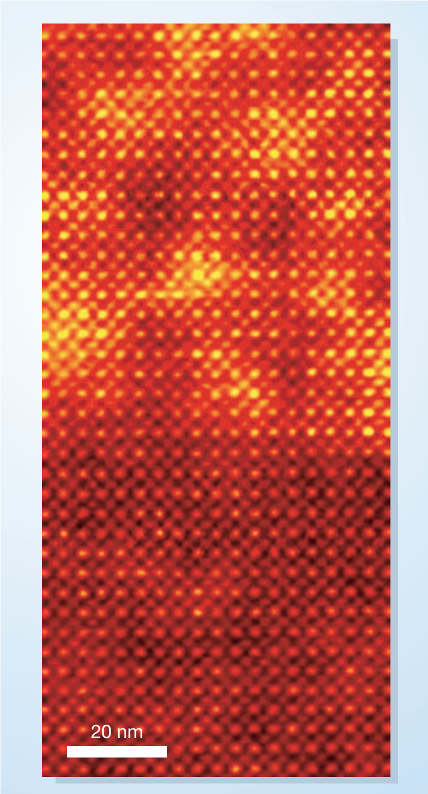

Figure 2 **What a difference a layer makes. The abrupt junction between layers of $SrTiO_3$ (bottom) and $SrTiO_{3-\delta}$ (top) is clear in this image created by Muller *et al.*[3] using a scanning transmission electron microscope. Each bright-orange blob is a cluster of oxygen vacancies.**

defects; simultaneously, the energy loss of the transmitted electrons is measured, revealing the electronic effects of the missing oxygen atoms on the surrounding atoms (that is, changes in their oxidation state). This powerful technique[6] offers outstanding sensitivity in resolving and identifying columns of atoms in crystalline samples, and has been used to image individual impurity atoms in silicon[7].

The team scanned their layered samples in cross-section and spotted regions in which as few as two oxygen atoms were missing. And here came the second breakthrough. The STEM images (such as the one in Fig. 2) show that the oxygen vacancy concentration can change with surprising abruptness — from a layer with no oxygen vacancies to a layer with some constant number of vacancies over a distance of only 0.4 nm (the thickness of a single unit cell of $SrTiO_3$). At 700 °C, oxygen diffuses in minutes over many micrometres[8], which would be expected to completely level out any nanometre-scale steps in the oxygen concentration profile. But it does not. That such sharp doping profiles are achievable is excellent news for the development of devices involving doped $SrTiO_3$ layers, as it has the highest mobility of any known oxide at low temperature[9]. Yet the data do raise the question of why the profiles are so crisp. Are, for example, the oxygen vacancies or the sample microstructure stabilized by an as-yet-unknown mechanism, which may even be applicable to other ionic materials? No doubt Muller and colleagues will set about unravelling this puzzle too.

This work greatly broadens the options available for manipulating the electronic properties of oxides, and probably ionic materials of all sorts, at the nanometre scale. At present, the standard means of doping is to replace one cation with a different cation (that is, an impurity). But the ability to dope films without introducing impurities — thereby avoiding the risk that they might ride on the growing surface or hang around in the deposition chamber and become incorporated at undesired locations — is an enticing advantage of doping with vacancies. As films can grow by the lateral movement of steps as atoms are incorporated, even lateral doping using vacancies might be possible, analogous to the lateral superlattices and one-dimensional wires created using conventional semiconductors[10]. Muller and colleagues show how a view of nothing can turn gems into electronics. ■

Jochen Mannhart is at the Centre for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, D-86135 Augsburg, Germany.
e-mail: jochen.mannhart@physik.uni-augsburg.de
Darrell G. Schlom is in the Department of Materials Science and Engineering, Penn State University, University Park, Pennsylvania 16802-5005, USA.
e-mail: schlom@ems.psu.edu

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Fisheries science

Why mothers matter

Stephen R. Palumbi

Fish population growth depends on older mothers, which in some species produce more and 'better' offspring than younger fish. When fisheries remove the most productive females, the whole population suffers.

English literature about the ocean is predominantly male. Ernest Hemingway's *The Old Man and the Sea* was about an aggressive fight against the elements and the imponderable deep, with the main protagonist being the masculine *el mar*. But the real state of fisheries depends more on the role of females in the replenishment of fish populations. As Steven Berkeley and colleagues[1] now report in *Ecology*, that role has surprising facets. They find, contrary to popular wisdom, that in the black rockfish, older, larger female fish produce eggs and larvae that are much more likely to survive. From the standpoint of population growth rate and the potential to recover from overfishing, the old saying and country-and-western lyric may apply more often than Hemingway: "If Momma ain't happy, ain't nobody happy."

