282**, 20150322.

Constance M. O'Connor
McMaster University
constanceoconnor@gmail.com