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24. The divergence between ITQ and non-ITQ fisheries is even more pronounced for less conservative definitions of collapse; i.e. 1 to 6% of historical maximum catch (Fig. 1B).
25. The LMEs with at least one fishery managed using an ITQ by 2003 are the California Current, Gulf of Alaska, Humboldt Current, Iceland Shelf, New Zealand Shelf, Scotian Shelf, Southest Australian Shelf, Southeast U.S. Continental Shelf, Southwest Australian Shelf, and West-Central Australian Shelf.
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Parasite Treatment Affects Maternal Investment in Sons

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Parasitism can be a major constraint on host condition and an important selective force. Theoretical and empirical evidence shows that maternal condition affects relative investment in sons and daughters; however, the effect of parasitism on sex ratio in vertebrates is seldom considered. We demonstrate experimentally that parasitism constrains the ability of mothers to rear sons in a long-lived seabird, the European shag *Phalacrocorax aristotelis*. The effect contributes to the decline in offspring survival as the breeding season progresses and hence has important population-level consequences for this, and potentially other, seasonal breeders.

One key ecological factor influencing the condition of parents, and therefore the potential fitness of dependent offspring, is parasitism (*1*). In sexually dimorphic species, offspring of the larger sex often require higher nutritional investment and are more vulnerable to changes in parental condition (*2*). Moreover, sex allocation theory predicts that parents in good condition should bias investment toward offspring of the sex that stands to gain more from extra resources provided at critical developmental stages (*3*). We provide experimental evidence that parasites can constrain the ability of mothers, in particular, to rear offspring of the more expensive sex. This contributes to differential mortality of sons and daughters as the breeding season progresses and could explain the seasonal decline in offspring survival that is commonly observed in this and many other seasonal breeders.

Populations of the European shag *Phalacrocorax aristotelis* frequently suffer from severe infections of gastro-intestinal parasites, in particular anisakid nematodes [*Contracaecum rudolphi* and *Anisakis simplex* (*4*)]. Although their effects are usually sublethal, these parasites compete with the host for nutrients and trigger costly immune responses (*5*) that may impair host breed-ing success. Shag chicks must be provisioned in the nest for ~50 days by both parents. Male-biased broods require more food than female-biased broods, and male nestlings grow faster, attain higher peak masses at fledging, and are about 20% larger than females as adults (*4*).

We experimentally manipulated parasitism levels in breeding adults just before chick hatch-ing by treating both male and female parents with a broad-spectrum antiparasite drug (iver-mectin), which removes gut parasites and pre-vents reinfection over a period of ~6 weeks and hence for most of the chick-rearing period. Throughout the laying period, nests were ran-domly allocated to either a treatment group, in which both parents were treated with ivermectin ($n = 34$ nests), or a control (untreated) group in which parents were exposed to natural levels of parasitism ($n = 83$ nests). Treated and control nests were matched for laying date, ensuring an equal spread of laying dates in each group span-ning the natural range (~6 weeks). The survival of sons was higher when their parents had been treated (Fig. 1A) [generalized linear mixed model
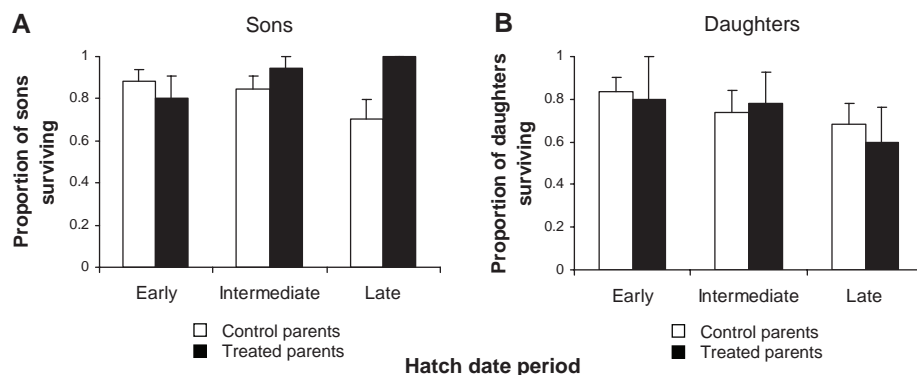