Larger female fish are vastly more productive than their smaller sisters. A single 61-cm-long red snapper (*Lutjanus campechanus*) has been estimated to produce as many eggs as 212 43-cm-long snappers[2]. This is largely because eggs are produced in proportion to a fish's volume, which is proportional to the cube of its length. The profligate fecundity of larger females has long been cited as a good reason to preserve fish populations in 'no-take' marine reserves. In some cases, larger fish in these reserves may double a species' egg production — even if the reserves encompass only 5% of the marine habitat[3].

Berkeley and co-workers[1] have documented another benefit from larger, older females. They studied rockfish of the genus *Sebastes* (Fig. 1, overleaf), and found that eggs from older females produced larvae that grew faster and were more resistant to starvation than larvae from younger females. The differences were huge: on the same diet, larvae of 12-year-old rockfish grew four times faster than larvae produced by 5-year-old rockfish. At the same time, offspring of older females had more metabolic reserves: larvae took an average of 12 days to starve whereas offspring of 5-year-olds starved in less than half that time.

The central difference lies in a small post-hatching gift each mother gives her offspring, a little oil droplet that serves as a metabolic reserve after the yolk-sac has been absorbed (Fig. 2). Older females provide a larger droplet than younger ones, ensuring a better head start for their larvae as they drift through the oceans, feeding and developing into juvenile fish capable of settling to the sea floor. Larger females, and females in better physical condition, produce better larvae as well, but these effects are slight compared with the effects of age. Such observations are particularly surprising in light of long-held views that the optimum reproductive allocation per offspring should be independent of age or parent size[4]. Berkeley and colleagues are not sure why age makes such a difference, but there may be hidden age-related shifts in reproductive effort that will eventually provide an explanation.

These data are also important for attempts to rebuild overfished rockfish populations. Fishers value larger, older fishes — remember Hemingway — and strip away these larger individuals from the reproductive populations. In other fish, such as grouper species that change sex from smaller females to larger males, this tendency to take larger fish has long been known to reduce the number of mature males. Some grouper spawning aggregations have fewer than one male for dozens of females[5], and this imbalance exhausts the fertilization abilities of the few surviving males. The opposite problem is seen in shrimp and crab populations where small males change into larger females[6]. Fishing down the family tree in these cases removes females first, and cuts egg production dramatically[7].

The new data show why heavy fishing pressure on older fish is also a serious problem in species that don't change sex. For example, in coastal Oregon, Berkeley and colleagues[1] document a decline in the average age of female rockfish from 9.5 years to 6.5 years during a period of intensified bottom fishing from 1996 to 1999. Such a culling of the older females reduces the average growth rate of larvae in the population by about 50%, and probably reduces the ability of these larvae to grow and survive to the next stage in their life history. Data on cod and haddock also show that larger females produce larger eggs: presumably these larger eggs produce better larvae[8,9]. The conclusion is that standard fisheries management tools that consider every female to be reproductively equivalent can be far off the mark.

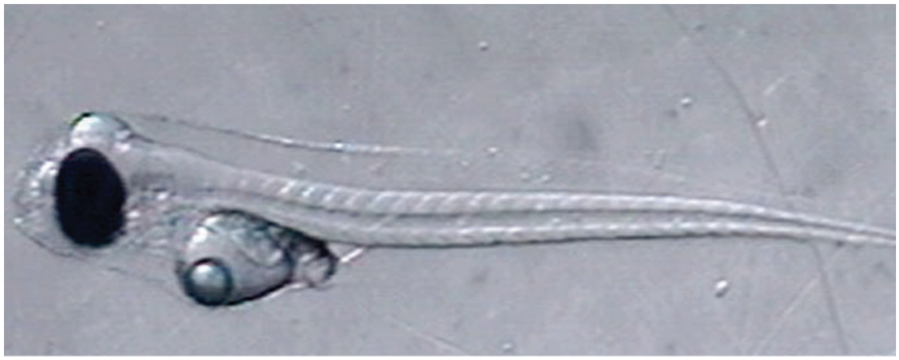

Figure 2 **Post-hatching gift. A larva from a 17-year-old black rockfish (*Sebastes melanops*), showing the large oil droplet used to fuel growth and stave off starvation. Younger mothers produce larvae with smaller droplets that are less likely to survive to the juvenile stage. (Courtesy S. Berkeley.)**

