Pinto and colleagues' data indicate that viruses with a single nucleoprotein mutation sufficient to cause escape from BTN3A3 show no substantial fitness loss.

Curiously, Pinto *et al.* found that amino-acid changes in the viral nucleoprotein that confer resistance to BTN3A3 were present in some avian IAV lineages before those viruses spilt over into humans. But BTN3A3-family members with anti-IAV activity are found exclusively in Old World monkeys and apes, and not in birds, suggesting that, when viral resistance to BTN3A3 first evolved in birds, it did so without any selection pressure. The authors' database searches also revealed fluctuations in the frequency of BTN3A3-resistant IAVs over time, correlating with recorded 'zoonotic' spillover events from birds to humans.

At present, there are no real clues to why resistance to BTN3A3 emerges in avian IAVs. But the co-occurrence with zoonotic infections of humans points to the importance of BTN3A3 resistance for the zoonotic potential of avian IAVs. That said, some disease-associated variants, termed highly pathogenic avian H5N1 IAVs, seem to cause human infections despite lacking the 'escape' mutations documented by Pinto and colleagues; this would indicate that resistance to this protein is not an absolute requirement for infecting humans. Presumably, a collection of genetic variants act together to allow these H5N1 viruses to override BTN3A3-mediated restriction and to replicate efficiently in human tissues.

Analyses of IAV sequences obtained from archival samples of lungs of people infected with the 1918 pandemic H1N1 virus have suggested that mutations conferring escape from MX1 arose sequentially in humans[8]. What's more, isolates from the beginning of that pandemic already possessed a nucleoprotein variant with changes at position 313 that confer BTN3A3 resistance[8]. It is tempting to speculate that this early adaptation drove the subsequent escape from MX1. Further studies are needed, however, to understand the possible synergistic interplay between BTN3A3 and MX1 resistance during zoonotic virus transmissions.

Overall, the identification of BTN3A3 as a component of the species barrier highlights the role of immune-related antiviral factors in preventing the spillover of avian IAVs to humans. This discovery has consequences for assessing the zoonotic potential of these IAVs. Only by understanding the diversity of adaptive mutations that viruses must acquire for successful transmission into the human population will we be able to identify, in a timely manner, zoonotic IAVs that have pandemic potential.

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Environmental science

Collaborations uncover extent of plastic pollution

Kara Lavender Law & Chelsea M. Rochman

Ambitious campaigns to sample plastic pollution in coral-reef and freshwater ecosystems demonstrate the value of international cooperation in assessing contamination to identify drivers and inform management. **See p.311 & p.317**

Plastic pollution evokes powerful images of injured marine life tangled in plastic ropes, or starving seabirds whose guts are filled with broken plastics. But clear evidence is emerging that plastic contamination extends beyond marine ecosystems to affect wildlife around the planet[1], as well as Earth's atmosphere[2]. In this issue, researchers report global evidence that plastics contaminate coral reefs and freshwater lakes – some of which are far away from the human populations that create such pollution. On page 317, Nava *et al.*[3] quantify microplastics in surface waters of lakes and reservoirs in 23 countries, and on page 311, Pinheiro *et al.*[4] measure larger plastic debris contaminating coral-reef ecosystems in 25 locations across the Pacific, Atlantic and Indian oceans.

As environmental contaminants, plastics are remarkably diverse in size – spanning nanometres to kilometres – and also vary in their chemistry, shape and other physico-chemical characteristics. This diversity complicates analyses of the abundance and distribution of plastics in the environment, because each type of plastic requires a tailored approach to

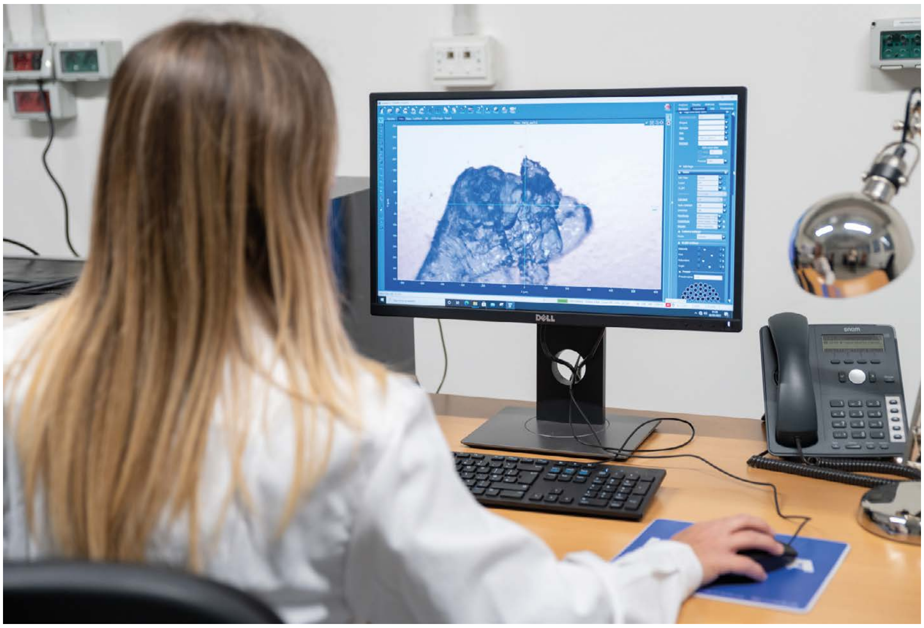
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Figure 1 | Analysing microplastics in freshwater systems. Nava *et al.*[3] sampled microplastics from 38 lakes and reservoirs, analysed them in a single laboratory and obtained a consistent data set showing that contamination is widespread, yet variable.