Fig. 1. Differential effect of ivermectin treatment on survival of sons (**A**) and daughters (**B**), and interaction with hatch date. Black bars represent chicks from treated parents, and white bars chicks from control parents. Hatch dates are grouped into early, intermediate and late periods, based on thirds of the distribution and corresponding roughly to 2-weekly intervals. The decline in the survival of sons is not apparent when their parents have been treated. Parasite treatment did not appear to affect the success of rearing daughters. Overall, parasitism in parents accounted for ~37% of the natural seasonal decline in chick survival. Data are means ± SEM. Effect sizes and statistics from logistic regression are given in the text.

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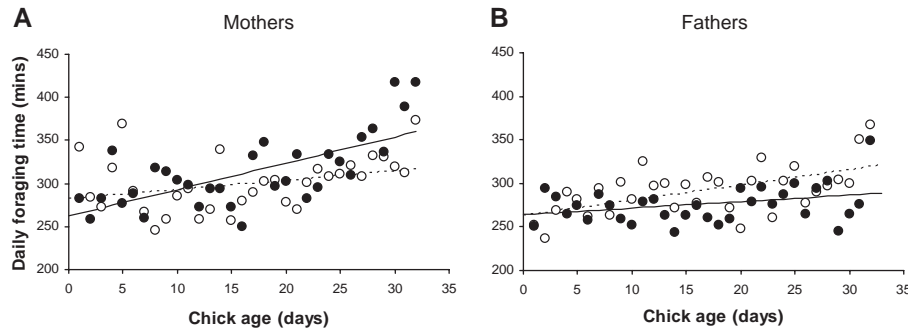
A
Mothers

B
Fathers

Fig. 2. Effect of the dosing procedure on average time spent foraging each day by mothers (**A**) and fathers (**B**) as chicks get older. Treated parents in both cases are represented by closed circles with a solid line showing the effect, and untreated (control) parents are indicated by open circles and a dashed line. The x axes show the age of the oldest chick in nests where the foraging effort of the parents was measured, and data points represent the mean daily time spent foraging by parents at each of these ages (day 0 is the day the first chick hatched). Mothers increased their foraging effort when treated with ivermectin, but fathers appeared to reduce theirs. Linear effects are best fits from the mixed-effects models, and statistics and sample sizes are given in the text.

(GLMM): treatment × chick sex interaction, $\chi^2 = 7.92$, $P = 0.005$; treated: $90.7 \pm 4\%$ (SEM) surviving; controls: $81 \pm 4\%$ surviving]. This was not the case for daughters (Fig. 1B) (treated: $71 \pm 9\%$ surviving; controls: $76 \pm 5\%$ surviving).

Parasitism can have population-level consequences. Like many birds, European shags that breed later in the season show reduced breeding success. In our study population, breeding 3 weeks after the population mean resulted in a 21% reduction in breeding success (GLMM of chick survival, date effect: $b = -0.123 \pm 0.032$, $\chi^2 = 15.34$, $P < 0.001$), mainly due to poorer survival of male chicks (decline in male survival: $b = -0.162 \pm 0.038$; female survival: $b = -0.078 \pm 0.038$; $\chi^2 = 5.70$, $P = 0.025$). However, following ivermectin treatment, the decline in offspring survival was significantly reduced in the group with treated parents compared with the control group (GLMM: treatment × hatch date interaction, $\chi^2 = 4.25$, $P = 0.039$; decline in controls: $b = -0.139 \pm 0.065$, treated: $b = -0.088 \pm 0.031$). This effect was driven by the increased survival of male chicks from treated pairs (GLMM: treatment × hatch date × chick sex interaction, $\chi^2 = 8.85$, $P = 0.003$), such that declines were no longer apparent for sons (Fig. 1A).

