Inside JEB is a twice monthly feature, which highlights the key developments in *The Journal of Experimental Biology*. Written by science journalists, the short reports give the inside view of the science in JEB.

Inside JEB

REFILLING SEA LIONS CUT CORNERS TO MAXIMISE FISHING TIME

Pursuing your prey can be metabolically challenging at the best of times, but diving seals and sea lions have to do all that on a single lung full of air. Andreas Fahlman, from the Marine Mammal Research Unit at the University of British Columbia, is intrigued by the fine metabolic balance struck by foraging mammals. But when Fahlman and his colleagues began analysing the metabolic cost of individual dives during a foraging session, something didn't add up. The metabolic cost of each dive seemed to vary: while diving freely, the sea lion's first dive was the least costly and the last the most expensive. What was going on (p. 3573)?

Knowing that sea lions rapidly replenish the majority of their oxygen during the first few minutes at the surface, but it takes much longer for the mammals to refill their haemoglobin oxygen stores completely, Fahlman wondered whether the sea lions were cutting corners and making subsequent dives on a partly filled tank to maximise the amount of time they spent foraging. If they were, that could account for the metabolic inconsistency; the first dive would look as if it cost less than all the subsequent dives, while the last dive (when the sea lions could finally restock completely) would appear to be the most costly.

Fahlman realised that if his theory was correct, he could do away with the metabolic cost pattern if he detained the sea lions at the surface for sufficient time to completely refill their haemoglobin tanks. Then all dives should cost the same, as the sea lion would not develop an oxygen deficit during the first dive that was only repaid after the final dive. Teaming up with Caroline Svärd, David Rosen and Andrew Trites from the Marine Mammal Research Unit and David Jones from the University of British Columbia, Fahlman set about testing his theory.

Working with a team of experienced animal trainers from the Vancouver Aquarium, the team prepared three sea lions to dive at a simulated foraging site. At the end of each dive, the animals swam to a respirometry dome at the surface where the team could monitor their oxygen levels as they replenished their oxygen supplies. During some of the dives, the team allowed the animals to make their own decisions when they returned to the foraging site. However, on other occasions, the team closed the door on the respirometry chamber as the animals surfaced, only allowing them to resume diving when they had completely refilled their oxygen stocks.

Recording the amount of oxygen that the freely diving animals consumed each time they surfaced, Fahlman confirmed that their first dive always appeared to be the least costly and the last the most expensive. However, all of the dives of animals that were forced to sit at the surface and completely recharge their oxygen supplies appeared to cost the same. So rather than wasting valuable time at the surface completely refilling their oxygen supplies, the sea lions were choosing to dive on slightly empty tanks to maximise the amount of time spent pursuing tasty fish diners.

10.1242/jeb.026203

Fahlman, A., Svärd, C., Rosen, D. A. S., Jones, D. R. and Trites, A. W. (2008). Metabolic costs of foraging and the management of O_2 and CO_2 stores in Steller sea lions. *J. Exp. Biol.* **211**, 3573-3580.

IS ALLOMETRIC SCALING A MATHEMATICAL ARTEFACT?

Every zoology undergraduate knows Max Kleiber's 'elephant to mouse' curve. In the early 1930s, Kleiber plotted the body masses and metabolic rates of animals ranging in size from ring doves up to steers on a log graph and found a rather simple relationship; the metabolic rates scaled as the ¾ power of the animals' body masses. This was later refined by F. G. Benedict, who restricted the curve to mammals, and the method is now known as allometric scaling. However, the reliability of this scaling factor has always been questioned, and never more so than since a theoretical model, published in 1997 by Geoffrey West and colleagues, claimed to explain the pleasing relationship. But Gary Packard and Geoffrey Birchard were suspicious. Could everyone have been missing the point for more than 70 years? What if the data simply didn't fit the assumptions that underpin Kleiber's classic curve and the ¾ power relationship was just an artefact of mathematical manipulation (p. 3581)?

Turning to a data set of body masses and metabolic rates for 626 species ranging from 2.4 g shrews up to a 3672 kg elephant assembled by Van Savage and colleagues in 2004, the duo tested whether all of the data points were equally valid and whether there were any statistical outliers that should be ignored. They found that the elephant was so far out there was no way it could be included in the calculation. Having ruled out the elephant, the pair plotted the data on a logarithmic scale to get a metabolic scaling factor that was close to ¾, before replotting the data from the logarithmic plot on an arithmetic scale to see how well it predicted the animals' metabolic rates. Packard and Birchard explain that although the graph predicted the smaller animals' metabolic rates well, it failed for larger animals. However, when they recalculated the scaling coefficient using a different method (non-linear regression), the value was between 0.656 and 0.686 and predicted all of the animals' metabolic rates well.

