would be difficult to disentangle this from the effects of age that may also increase grey-matter density.

Understanding the neural basis of mathematical processes could play an important role in improving mathematical education. This would help individuals struggling to learn about numbers and arithmetic, such as dyscalculics, but it would also have a wider impact. Poor numeracy affects not only the life chance of individuals, it is a significant cost to society (about £2.4 billion per year in the UK, for example). Moreover, the level of mathematical competence in a society plays a causal role in its economic performance, as a recent OECD report demonstrates. However, for neuroscience to have a practical impact, we will need to know more about the neural networks underlying mathematical skills more complex than simple arithmetic, and in other areas of mathematics, including geometry and algebra.

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Institute of Cognitive Neuroscience, UCL, 17 Queen Square, London WC1N 3AR, UK.
E-mail: b.butterworth@ucl.ac.uk; v.walsh@ucl.ac.uk

Correspondence

Genetic detection of mislabeled fish from a certified sustainable fishery

Peter B. Marko[1,*], Holly A. Nance[1,2], and Kimberly D. Guynn[3]

The decline and collapse of many of the world's fisheries has led to the implementation of social marketing that promotes the consumption of sustainably harvested seafood [1,2]. Because the success of this strategy depends on supply chain integrity, we investigated the accuracy of eco-labels for Patagonian toothfish, marketed as 'Chilean sea bass' (*Dissostichus eleginoides*), by genetically analyzing retail fish bearing certification labels from the Marine Stewardship Council (MSC). For Chilean sea bass, MSC certification labels indicate that fish were harvested from the only sustainable fishery [3,4], a population in waters surrounding the sub-Antarctic island of South Georgia and the nearby plateau at Shag Rocks [3]. We found that not all MSC-certified fish were Chilean sea bass from the certified stock: some were simply not *D. eleginoides,* but among those that were, we found significant genetic differences between the retail sample of fish and the certified stock population. Uncertified fish may not necessarily resemble stocks closest to their country of origin because capture and processing often occur at different places. However, significant differences between MSC-certified Chilean sea bass and the sole certified fishery for this species indicate that uncertified fish were inserted into the MSC supply chain.

Best known to consumers by its market name, 'Chilean sea bass', the Patagonian toothfish (*Dissostichus eleginoides*) is a slow-growing, long-lived species found primarily in the Southern Ocean surrounding Antarctica (Figure 1). Reported and unreported catches of *D. eleginoides* increased substantially in the 1990s [3,5] such that *D. eleginoides* is now regarded as overfished [3–6]. At present, the only fishery where this species is considered by the Marine Stewardship Council (MSC) as sustainably harvested is the South Georgia/Shag Rocks population (SGSR) fishery [3,4].

Our primary goal was to investigate supply-chain reliability for Chilean sea bass with respect to MSC certification. Although species substitutions (labeling less expensive species as more expensive species) are relatively easy to detect, resolving the geographic origin of samples within a single species requires genetic characterization of source populations. Therefore, we analyzed mitochondrial DNA (mtDNA) from retail-acquired fish using the same methods as a previous study [7] that revealed SGSR to be genetically highly distinct from populations north of the Antarctic Polar Front (APF), an oceanographic discontinuity separating the Southern Ocean from warmer water to the north (Figure 1). Briefly, we characterized fish by amplifying ~1200 nucleotides of mtDNA (control region flanked by tRNA proline and 12S rRNA) followed by digestion with a single restriction enzyme (*Bst*NI) and visualization with agarose electrophoresis (Supplemental information). Using the same method as the previous study [7] allowed us to compare retail MSC-certified fish to the only stock from which they could have been caught and validly labeled as MSC-certified. For comparison, we applied the same methods to a sample of uncertified fish, most of which were labeled with Chile as the country of origin.

We found that not all MSC-certified Chilean sea bass came from the certified fishery. A combination of PCR, *Bst*N1 digestion, and nucleotide sequencing showed that 8% (3 of 36) of fish labeled as MSC-certified Chilean sea bass were actually other species (Supplemental information). Among retail MSC-certified fish that were actually *D. eleginoides* (33 samples), 15% (5 of 33 samples) had mtDNA haplotypes not present in SGSR (haplotypes E, F, I, and J); haplotype B was found at an elevated frequency in the retail sample, and haplotypes C and D were not found in the retail sample (Figure 1). Overall, the haplotype content of retail certified *D. eleginoides* differed significantly from the SGSR stock (exact test for differentiation $P = 0.0026$; Supplemental information).