To examine possible reasons why sons were reared more successfully by ivermectin-treated parents, we used activity loggers to compare the foraging performance of treated and untreated males and females. As chicks became older, parents increased their foraging effort, but the patterns were different for treated mothers and treated fathers (Fig. 2) [linear mixed effects model (LMM): treatment × parental sex × chick age interaction, $n = 14$ mothers, $n = 16$ fathers; $\chi^2 = 9.65$, $P = 0.002$]. Treated mothers spent more time foraging as their chicks became older relative to control mothers (Fig. 2A) (LMM for mothers only: treatment × chick age interaction, $\chi^2 = 6.27$, $P = 0.013$). Treated fathers, by contrast, tended to reduce their effort through the

chick-rearing period relative to control fathers (Fig. 2B) (LMM for fathers only: treatment × chick age interaction, $\chi^2 = 2.80$, $P = 0.095$). Treated parents did not maintain body mass over the chick-rearing period any better than control parents (average mass lost by $n = 10$ treated birds, mothers and fathers combined, was 39.0 ± 37.9 g, and 23.3 ± 32.3 g for $n = 15$ control birds; $t = 0.311$, $P = 0.758$, no significant sex differences) and presumably were not allocating additional resources to themselves. The treated mothers, it seems, passed the nutritional benefits on to their sons. Treated fathers may have reduced their investment in the brood as a whole (and so spent less time foraging) in response to a perceived increase by their partners. The net effect, nevertheless, was an increase in the survival of sons from treated nests, suggesting that sons benefited from increased maternal investment regardless of any reduction in effort by their fathers.

Given that mothers suffering from infection struggle to rear sons, should they not then prioritize investment in daughters? If so, we would expect the daughters of control parents to survive better than sons. This pattern was observed in the first year of the study, but not the second year. Environmental conditions were poor in 2005, and productivity in the colony was low. As expected, survival of daughters was significantly higher ($83 \pm 9\%$) than that of sons ($58 \pm 11\%$) for untreated pairs in this year ($n = 27$ nests, $\chi^2 = 10.97$, $P = 0.003$). In contrast, conditions were much more favorable in 2006 (and overall productivity much higher), and untreated parents were more successful at rearing sons (survival of daughters = $74 \pm 6\%$, survival of sons = $87 \pm 4\%$, $n = 56$ nests, $\chi^2 = 6.58$, $P = 0.012$). When resources are limited, it appears that mothers preferentially invest in daughters, and only when conditions improve do they shift the balance of resources over to sons. The effect that parasitism has on parents' ability to rear sons may depend, therefore, on environmental quality, most obviously the availability of food.

We have shown that the costs of parasitism to mothers can have a differential effect on the survival of male and female chicks, large enough to induce a marked decline in chick production in the population during the breeding season. Parasite prevalence tends to increase as the season progresses (fig. S1), and hence late breeders may suffer higher burdens. Late breeders may be also more susceptible to infection or its associated costs (6), because they tend to be in poorer physiological condition, less experienced, and less capable of mounting effective immune responses (7). Previous studies have shown that maternal condition can be a key factor in determining primary offspring sex ratio in birds (8), and parasitism has many well-documented effects on primary sex ratio in invertebrates (9). Our study illustrates that parasitism may be a key factor in limiting secondary sex ratio, but the effects of parasitism and its interaction with maternal condition on primary sex ratio in wild bird populations remains untested. Untangling these potentially interacting effects remains a challenge, but it is clear that parasites can have a substantial impact on the relative success of rearing male and female offspring.