So why have scientists been using log transformations to derive the ¾ allometric scaling factor when it could well be overestimating the relationship? Packard and Birchard explain that scientists traditionally replotted their data on log graphs to 'linearize' complex data sets over several orders of magnitude. But they explain that this assumption was only true if the 'data conformed with a two paramater power function', and the relationship between animals' body masses and their metabolic rates does not. No one had tested this assumption, and consequently the log transformation introduced a new relationship between metabolic rate and body mass that over estimated the metabolic scaling factor. On top of that, no one had checked for outliers, such as the elephant, in the data set and having derived the scaling factor, no one went back to check that it correctly predicted a mammal's metabolic rate from its body mass.

Packard adds, 'Our work certainly calls into question the validity of "Kleiber's Law", but points to a larger and more general problem with the standard method for allometric analysis.' Doubtless this is not the final word in the allometric scaling debate, but it could be another nail in the ¾ power coffin.

10.1242/jeb.026211

Packard, G. C. and Birchard, G. F. (2008). Traditional allometric analysis fails to provide a valid predictive model for mammalian metabolic rates. *J. Exp. Biol.* **211**, 3581-3587.

POLARIZED LIGHT GUIDES EGG-LAYING MIDGES

Picture by Amit Lerner

Cholera is a major killer and since the first pandemic in the early 19th century it has claimed millions of lives. According to Amit Lerner from The Hebrew University of Jerusalem, Israel, the lethal infection is harboured by an equally infamous insect: chironomids (midges). Lerner explains that the females contaminate water sources with the deadly bacteria when laying their eggs. He adds that his colleagues Nikolay Meltser and Meir Broza had found that females actively choose the body of water where they lay their eggs, but it wasn't clear what drives a female to select a particular pond. Meltser and Broza had noticed that the tormenting insects prefer patches of water that reflect little light, and when they heard that dark water reflects more polarized light than brightly lit water the pair wondered whether the insects were basing their choice on the amount of polarized light reflected by water or the brightness of the reflection. Broza contacted animal polarization vision expert Nadav Shashar and his student Lerner to find out whether polarization or intensity was the guiding factor for midges (p. 3536).

First Lerner and Meltser had to prove that the insects could use polarized light to select egg-laying sites. Tempting the irritating insects into a tent at dusk, they offered them a choice of four trays of tap water to lay their eggs in. Two trays were illuminated with polarized light, one at high intensity and the other at low intensity. The remaining two trays were illuminated with bright and dim unpolarized light. Returning to the tent the next day, the duo counted the numbers of egg clusters laid in each tray, and found that over 60% of the females chose to lay their eggs in trays emitting polarized light, with more than 40% of the females opting for the water with the highest intensity polarization.

Having found that the insects responded strongly to polarized light, the team next tested the midges' preferences under more natural circumstances. Knowing that cloudy water reflects much more polarized light than clear tap water, they offered midges four more choices of bright and dark water, this time varying the degree of reflected polarization by using either tap or cloudy pond water. The results were even more clear cut. Virtually no midges laid their eggs in the unpolarized tubs of water, while the number of eggs laid in the tubs of water reflecting polarized light was proportional to the percentage of polarized light reflected, regardless of the intensity.

