Making statistical sense of scents

In spite of what we might have been taught at school or as undergraduates, for most animals, finding the source of an odour is not simply a case of following an increasing concentration gradient. For organisms bigger than single cells, such simple chemotaxis is practically impossible because of the influence of turbulence on fluid motion. How then do animals that track odour trails during the course of mating, feeding, dispersal, settlement, or social interaction, manage to do so?

By analyzing the statistical physics of mixing, Balkovsky and Shraiman [1] have recently developed an efficient strategy for olfactory searching that throws new light on the behavioural strategies that animals use to track odours. On scales relevant to most animals, the movement of both water and air is mostly turbulent. This means that odour trails comprise complex plumes that can be conceptualized as small discontinuous packets of material that are likely to be moving in a random direction with respect to mean fluid motion. The lack of smooth concentration gradients means that simply following a gradient is impossible, and even tracing the source from the direction from which sequentially encountered packets came from, whilst possible, will take an impracticably long time.

Because of the relatively low probability of encountering packets of odour far from the source, Balkovsky and Shraiman found that the best way to minimize the mean time to discovery of the source is to explore actively the surrounding area. Furthermore, they suggest that the most efficient strategy is one where the searcher uses transverse movements perpendicular to the mean fluid flow to increase the rate at which packets of odour are encountered and to home in on the midline of the plume. Once a packet is encountered, the searcher should assume that it originated from a point within a cone-shaped space, the base of which is upstream of the encounter point. Thus, the searcher should search this volume using a zigzag motion until another packet is encountered. At this point, the search cone is repositioned and the search continues. This strategy utilizes simple behavioural rules for movement, combined with knowledge of mean air or water speed and direction.

Pleasingly, Balkovsky and Shraiman's strategy appears very similar to that used by many moths to trace pheromone cues, so-called casting and counterturning. Although the complexity of the problem allows for numerous efficient strategies, this similarity is encouraging, and should stimulate new experimental studies of olfactory search in a variety of animals from moths to lobsters to ants.

1 Balkovsky, E. and Shraiman, B.I. (2002) Olfactory search at high Reynolds numbers. *Proc. Natl. Acad. Sci. U. S. A.* 10.1073/pnas.192393499

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In Brief

Equatorial Prize's for Sustainable Development in Tropics awarded

The Equator Initiative (http://www.equatorinitiative.org.) announced the winners of the Equator Prize 2002 at an awards ceremony held at the World Summit on Sustainable Development (WSSD) during August 2002. These prizes recognize community initiatives throughout the tropics for their work to reduce poverty whilst conserving and using biodiversity sustainably. Out of 420 nominations, 27 winners (each awarded US$30 000) were announced (http://nature.org/pressroom/press/press752.html).

Winning projects included the production of natural medicines and cosmetics, locally managed marine reserve networks, ecotourism, honey production, village-based forestry management, oyster culture, and numerous other innovative efforts that balance human needs and respect biodiversity. A major theme to emerge from the WSSD is that conservation will be impossible unless it is partnered with meeting the needs of people. The Equatorial Awards are one of the few examples in which biodiversity and people are served simultaneously. *PK*

The Darwin Centre

What do you do with 22 million spirit specimens in 450 000 jars, and 350 scientists? Answer: house them in a state-of-the-art ecofriendly building, with 27 km of shelving, 51 spirit tanks, light and temperature controls and, for the scientists, ultra-modern laboratories.

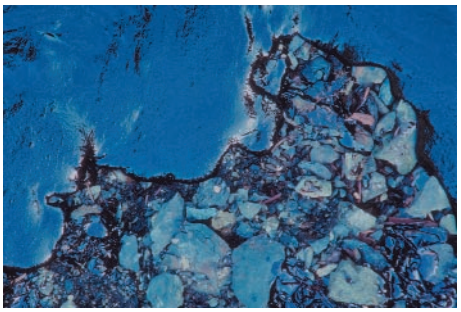
This is the new Darwin Centre at the Natural History Museum, London, UK (http://www.nhm.ac.uk/darwincentre/), which opened to the public on 30 September 2002. Not only is it a research and storage facility, but the centre gives the public the opportunity to meet the scientists, and to see their work and the collections at first hand.