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ERRATUM

Post date 30 April 2010

Reports: "Parasite treatment affects maternal investment in sons" by T. E. Reed *et al.* (19 September 2008, p. 1681). The sample size of the experimental group receiving sham treatment in 2006 should read $n = 20$ nests, not 22 nests (see "Experimental methods" in the corrected Supporting Online Material). Therefore, the total sample size quoted in the main text should be $n = 81$ nests, not 83.
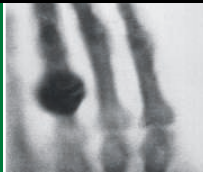
LETTERS

edited by Jennifer Sills

Food Security: Farming Insects

G. VOGEL'S NEWS STORY "FOR MORE PROTEIN, FILET OF CRICKET" (12 FEBRUARY, SPECIAL section on Food Security, p. 811) draws attention to the potential role of insects in food security. Although insects such as mopane worms and termites are widely consumed by some societies, especially in Africa (*1–7*), globalization and creation of a food culture based largely on Western values has led to their marginalization (*1, 5, 6*). Unlike steak, such insects are easily accepted only where indigenous knowledge and willingness to consume them exists (*1–5, 7*).

In addition to overcoming the cultural aversion to eating insects, it will be necessary to address ways to make them available throughout the year. Insects are seasonal, and there are technical difficulties in mass-rearing, processing, and storing them (*8, 9*). Our experience (*8, 9*) in Africa points to the need for greater public-private partnership in research and development. Governments could provide incentives to investors that come up with green business ideas on mass-production of edible insects. Currently, insects such as the mopane worm are treated as open-access resources, and their increasing commercialization is raising fears of extinction (*10*). Unsustainable wild harvesting could be reduced and conservation goals achieved with arrangements that encourage on-farm production of such insects.

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MRI Safety Not Scientifically Proven

WE APPRECIATE THE SIGNIFICANCE OF MAGnetic resonance imaging (MRI) for patients and research, but we are concerned by the tone of the News of the Week story "Fear of MRI scans trips up brain researchers" (L. Jiao, 19 February, p. 931), in which Arno Villringer (Max Planck Institute, Germany) says, "Millions of people have been examined with MRI so far; thus it seems now very unlikely that there would be a side effect." This statement cannot be advanced as a proof of MRI safety. Large patient groups have never been monitored longitudinally in a standardized FDA-approved study. A further argument for caution lies in the increasing evidence that MRI exposure can have biological effects (*1, 2*).

The logical fallacy in this statement becomes apparent when we consider that this argument for MRI could also be applied to the risks of x-ray computed tomography (CT) exposure. In the case of x-rays, it may be factually correct to state that no study to date has shown that CT increases cancer risk, but it is incorrect to state that there are no cancer risks from the radiation exposure associated with CT. Absence of evidence is not proof of the absence of risk, and it is widely accepted that there are small but nonzero risks associated with CT (*3*).

Side effects of these procedures may take decades to detect. One example is the induction of severe side effects in a small fraction of the population years after administration of the MRI contrast agent gadolinium-DTPA (diethylenetriamine penta-acetic acid) (*4*). Now that this risk has been identified, benefit-risk ratio is known and thus manageable. In

Letters to the Editor

Letters (~300 words) discuss material published in *Science* in the previous 3 months or issues of general interest. They can be submitted through the Web (www.submit2science.org) or by regular mail (1200 New York Ave., NW, Washington, DC 20005, USA). Letters are not acknowledged upon receipt, nor are authors generally consulted before publication. Whether published in full or in part, letters are subject to editing for clarity and space.

the case of caregivers volunteering their healthy children, however, the risk is unknown and there is little if any benefit to them; this practice should be questioned.

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Fundamental Change in German Research Policy

UNTIL RECENTLY, AN ESSENTIAL INDICATOR in the evaluation of grant applicants by the Deutsche Forschungsgemeinschaft (DFG), Germany's leading research foundation, was the quantity and impact of the applicant's publications. This policy fit the increasing attention paid to Web of Science–listed publications, impact factors, and the h-index for competitive funding in science (*1*, *2*). The rationale is clear: On the basis of such variables, it is possible to compare performances and to provide a foundation for decisions. However, the process overlooks one fundamental point: the content of research.