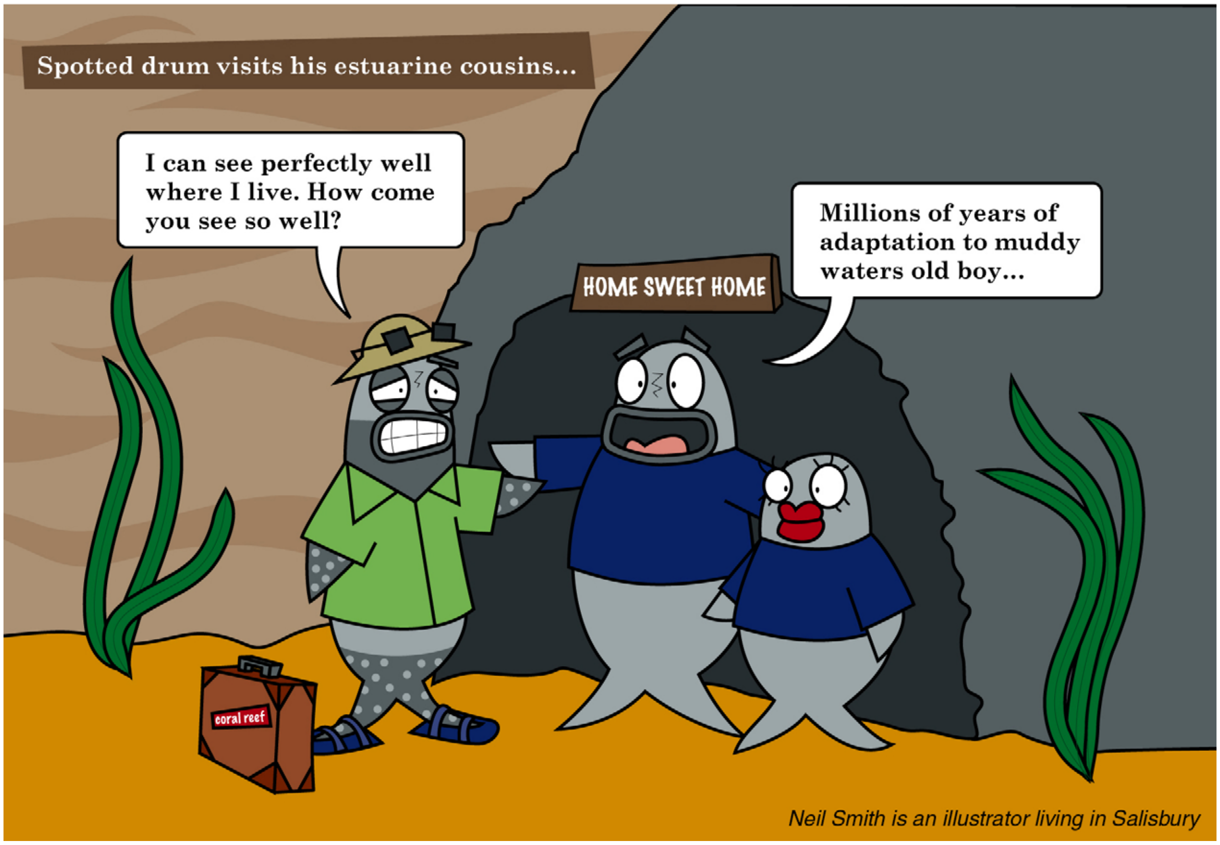
So why are midges so strongly attracted to polarized reflections? According to Lerner, the percentage of polarization in reflections from ponds where the midges lay their eggs does not vary as the light's intensity changes. Polarization is a reliable cue at sunset. This is particularly important for short-lived female midges that only have a matter of hours to find water and lay their eggs when the light is fading.

And there could be another reason for the midges' polarization preference. Lerner explains that the reflections from cloudy water are highly polarized. Could a high level of polarization in reflections be related to the amount of nutritious organic matter in the water? By measuring the polarization of reflections from increasingly cloudy water samples, it was clear that the cloudiest water produced the most polarized reflections, suggesting that the water offers the best start in life to the midges' larvae, and their cholera bacteria hitchhikers.

10.1242/jeb.026237

Lerner, A., Meltser, N., Sapir, N., Erlick, C., Shashar, N. and Broza, M. (2008). Reflected polarization guides chironomid females to oviposition sites. *J. Exp. Biol.* 3536-3543.

SEEING IN THE SEA



Seeing in the sea is a difficult task when the visual conditions can range from crystal clear ocean to muddy tidal estuaries. Light intensities can vary over nine orders of magnitude depending on water clarity and the colour of the light. According to Andrij Horodysky from the College of William and Mary, members of the sciaenid fish family inhabit a wide range of coastal and estuarine environments, and have successfully adjusted to their dramatically different visual worlds. However, it wasn't clear how each individual species' visual systems had adapted to the different light conditions. Teaming up with colleagues from the College of William and Mary, the US National Marine Fisheries Service and Lund University, Horodysky looked at the light sensitivity, colour sensitivity and temporal resolution of five sciaenid species from different visual environments in the Chesapeake Bay to see what adaptations they have made (p. 3601).

The team found that the visual systems of species living at depth were more sensitive than those of species found in shallow waters. Testing the temporal resolution (the fish's responses to flickering light), the team found that the weakfish's responses were much slower than those of other species. Horodysky explains that this allows the weakfish to gather more light in muddy estuary waters, to improve their sensitivity, and adds that 'benthic-foraging sciaenids likely possess generalist eyes that balance luminous sensitivity, speed and resolution without excelling at any one task.'

Having found that the adaptations of each sciaenid make the fish well suited to light conditions in their own particular niche, Horodysky sounds a note of warning. He explains that human activity is probably muddying the waters 'at a pace faster than the evolution of the visual system of Chesapeake Bay's fauna,' and adds that 'Studies that examine the relationships between sensory physiology and behavioural ecology are important… to support the management of aquatic resources.'

10.1242/jeb.026245

Horodysky, A. Z., Brill, R. W., Warrant, E. J., Musick, J. A. and Latour, R. J. (2008). Comparative visual function in five sciaenid fishes inhabiting Chesapeake Bay. *J. Exp. Biol.* **211**, 3601-3612.

Kathryn Phillips
kathryn@biologists.com