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Figure 2 | A visual survey of plastics on coral reefs. Pinheiro *et al.*[4] quantified debris on coral reefs in 84 ecosystems collected by teams of divers and underwater vehicles. The study shows that 92% of ecosystems are contaminated by debris, 88% of which is plastic.

sampling and measurement. Scientists must first target a particular size range, and then design sample collection and analysis tools that are suitable to the task.

The need for specialized tools has resulted in an immense number of independent methods to document environmental contamination by plastics. As a result, data often cannot be compared or combined in a systematic way, making it difficult to identify 'hotspots' where pollution might have the greatest impact, or where interventions could be best deployed. The two studies reported in this issue demonstrate impressive coordination across many research groups and multiple locations. Both teams used standardized (or at least comparable) methods to conduct their analyses. In doing so, they have shown that coordinated field research can reveal widespread patterns in debris abundance, and identify potential drivers of plastic accumulation.

Nava *et al.* looked specifically at plastics that were larger than 250 micrometres by sampling the surface-water outflow of 38 lakes and reservoirs using a plankton net, which filters water through a fine nylon mesh. Multiple samples were taken at the same location and time, and then samples from all sites were analysed by a single laboratory (Fig. 1). This approach resulted in a consistent data set demonstrating, with high confidence, that contamination is widespread, yet variable. Plastics were found in all water bodies sampled by the authors, and 94% of these plastics were smaller than 5 millimetres — making them microplastics. Concentrations ranged from 0.001 to 10 particles per cubic metre and varied relatively little between samples taken from a single location.

The shape of particles measured by Nava *et al.* varied by lake size — smaller lakes, and those with low plastic concentrations, were dominated by plastic fibres, whereas larger lakes contained a higher proportion of plastic fragments. The strongest predictors of plastic concentration were lake surface area and population density in the watershed (the area of land that channels water to the ocean).

Pinheiro *et al.* compiled data from independent visual surveys conducted by divers and underwater vehicles. To achieve this, several research groups worked together to quantify debris larger than 5 centimetres on coral reefs in 84 distinct ecosystems in both coastal and offshore regions around the globe (Fig. 2). The depth of these ecosystems ranged from shallow, sunlit regions less than 30 metres from the surface to deep, low-lit areas between 30 and 150 metres from the surface. Using similar methods, the teams documented widespread contamination by debris (in 92% of ecosystems, measured in all but one location), most of which (88%) was composed of plastic.

> **"Coordinated field research can identify potential drivers of plastic accumulation."**

In much the same way as Nava and colleagues, Pinheiro's team found that debris densities varied widely across sites — ranging from around 500 to about 90,000 items per square kilometre. The maximum densities were observed in a single location, the Comoros islands off Africa's east coast, and consisted mainly of consumer-derived items. But most other sites were dominated by fishing-related debris, and the density of debris on deep reefs was typically greater than that on shallow reefs. Correlations between consumer debris and proximity to large population centres, and between fishing debris and habitat complexity, suggest potential drivers of contamination that could be targeted for intervention.

Widespread environmental contamination by microplastics and larger plastic debris occurs globally, and there is ample evidence that this pollution causes harm[5]. To make it easier to manage and mitigate this contamination, coordinated monitoring efforts are needed to identify locations where exposure is highest and presents the greatest risk[6]. Cooperative approaches such as those adopted by Nava and Pinheiro and colleagues can also identify pathways for upstream prevention and environmental clean-up. Such coordination will help monitoring programmes, on local and global scales, to assess baseline contamination and its drivers, and to measure the effects of mitigation and preventive actions when surveys are repeated in future.

United Nations member states have until the end of 2024 to negotiate the terms of an instrument, bound by international law, to address plastic pollution (see go.nature.com/43xhx8r). This task highlights the urgency of the plastic-pollution problem, and reflects international concern about the impact of contamination on the environment. Regardless of the measures agreed on, and ultimately taken, an assessment of their effectiveness will require widespread use of sampling and analysis methodologies grounded in science, and this will be best achieved with standardized protocols. The two studies highlighted here demonstrate that, with proper resources and coordination, such protocols can be implemented with great success at a global scale — over a spectrum that spans the vast scales of plastic pollution.

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