The Centre dispels the images of scientists working away in musty, antiquated environments, and there is a comprehensive schedule of talks planned at which scientists discuss their work and answer questions from the public. The Centre also strengthens the position of the Natural History Museum as one of the most important natural history collections in the world. *LS*

Post-Exxon Valdez monitoring program struggles with cumbersome planning process

The Exxon Corporation was required to give US$900 million to an Oil Spill Trustee Council for compensation of lost resources, and for monitoring and research, as a result of the oil spill off the Alaskan Coast in 1989. Funds were set aside to endow long-term research and monitoring aimed at understanding the Alaskan Gulf ecosystem. The National Research Council recently

reviewed the plans being developed for this long-term monitoring and research plan, and found the efforts admirable, but sidetracked by an unwieldy planning process that requires all council-members to unanimously agree on monitoring plans (http://www.nap.edu/openbook/).



The result is that this unique opportunity for fundamental research and monitoring aimed at understanding an amazing ecosystem could be squandered for lack of clear hypotheses, and tangents that deal with day-to-day management questions as opposed to the bigger picture. When everyone has their say and input, it is hard to develop a sharply focused plan, a lesson that has been learned over and over again with other 'big science, multi-stakeholder' science panels. The question is whether the benefits from such consensus building outweigh the cost in terms of cumbersome and often bloated science. *PK*

The state of ecosystems in the USA

At the request of the White House in 1997, the Heinz Center (http://www.heinzctr.org/) established a program to measure and report the state of ecosystems in the USA. The 2002 report covers the coastal zone and oceans, farmlands, forests, fresh waters, grasslands and shrublands, and urban and suburban lands. Just as key economic indicators (e.g. the Dow Jones Index, unemployment or inflation rates) guide economic policy, the hope is that, by assembling key indicators for the health of american ecosystems into an easily digested report, policy makers might be able to make better decisions regarding the use of public lands and environmental regulations.

Academics will certainly find this report both interesting and of great use, because of the data synthesized and the type of indicators that were selected to represent the state of each ecosystem. But there is some doubt as to whether, when formulating its environmental policy, the current White House staff and administration would be interested in the sort of information presented in this report. Fortunately, the project is due for repeated revision and updating, and will hence endure through a wide variety of political regimes. *PK*

Global Ecosystem Assessment puts its methods out for review

It is hard to imagine a more ambitious goal than measuring the health of the ecosystems of the world. The widely supported Millennium Ecosystem Assessment sets out to do exactly that, at a coarse global level, and in more depth region-by-region and country-by-country. The challenge is not just obtaining data, but knowing what questions to ask of the data and how to structure the analyses. To that end, the first draft methods of this assessment have been released for broad scientific review (http://www.millenniumassessment.org/en/about/cfreview.htm), with reviews due in mid-November and a round of revision expected soon thereafter.

The assembly of scientific leaders put together for this assessment is staggering, and the review process matches in ambition the project itself. The hope is that the quality exemplified by the scientists involved and the extensive objective review process applied to this global assessment will make it impossible for even the dimmest of national leaders to overlook whatever findings emerge. Certainly, all ecologists should be interested in the approach being taken, as it is an example of a cutting-edge application for ecosystem science and decision theory. *PK*

Gabon preserves land for parks

The nation of Gabon, which contains some of the most biologically important ecosystems in central Africa, has announced that a full 10% of its land will be set aside as national parks (http://www.gabonnationalparks.com). Before this bold move, Gabon lacked any national parks.

The decision, announced by Gabonese President El Hadj Omar Bongo, was promoted by Wildlife Conservation Society (WCS), a New York-based environmental organization. In total, some 13 national parks spanning >25 000 km^2 will be designated. Parks on the nation's coastline will protect large populations of hippopotamus and leatherback turtles, whereas inland parks will shelter lowland gorillas and a diversity of other wildlife.

