periodic stack of silver and aluminium oxide deposited on their half-cylinder cavity, which is fabricated on a quartz substrate. They use this system to produce an image of a pair of lines with sub-wavelength spacing and the letters 'ON', both with sub-diffraction resolution.

Smolyaninov *et al.*[2], on the other hand, combine the idea of a hyperlens with the earlier concept of the superlens[6]. A superlens is made of a single layer of material with a negative refractive index. Rather than immediately converting evanescent waves into propagating fields, a superlens enhances the evanescent waves through resonant coupling to fields on the surface of the lens known as surface plasmon polaritons. In Smolyaninov and colleagues' device, formed of concentric rings of the plastic polymethyl methacrylate (PMMA) on a gold surface, the evanescent waves experience such a boost, in addition to the device's strong anisotropy. The magnifying action of this lens is demonstrated by imaging rows of two or three PMMA dots placed near the inner ring of the device.

These novel imaging devices[1,2] have significant advantages over traditional approaches, and should therefore find numerous applications in optical imaging. Above all, they produce a direct optical image, and so do not require the time-consuming scanning process of near-field scanning optical microscopy.

Recently, the Berkeley group has also developed an alternative approach to the far-field superlens[7], in which the conversion from evanescent to propagating waves is achieved through scattering on surface corrugations. Although it is still too early to tell which of these devices will prove the most useful, the recent explosive progress in sub-wavelength imaging undoubtedly opens up many exciting possibilities. ■

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1. Liu, Z., Lee, H., Xiong, Y., Sun, C. & Zhang, X. *Science* **315,** 1686 (2007).
2. Smolyaninov, I. I., Hung, Y.-J. & Davis, C. C. *Science* **315,** 1699–1701 (2007).
3. Abbe, E. *Arch. Mikrosk. Anat. EntwMech.* **9,** 413–468 (1873).
4. Jacob, Z., Alekseyev, L. V. & Narimanov, E. *Opt. Express* **14,** 8247–8256 (2006).
5. Salandrino, A. & Engheta, N. *Phys. Rev. B* **74,** 075103 (2006).
6. Pendry, J. B. *Phys. Rev. Lett.* **85,** 3966–3969 (2000).
7. Liu, Z. *et al. Nano Lett.* **7,** 403–408 (2007).

ECONOMIC ECOLOGY

In the market for minke whales

Stephen R. Palumbi

The capture–recapture technique is a mainstay of ecology. This principle has been applied with individual genotyping to estimate how many accidentally killed minke whales reach the markets of South Korea.

Behind this stack of parboiled strips of fatty skin, and red meat with thick strips of blubber (Fig. 1), lies a story of scientific detective work. The picture shows a shop in South Korea where the whale products for sale could have come from an endangered population of minke whales from the East Sea, elsewhere called the Sea of Japan. Despite the ban on commercial whaling administered by the International Whaling Commission (IWC), this sale is probably perfectly legal: whales accidentally entangled and killed by fishing gear in the East Sea can be sold for food, as long as the accidental death is reported.

But how many whales really suffer this fate? Writing in *Molecular Ecology*, Baker and colleagues[1] describe how they have developed a genetic capture–recapture method to tackle this question. They conclude that some 827 whales were killed and sold this way during their five-year study — far more than the 458 reported to the IWC.

Minke whales in the East Sea make up a distinct population referred to by the IWC as the J stock, which suffered severe declines until the moratorium on commercial whaling began in 1986. Despite the ban, meat from this population continued to be found in Asian markets[2], and these animals were eventually traced to whales accidentally drowned by fishing gear. After the genetic detection of J-stock animals in Japanese markets, Japan and Korea began reporting whales that were mistakenly killed — up to 150 in some years, but usually far fewer. The reported value of a minke whale (at least US$30,000 each) underscores the difficulty of protecting this population from exploitation[3].

Baker *et al.*[1] took the approach of market ecologists, setting up a genetic capture–recapture study. Mark–recapture surveys in ecology seek to estimate the number of animals in a population by releasing a known number of marked individuals, and then estimating total population size based on the fraction of marked individuals recaptured[4]. Capture–recapture methods use individual identification tools such as DNA genotype analysis instead of marks[5]. And like a typical experiment in ecology, the chance of identifying the same whale twice in a market depends on the whale's 'lifespan' in the market — how long meat samples from an individual whale last before they are all sold. To estimate this figure, a co-author, Justin Cooke, developed

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Figure 1 | Whale for sale. This parboiled minke-whale meat from the East Sea (Sea of Japan) is on offer at a shop in South Korea. A five-year estimate[1] based on individual genetic identification of whale products in South Korea shows that almost twice the number of minke whales were accidentally killed in fishing gear compared with official estimates. Especially given the large number of minkes from the same population that are accidentally killed and landed in Japan, this rate of loss is likely to be unsustainable.

a recapture model that considers that a whale persists on the market with a particular half-life. The model takes observations of identical DNA genotypes in the same and different surveys, and estimates the flow of whales into the market and how long each one persists.

Individual identification was based on genotypes at multiple genetic loci. The regulations laid down by the Convention on International Trade in Endangered Species require permits to transfer whale-meat samples or DNA out of the country in which the whale was landed. So initial work had to take place in hotel rooms using a portable lab. An innovation in this study was the use of multi-gene microsatellite amplification methods, which allowed the archiving of a complete, synthetic set of gene markers from each individual whale for study elsewhere.

