Conservation biology

Science, sex and the kakapo

William J. Sutherland

Sex-allocation theory predicts how the sex ratio of offspring should vary with the mother's physical condition. Applying this theory has helped in retrieving a charismatic parrot from the edge of extinction.

The kakapo, a nocturnal, flightless parrot found in New Zealand, is an endangered species, its rarity and eccentricity making it a high-profile test for conservationists. At a meeting last month*, Mick Clout (Univ. Auckland) reported a scientific success story in reducing the bird's risk of extinction. Providing extra food to improve fledging success seems to have inadvertently resulted in breeding females producing an excess of male young, as predicted by evolutionary theory[1,2]. Given this finding, conservation workers decided to withhold extra food until after the females had laid their eggs, resulting in a much-needed boost in the number of female fledglings this year.

The kakapo (*Strigops habroptilus*; Fig. 1) was once common in the three largest islands of New Zealand, but its distribution shrank following the spread of black rats and stoats introduced from Europe in the 1870s and 1880s. By the 1950s, kakapo were extinct on North Island and only 18 remained in a remote and mountainous part of South Island. The stoats are thought to have eaten not only eggs and chicks, but also incubating females, so all 18 survivors were male. The only remaining wild females were on Stewart Island (south of South Island), which stoats had not colonized, although rats and feral cats were present. A bold decision, taken in 1982, was to capture all of the remaining birds and release them on predator-free islands, including Codfish Island, off the coast of Stewart Island. A world population of 62 birds in 2001, with only 21 adult females, created an urgent need for more females, yet only six female fledglings had been produced since 1982.

In most years, kakapo feed mainly on foliage and other poor-quality foods that are insufficient to allow breeding. Egg-laying is restricted to those years in which certain trees — podocarps — undergo mass fruiting, known as masting. Since 1989, supplementary food, such as nuts and sweet potato, has been given to some individual kakapo from dispensers in their home ranges, resulting in a 15% increase in body weight for fed birds. Unlike natural masting, supplementary food did not seem to induce breeding. But fed females spent less time off the nest, which increased chick survival.

The theory of sex allocation proposed by Trivers and Willard[1] states that females in better physical condition should produce more offspring of the sex that shows the greater benefit from the improved condition. Kakapo reproduce in leks — communal display grounds in which males fight to defend small territories within which they display vigorously. Females visit just to select a mate before raising the young alone elsewhere. Studies of various lek-breeding species show strong competition between males, with a few high-quality individuals obtaining almost all the matings[3].

Male kakapo fight, sometimes to the

International Ornithological Congress, Beijing, China, 11–17 August 2002.

RON MOORHOUSE

Figure 1 **The eccentric kakapo. This remarkable nocturnal species differs from all other parrots in many ways, including being flightless, mating in display grounds ('leks') and breeding only in the infrequent years when specific trees undergo mass seeding. The sex ratio of the offspring depends on the condition of the mother, which has considerable implications for conserving the species.**

100 YEARS AGO

I have frequently observed with interest the erect attitude assumed by the small Agamid lizard *Otocryptis bivittata*, Wiegm., when running rapidly, and have long suspected that the short front legs were not used at such times. But the rapidity with which the animal runs, and the nature of the ground which it usually frequents, have prevented very close observation. I have, however, recently fully satisfied myself that its action is truly bipedal… On several occasions one of them has crossed a smooth sanded road immediately in front of me. I have thus been able to see clearly that the anterior limbs are carried quite free from the ground, progress being effected solely by the long hind limbs.

ALSO...

According to a Reuter telegram from Rome, the Italian postal authorities have examined a scheme submitted by an engineer, named Piscicelli, for the establishment of an electric postal service. It is proposed, by means of this system, to transmit letters in aluminium boxes, travelling along overhead wires at the rate of 400 kilometres an hour. A letter could thus be sent from Rome to Naples in twenty-five minutes and from Rome to Paris in five hours.

From *Nature* 18 September 1902.