This discrepancy is likely caused by mislabeling of less desirable species and uncertified Chilean sea bass as MSC-certified Chilean sea bass at

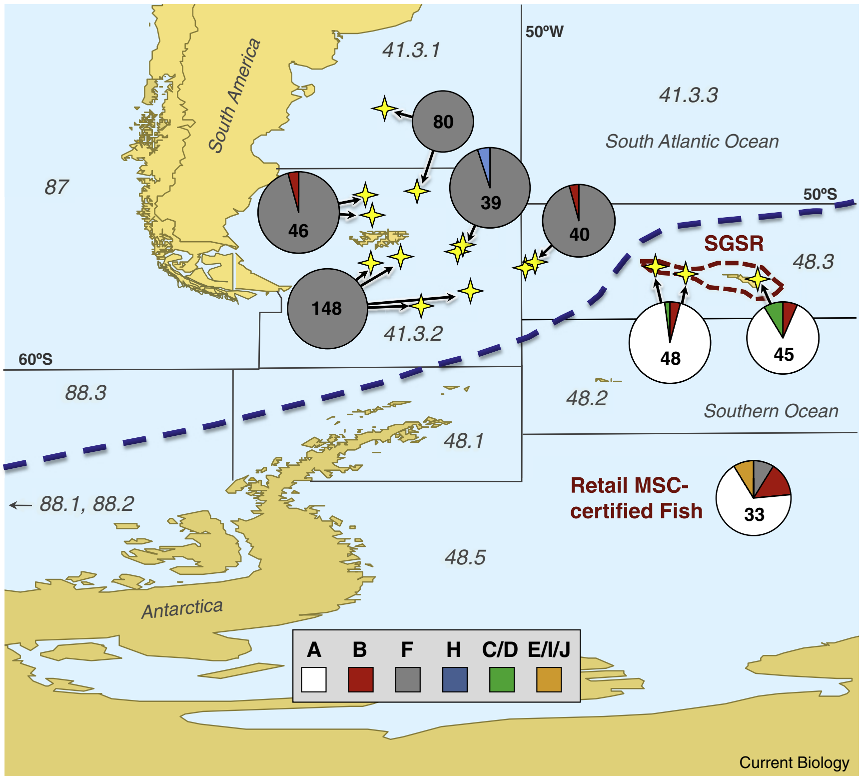

Figure 1. Chilean sea bass (*Dissostichus eleginoides*) mitochondrial DNA (mtDNA) haplotype frequencies.
Pie diagrams (sample sizes within) show the frequencies of mtDNA haplotypes from locations marked by yellow stars [7] and for the retail MSC sample which was ostensibly harvested from the South Georgia/Shag Rocks fishery (SGSR). The size of each pie is proportional to the sample sizes, including the retail MSC sample. The heavy dashed blue line indicates the position of the Antarctic Polar Front; gray lines and italicized numbers denote United Nations Food and Agriculture (FAO) fishing areas.

one or more steps in the supply chain between fisher and consumer. Although a significant difference between retail fish (that were actually *D. eleginoides*) and the SGSR stock could also have been caused by recent migration, exchange on a scale that could alter haplotype frequencies seems unlikely given the slow maturation of *D. eleginoides* (>10 years) and the short time between the population genetic study (2001) and our retail sampling (2008); additional evidence has also established SGSR as highly distinct and likely isolated from other stocks (Supplemental information). Genetic exchange with nearby stocks also seems particularly unlikely given that the nearest potential source populations (South America) lack three unusual haplotypes (E, I, and J) found in the retail sample (Figure 1); in fact, haplotype E has only been found at Heard Island, in the southern Indian Ocean [8].

In contrast to certified fish, analysis of uncertified fish exposed the ambiguity of country-of-origin labelling [9] likely resulting from the large distances uncertified fish are often shipped after capture. Although 92% of uncertified fish that were actually Chilean sea bass (13 of 19 samples or 68%) were labeled as having originated from Chile, 46% (6 of 13) had haplotype A, which is not present north of the APF (Figure 1). Because haplotype A is common south of the APF, nearly half of the uncertified fish 'originating' from Chile were most likely captured in Antarctic waters, but processed later in Chile. This result is qualitatively consistent with recent catch records: although most (91%) of the reported 2009 Chilean harvest originated from north of the APF (FAO area 87, Figure 1), vessels also harvested south of the APF (FAO areas 41.3.2, 48.3, 88.1, 88.2), plus 5% of exports to the United States were harvested by vessels from other countries [10].

Although social marketing has the potential to positively impact threatened species by guiding consumers towards sustainable fisheries, our study showed that retail labeling of MSC-certified Chilean sea bass was inaccurate and that country-of-origin labelling was highly misleading. With respect to certified sustainable fisheries, mislabeling ultimately results in misplaced consumer demand for uncertified fisheries, thereby undermining the most basic goal of this conservation strategy.

Supplemental information

Supplemental information includes experimental procedures as well as supplemental results and discussion and can be found with this article online at doi:10.1016/j.cub.2011.07.006.

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[1]Department of Biological Sciences, Clemson University, Clemson, SC 29631, USA. [2]Harbor Branch Oceanographic Institute at Florida Atlantic University, 5600 US 1 North, Fort Pierce, FL 34946, USA. [3]Fisheries National Seafood Inspection Lab, National Oceanic and Atmospheric Administration, 3209 Frederic Street, Pascagoula, MS 39567, USA.
*E-mail: pmarko@clemson.edu