Although logging activity is increasing in Gabon, the new parks demonstrate a growing commitment by the Government to promote ecotourism and sustainable development. These efforts will be aided by funds from the environmental groups WCS, World Wildlife Fund, and Conservation International, and the US Government, as part of a broader initiative to conserve forests of the greater Congo Basin. *WFL*

US Congress considers Aquatic Invasive Species Act

The 107th US Congress is considering a reauthorization of the National Aquatic Invasive Species Act (http://www.ucsusa.org/environment/nisa.pdf). Invasive species are spread across the USA and its waters, with >800 invasive aquatic species established in the Great Lakes Basin and the Gulf of Mexico alone. Conservation organizations support this act because it covers all waters of the USA, including inland lakes and streams, and contains provisions to deal with screening of intentional introductions. Given the great difficulty of controlling invasive species after populations are established, the Act provides for establishing an early warning system, coupled with rapid response capability, which might be the only hope of curbing this major environmental threat.

Although this is a reauthorization of the 1996 act, significant changes include much greater attention to monitoring and early detection, and an expansion of focus to all of the Nation's waters (the original act was a reaction to the zebra mussel invasion of the Great Lakes, and hence limited in its scope). *PK*

Irresponsible harvest puts white abalone on verge of extinction

In just 30 years, numbers of white abalone *Haliotis sorenseni* off the coast of California have declined from >1.5 million to <2000 individuals. The primary cause of decline is excessive harvest. They are now so sparse that fertilization is not adequate to replace the remnant populations, and extirpation from the coast of California could come within ten years.

Anyone familiar with fisheries will be unsurprised to learn about egregious overharvest and population collapse. What is surprising is that this abalone harvest could have been so tenacious that a species might actually disappear entirely from Southern California. The species could still persist off the coast of Mexico, but even there overharvest is threatening its

persistence and the absence of dire predictions regarding Mexican abalone might be nothing more than an absence of data of any kind. The National Marine Fisheries Service is attempting to put together an abalone recovery plan, the first of its kind for a marine invertebrate species (http://www.nmfs.noaa.gov/prot_res/species/inverts/White_AB.html). There is little doubt that many other marine invertebrates are threatened and endangered, but have simply escaped our notice. *PK*

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Letter

Seed dispersal and tree species diversity

In their review of seed dispersal [1], Wang and Smith echo the many voices that have recently proposed that limited seed dispersal contributes to maintaining tropical tree diversity. According to this proposal, superior competitors often fail to arrive at sites that are favourable for their recruitment, enabling inferior competitors to 'win by default' and thus avoid local extinction. I believe that this argument misses some crucial points and that limited dispersal probably has a net negative effect on the species richness and ultimate fate of local communities.

Recent studies have modelled species coexistence as a balance between speciation (by mutation in a single individual) and extinction [2,3]. In Hubbell's neutral theory, all speciation events produce ecologically identical organisms, and species go extinct by random drift [2]. Actually, many mutations are deleterious. Most, but not all, of these inferior variants disappear rapidly because of competitive exclusion (or natural selection).

A niche-based theory of biodiversity includes the same elements as the neutral theory (mutation, elimination of inferior variants by selection, and random drift) plus variants whose relative competitive ability depends on context, such that a number of variants do not drift to extinction but persist deterministically for much longer than would be expected by chance. All else being equal, communities with niche-based dynamics have more species than do neutral communities.

Limited fecundity, dispersal and longevity all decrease the component of species richness that is attributable to niche differences. This is because variants need to reach those particular places or times where they have a competitive advantage, to compensate for demographic losses in unfavourable situations and to escape random drift [4–6]. If dispersal is severely limited, niche differences among species cannot promote species richness, and the community becomes effectively neutral.

In models without deleterious mutations, local dispersal tends to create local monospecific clumps and increases species richness at larger scales [2,3]. If dispersal distances are sufficiently short, this enhances the total richness of what is usually called a 'local community' [3]. Now consider deleterious variants. By preventing the spatial mixing of genotypes and species, and competition among variants, local dispersal hampers the elimination of inferior variants [7–9]. At first sight, this appears to enhance the total number of coexisting variants. However, a population or community that does not eliminate enough deleterious variants eventually becomes dominated by organisms that are unable to replace themselves, and goes extinct by mutational meltdown [8,9].

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Published online: 14 October 2002