The essence of the "Einsteins" of science history was surely not the quantity of their publications, but the quality of their research ideas. Ideas are hard to quantify— they are even harder to compare. But wise peer-referees can qualify them.

The DFG has recently taken an important step toward valuing content. The organization has changed its policy for evaluating research grants by restricting references in forthcoming applications to five of the authors' most important publications and limiting reports of finished projects to the two most important publications per year (*3*). This helps reviewers appreciate the quality and the innovativeness of research. Of course, not every paper can introduce a Theory of Relativity. But we must focus on quality rather than quantity if we are to advance the world's intellectual capital.

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Measuring Forest Changes

D. NEPSTAD *ET AL.* ("THE END OF DEFORESTA-tion in the Brazilian Amazon," Policy Forum, 4 December 2009, p. 1350) highlight promising efforts by Brazil to reduce Amazonian deforestation, in part by harnessing funds from international carbon payments—termed REDD (reducing emissions from deforestation and forest degradation). For a country to engage in REDD, reliable data on past and current changes in its forest carbon stocks are essential (*1*). Having established in 1989 a world-leading program to monitor its Amazonian deforestation using remotely sensed imagery, Brazil is in many ways uniquely poised for REDD (*2*).

Current efforts to promote REDD, including those with pilot funding from the World Bank, assume that each developing nation will develop its own estimates of changes in forest carbon stocks, as Brazil is doing. We believe that this approach is unrealistic and prone to conflicts of interest. First, even if standard monitoring tools are developed (*3*, *4*), the costs will be high if each country must independently develop the capacity to apply them. Second, when applying these tools, there will invariably be decisions—for example, about which remotely sensed images to use and how to interpret them—that offer opportunities to bias results. Such variability between nations has long plagued the U.N. Food and Agriculture Organization's efforts to estimate national changes in forest cover (*5*). Nations will have strong incentives to overestimate their past deforestation rates and underestimate their present rates in order to maximize their eligibility for REDD funds. This could create conflicts between those selling and buying forest-carbon credits that undermine REDD initiatives.

Rather than the current approach, we believe that an independent organization— such as the World Conservation Monitoring Centre of the United Nations Environment Programme—should be tasked and funded with determining historic and current rates of change in forest-carbon stocks, using cutting-edge approaches [e.g., (*4*)], in a consistent and unbiased manner across all developing nations. This will, we believe, be far more cost-effective and reliable than expecting each nation to develop its own estimates, even if these estimates are subject to third-party verification. Brazil's leading efforts to monitor its forests might provide useful lessons for scaling up to global monitoring.

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CORRECTIONS AND CLARIFICATIONS

Reports: "Decorrelated neuronal firing in cortical microcircuits" by A. S. Ecker *et al.* (29 January, p. 584). In Fig. 1E, the labels (r_{sc} values and colored dots) were accidentally applied in reverse order. The correct labels (color *x*/color *y*/r_{sc}) should read for the first row from left to right: green/light blue/–0.01; dark blue/light blue/0.02; dark blue/green/–0.14; for the second row from left to right: red/light blue/–0.01; red/green/0.21; red/dark blue/0.04.

Reports: "Metagenome of a versatile chemolithoautotroph from expanding oceanic dead zones" by D. A. Walsh *et al.* (23 October 2009, p. 578). There are two changes to the names of sequences within tree 1 in Fig. 1A. The first two Eastern South Pacific clones are ESP60-K23I-54 (DQ810449), not ESP200-K23I-54, and ESP60-Khe2-29 (DQ810511), not K23II-30 (DQ810478).

Reports: "Parasite treatment affects maternal investment in sons," by T. E. Reed *et al.* (19 September 2008, p. 1681). The sample size of the experimental group receiving sham treatment in 2006 should read $n = 20$ nests, not 22 nests (see "Experimental methods" in the corrected Supporting Online Material). Therefore, the total sample size quoted in the main text should be $n = 81$ nests, not 83.