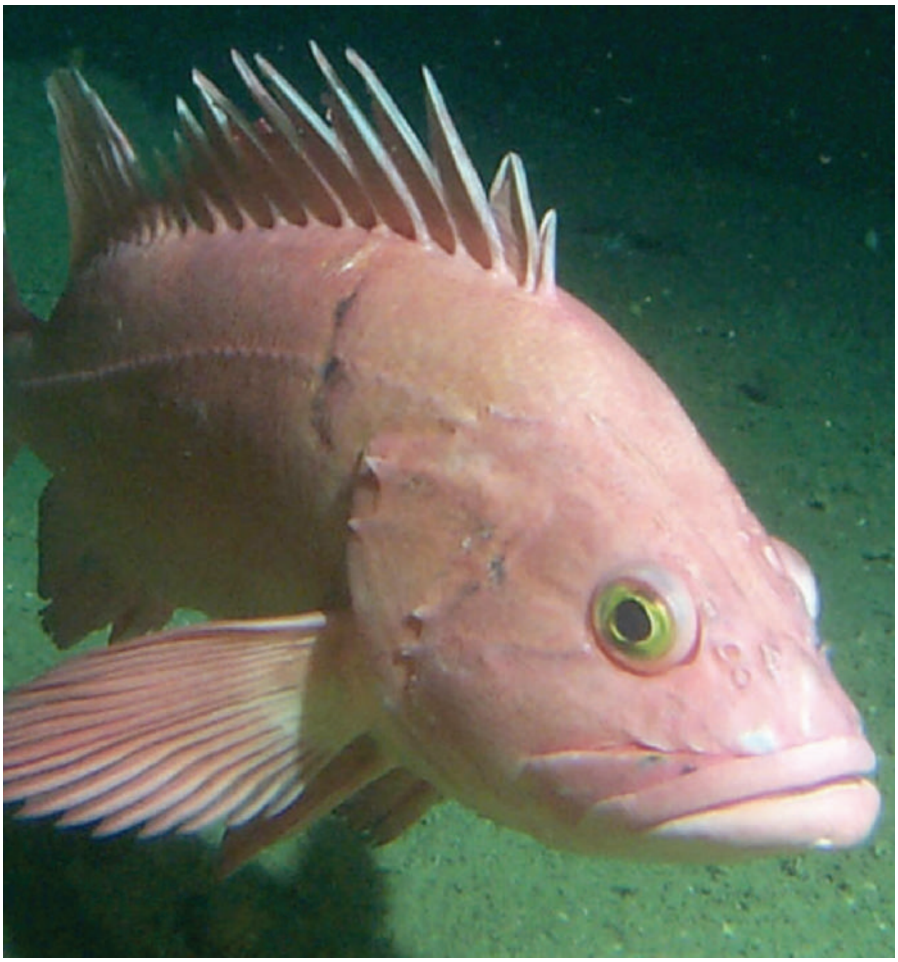

Figure 1 **Yelloweye rockfish (*Sebastes ruberrimus*) from the west coast of North America. Berkeley *et al.*[1] find that older female rockfish produce larvae that have higher rates of growth and survival than those produced by younger mothers. (Courtesy Victoria O'Connell, Alaska Department of Fish and Game.)**

Marine reserves change the landscape of fishing regulations by protecting the entire local populations of fish and invertebrates. The resulting dramatic reduction in mortality has an immediate benefit in producing larger fish in reserves — an effect that has been seen in tropical and temperate settings, along reefs, kelp beds and in estuaries. So protecting larger, older females can be more efficient in producing larger numbers of higher-quality offspring. Not all fisheries suffer from the need for more offspring. But because reproduction is the fuel that keeps all fisheries alive from one generation to the next, enhancing the success of larvae is a key to a sustainable fisheries future.

And Hemingway's Old Man Santiago may have known the power of females in the sea all along. Younger fishermen thought of the sea as masculine: "But the Old Man always thought of her as feminine and as something that gave or withheld great favours"[10]. Those favours are written in the next generation of the sea's creatures, and these new research results tell us that it is the favours of the mothers that matter most. ■

Stephen R. Palumbi is in the Department of Biological Sciences, Stanford University, Hopkins Marine Station, Pacific Grove, California 93950, USA.
e-mail: spalumbi@stanford.edu

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