50 YEARS AGO

The dusky-footed wood rat (*Neotoma fuscipes* Baird.) is a medium-sized rodent native to North America… Wood rats are nocturnal and are seldom seen without special search, but the conspicuous houses in which they live, built of sticks above ground, readily show their presence… A wood rat's ability to survive is affected by the conditions that enable it to leave its home and those that affect it away from shelter. A rat that lives in a house providing protection from the weather and predators is exposed to these dangers when away from home. It leaves its house mainly to get food and housebuilding material, to escape from dangerous intruders or intolerant members of its own family, and to find other rats. Many rats contribute to the maintenance of few houses, which last much longer than any single occupant, but the character of each house is dictated by its situation and the available materials; it remains constant in type throughout successive tenancies.

From *Nature* 20 September 1952.

death[4], and larger males are more likely to mate. Male kakapo also grow faster and larger than females, and are thus presumably more costly to raise[5]. So if Trivers and Willard's hypothesis applies, mothers in good condition should produce more sons. Females provided with supplementary food indeed produced significantly more sons (an average of 67% against 29% for birds not given supplementary food)[2]. There is accumulating evidence that maternal condition regularly affects the offspring sex ratio in a range of species[6], including tree swallows[7], lesser black-backed gulls[8], great reed warblers[9] and another species of parrot[10].

A profuse fruiting of podocarp trees was expected to trigger kakapo breeding on Codfish Island this year, so the New Zealand Department of Conservation concentrated all remaining 21 adult females there. Supplementary feeding was delayed until after egg production. The idea was to avoid boosting female condition too much before laying, to avoid a male bias in offspring. Extra food was still provided after laying to maximize fledging success.

The strategy seems to have worked: as Clout described at the meeting, 15 of the 24 young fledged this year were female. This is a neat example of how behavioural ecology can benefit conservation, although the mechanism by which females manipulate the sex ratio remains a mystery.

A common problem in conservation is that endangered species are pushed into suboptimal areas as a result of predation by introduced species or exploitation in their core range. Among the bird species that have only really flourished once they were moved are the nene in Hawaii, the Lord Howe woodhen on Lord Howe Island, the takahe in New Zealand and the red kite in Britain. Intensive manipulation of the kakapo has had its successes, but the long-term solution will surely lie in finding ways of restoring predator-free areas on the main islands of New Zealand. ■

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1. Trivers, R. L. & Willard, D. E. *Science* **179,** 90–92 (1973).
2. Clout, M. N., Elliot, G. P. & Robertson, B. C. *Biol. Conserv.* **107,** 13–18 (2002).
3. Höglund, J. & Alatalo, R. V. *Leks* (Princeton Univ. Press, 1995).
4. Clout, M. N. & Merton, D. V. *Bird Conserv. Int.* **8,** 281–295 (1998).
5. Powesland, R. G. *et al. Ibis* **134,** 361–373 (1992).
6. Tella, J. L. *Trends Ecol. Evol.* **16,** 76–77 (2001).
7. Whittingham, L. A. & Dunn, P. O. *Mol. Ecol.* **9,** 1123–1129 (2000).
8. Nager, R. G. *et al. Proc. Natl Acad. Sci. USA* **96,** 570–573 (1999).
9. Westerdahl, H. *et al. Behav. Ecol. Sociobiol.* **47,** 312–318 (2000).
10. Heinsohn, R., Legge, S. & Barry, S. *Proc. R. Soc. Lond B* **264,** 1325–1329 (1997).

Chemical physics

A delayed reaction

David E. Manolopoulos

The simple hydrogen exchange reaction was well understood until an unexpected effect emerged in detailed experimental measurements of the process. An explanation for this effect has now been found.

The scattering of a hydrogen atom from a hydrogen molecule ($H + H_2 \rightarrow H_2 + H$) is the simplest possible chemical reaction, as it involves only three nuclei and three electrons. This reaction has served as a benchmark system for understanding chemical reaction dynamics for nearly a century, and quantum-mechanical calculations of the electronic aspects of the process have been made with unrivalled accuracy. As a result, quantitative agreement between theory and experiment for the related reaction involving a deuterium molecule, $H + D_2 \rightarrow HD + D$, was achieved in the middle of the last decade[1].