Baker and colleagues collected 289 samples in 12 surveys in South Korean markets between 1999 and 2003. Sometimes they found the same whale individual twice in one survey, but this occurred only 13% of the time. One individual was discovered four times in one survey. These low rediscovery rates during the same survey suggest that there are many different individual whales in the market at any one time. In nine cases the authors found the same individual in two surveys — always in subsequent trips. And once they found an individual in three consecutive surveys.

Fitting these data into the capture–recapture model, Baker *et al.*[1] conclude that minke whales in the Korean market are sold quickly. The half-life of a whale — the time during which half of the whale's meat is estimated to have been sold — is about 1.8 months. The only previous hint about the market half-life of whale products came from Japan and was far longer; products from a genetically unique fin/blue whale hybrid were purchased in Japan in 1993 and 1995, but came from an animal killed off Iceland on 29 June 1989, during the last scientific hunt of fin whales[6].

Poorly known features of Korean whale markets could affect the accuracy of the authors' estimates[1]: in particular, variance in the number of products from different whales, differences in half-life owing to different storage methods, or non-random distribution of products among markets. Baker *et al.* suggest that these factors would probably make their figures lower bounds. But an overestimate of whale flow might occur if products from a particular whale individual were sold to only one or a few vendors. This possibility can be investigated only with more complete sampling of single markets. A future refinement is that truly accurate estimates will probably benefit from more frequent sampling.

Although the current model is simple, Baker *et al.* argue that the value they calculate probably represents a minimum for the number of J-stock whales in the East Sea that are accidentally killed and sold in South Korea. Adding the figure of 827 to the 390 J-stock minkes that Japan reported killed accidentally in the Sea of Japan by their fishermen in 1999–2003 gives a total (assuming no under-reporting in Japan) of more than 1,200 whales taken from this protected stock during this period.

Models of minke-whale population dynamics suggest that the J stock cannot sustain this rate of loss. An earlier model, based on the current best models used by the IWC, concluded that killing 50–150 animals a year would drive the population to near extinction by mid-century[2]. Continued take of more than 200 animals a year will accelerate this collapse. Populations of minke whales in the offshore waters of the western North Pacific are larger than the J stock, and these whales are hunted under a permit that the Japanese government issues to itself every year to conduct lethal scientific research. The larger oceanic population might be able to sustain a catch of 200 animals a year, but the structure of whale populations is sometimes so local that small and isolated populations such as the J stock cannot support a loss rate that may seem minor on a whole-ocean scale.

Debate about a return to commercial whaling often runs up against the lack of clear information about the number of whales actually hunted, and the size of the local population from which those animals are drawn. The work by Baker *et al.*[1] takes forensic identification of whale products[7] to the individual level and provides a market-eye view of commerce in whale meat that would be unavailable from official reports. For J-stock minke whales, it shows that reform of rules for the legal sale of accidentally killed animals is required if the East Sea is to be the home of whales in the future. ■

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1. Baker, C. S. *et al. Mol. Ecol.* doi: 10.1111/j.1365-294X.2007.03317.x (2007).
2. Baker, C. S. *et al. Proc. R. Soc. Lond. B* **267,** 1191–1199 (2000).
3. Clapham, P. & Van Waerebeek, K. *Mol. Ecol.* (in the press).
4. Williams, B., Nichols, J. & Conroy, M. *Analysis and Management of Animal Populations* (Academic, New York, 2002).
5 Mills, L. S. *et al. Ecol. Appl.* **10,** 283–294 (2000).
6. Cipriano, F. & Palumbi, S. R. *Nature* **397,** 307–308 (1999).
7. Baker, C. S., Cipriano, F. & Palumbi, S. R. *Mol. Ecol.* **5,** 671–685 (1996).

SPINTRONICS

Silicon twists

Igor Žutić and Jaroslav Fabian

For decades, silicon has been the dominant material for conventional, charge-based electronics. A new twist makes silicon ripe to enter the domain of spintronics, where the new currency is electron spin.

Modern computers present serious challenges for conventional, silicon-based electronics. Ever-increasing demands on processor speed, memory storage and power consumption — the era of the laptop that can keep us warm in winter is fast upon us — are forcing researchers to explore unfamiliar territory in the quest for increased performance. In these endeavours, Appelbaum and colleagues (page 295 of this issue)[1] report a possibly decisive development: the first demonstration of the transport and coherent manipulation of electron spin in silicon.

In spin electronics, or spintronics[2], information is represented by spin and by its proxy, the direction of magnetization. Ferromagnets such as iron or cobalt have a finite magnetization, because most of their electrons' spins are oriented either with or against the magnetization axis, depending on the material. This magnetization direction persists without an outlet power, and is therefore stable[2,3]. For that reason, spintronic applications based on metallic ferromagnetic nanostructures[3] — such as magnetic hard drives and, more recently, magnetic random access memories (MRAMs) — have already proved commercial hits. But for other applications, such as reprogrammable logic, spintronics has not yet broken through into the industrial mainstream.

For that to happen, spintronics must conquer silicon, the abundant, inexpensive and entrenched material of choice for conventional semiconductor electronics. The spin of silicon's electrons is believed to survive sufficiently long to allow the persistence of spin-encoded information, and silicon-based devices might offer significant improvements on proposed spin transistors and spin-based quantum-computation schemes[2,4–7]. Yet a demonstration of even basic spintronic ingredients, such as spin injection, transport, manipulation and detection, has been elusive in silicon[2]. So why has silicon resisted for so long, when other semiconductors, such as the gallium arsenide (GaAs) used in mobile-phone electronics, have proved more pliant?

The two established ways of introducing spin into semiconductor materials are optical and electrical spin injection[2]. In optical injection, a semiconductor absorbs circularly polarized light, generating, through transfer of angular