But more refined experiments and improved theoretical methods have since raised an intriguing question about the dynamics of this reaction at the quantum level[2,3]. Although the reaction is dominated by a direct recoil mechanism — the incident hydrogen atom recoils along its original path after abstracting a deuterium atom to form the HD product molecule — some of the more subtle aspects of the reaction dynamics revealed by recent experiments have been traced to a second, slower mechanism that occurs with a time delay of around 25 femtoseconds[2]. The question concerns the physical origin of this time delay, which has become the subject of some debate[3,4]. On page 281 of this issue, Harich *et al.*[5] provide an explanation.

In the $H + D_2 \rightarrow HD + D$ reaction, effects beyond the direct recoil mechanism are expected to become apparent only when the quantum states of the reactant and product molecules are directly interrogated. A useful, measurable quantity is the 'state-to-state differential cross-section' — the probability for the reaction to proceed from reactants in a specific initial quantum state to products in a specific final quantum state as a function of the scattering angle between them. This quantity was first measured for the $H + D_2$ reaction at a single collision energy by Welge and co-workers[1] in the 1990s.

Following the suggestion of Miller and Zhang[6], Althorpe *et al.*[2] have since measured the state-to-state differential cross-section over a range of collision energies, in the hope of gaining greater insight into the reaction dynamics of the $H + D_2 \rightarrow HD + D$ process. By varying the wavelength of the photolysis laser used to photodissociate HBr precursor molecules (and hence generate the reagent H atoms), they were able to measure the differential cross-section for collision energies from 1.39 to 1.85 eV. Their reward was the observation, at a collision energy of around 1.64 eV, of an intriguing forward-scattering peak for the HD product molecule in a quantum state with a vibrational quantum number of three and a rotational angular momentum quantum number of zero. A theoretical analysis by the same authors[2] of this forward scattering showed that it was delayed relative to the backward-scattering recoil mechanism by some 25 femtoseconds, but their analysis did not produce a physical explanation.

In fact, there are two conceivable explanations for such a time delay[3]. The more obvious is a simple 'threshold' effect: as the reactants approach a potential-energy

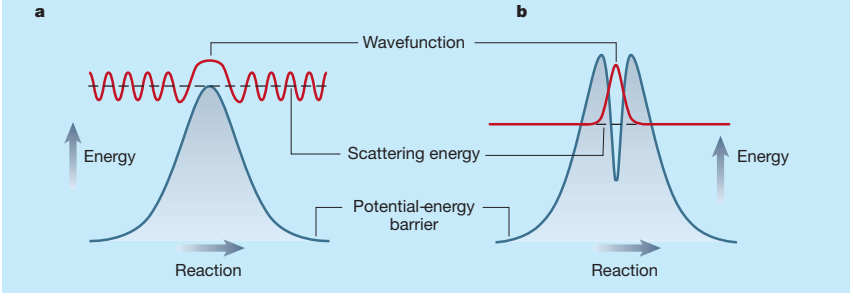

Figure 1 **Wavefunctions and barriers. There are two possible explanations for the time delay seen in forward scattering in the reaction $H + HD \rightarrow H_2 + D$.** a, **The scattering energy (dashed black line) coincides with the top of a potential-energy barrier (solid blue line); crossing this 'threshold' causes the reactants to slow down and leads to the increased amplitude of the quantum-mechanical wavefunction (solid red line) at the barrier maximum.** b, **A 'quasi-bound' quantum state exists in the well between the double maxima of a potential-energy barrier (solid blue line) before decaying into reaction products. The highly localized wavefunction (solid red line) indicates a 'resonance' effect. Harich and co-workers' analysis[5] of wavefunctions in the $H + HD \rightarrow H_2 + D$ reaction suggests that the time delay is due to the threshold effect, not the resonance process.**