formation in their human culture systems. Nonetheless, their protocols will undoubtedly help to advance our understanding of the molecular basis of normal segmentation and to reveal the genes that, when mutated, lead to the development of disorders of the spine.

More broadly, gene-regulatory networks are highly conserved between mammals, regardless of the animals' size or whether they are bipedal or quadrupedal. This is in stark contrast to the species-specific timing of gene oscillations, which is fundamental to body-plan development. What causes these crucial differences in timing remains an enigma – but one that can now begin to be unravelled.

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Marine conservation

Predators on track for ocean protection

Ana M. M. Sequeira

Satellite tracking of marine predators in the Southern Ocean has revealed key ecological areas under disproportionate pressure from human activities. These results show the value of tracking data for informing conservation efforts. **See p.87**

Even the most remote marine ecosystems on Earth – such as those at high latitudes, including in the Southern Ocean around Antarctica – can no longer be considered pristine[1]. The effects of humans on marine ecosystems now have a global footprint[2–4], and mitigation of associated threats requires knowledge of the areas of particular ecological and biological significance. Such areas sustain the healthy functioning of marine ecosystems and should therefore be protected. On page 87, Hindell *et al.*[5] report analyses of tracking data for marine species that reveal these key areas in the Southern Ocean.

The waters of the Southern Ocean encircle the Earth through the Drake Passage, the ocean region between the tip of South America and Antarctica. Because of this passage, the Southern Ocean has a key role in global climate and ocean circulation[6]. This ocean is also home to a unique range of marine fauna, including many charismatic predators, such as penguins (Fig. 1) and seals, as well as the precious Antarctic krill (*Euphausia superba*). These krill are at the base of the marine food web, and, alongside species of toothfish (*Dissostichus eleginoides* and *Dissostichus mawsoni*), are the target of the largest fishing industries in the Southern Ocean[7,8]. The fisheries compete with animals for food resources, and fishing activities along with the pressures from climate change are raising concerns about the possibility of ecosystem collapses there[8,9].

"Tracking data are increasingly being used to inform conservation policy around the world."

The Commission for the Conservation of Antarctic Marine Living Resources is the main management body for the Southern Ocean, and is tasked with ensuring the preservation of this ecosystem. To succeed, the commission needs to take precautionary steps, including the establishment of more and better-designed marine reserves as has been suggested[8], and sites for these should be chosen on the basis of knowledge of the whereabouts of ecologically significant marine areas[10]. However, accurately defining these areas in a highly dynamic, changing environment is challenging.

Monitoring predators at the top of a marine food web can help with this task. Such predators migrate within and between ecosystems, and can be used as indicator species[11] – those able to provide information on the status of an ecosystem or habitat if alterations occur in their movement patterns, behaviour or reproductive success. In particular, tracking top predators can assist with identifying the areas that they use most, which can be considered as regions of great ecosystem importance, not only for the predators but also for a wide range of other species[11]. Indeed, tracking data are increasingly being used to inform conservation policy around the world[12], and have been used to quantify the extent of spatial overlaps between species and fishing activities globally[3].

Hindell *et al.* report analyses of tracking data from 4,060 individuals of 17 species of marine predators (seabirds and mammals), and suggest a way to use such data to predict key ecological regions in the Southern Ocean. Tracking data were collected between 1991 and 2016 using electronic tags attached to the animals. These tags provided location estimates (obtained using satellite information or other methods) as the animals migrated. The authors used some of these data (for 2,823 individuals) to develop predictive models to identify crucial habitats in the Antarctic region for all of the predator species combined. These integrated results provide a spatially defined assessment of areas of high biodiversity that includes species across multiple levels of the food chain (termed trophic levels) in the Southern Ocean.

Defining a single, integrated result from such varied data sets and from so many species is a complex undertaking. Predators in the Southern Ocean include a large range of species from across different taxonomic groups. These include species living in the Antarctic region and species residing immediately north of it (in the sub-Antarctic), all with different diets and patterns of movement. The authors used a series of data-processing steps to generate a value they termed 'habitat importance', which they predicted using data across all of these species together (assemblage-level maps). To do this, Hindell and colleagues first mapped habitat importance for the species living in the Antarctic separately from those living in the sub-Antarctic, and then selected the maximum habitat-suitability values in those two maps to generate an overall assemblage-level map for all of the predator species combined.

Finally, the authors defined the regions in the top 10% of their calculated habitat importance value as the areas of the most ecological significance in the Southern Ocean. This final

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Figure 1 | Emperor penguins (*Aptenodytes forsteri*) in Antarctica. Hindell *et al.*[5] report analyses of tracking data for marine predators, including this penguin species. The authors' results pinpoint regions of the Southern Ocean around Antarctica that should be protected.

step was a central part of their study. It enabled comparisons to be made between the areas of ecological significance and the areas affected by human activities, as well as between the levels of existing protection inside and outside these areas.

Hindell and co-workers report that the predicted areas of ecological significance they identified match the ocean regions of known elevated productivity for Antarctic krill[13] and for other organisms at the base of the food web, including myctophids (lanternfish)[14]. This result is consistent with the idea that marine predators can be used as indicators to identify areas of ecological significance. The authors report the particularly striking finding that a disproportionately higher level of human pressures (fishing and the effects of climate change) occurred inside rather than outside the areas identified as being of ecological significance. On the basis of this, the authors recommend that the current network of protected marine areas in the Southern Ocean be extended. They confirm that these extensions should include the areas for which protection is already being planned.

It would have been interesting if the authors had suggested how an approach similar to theirs could best be used to tackle comparable problems on a global scale. For example, the authors' views on the best strategy for contributing scientific knowledge to inform efforts to protect biodiversity on the high seas (the waters outside national jurisdictions) would have been a valuable addition. This topical issue is currently being discussed by the United Nations General Assembly, and negotiations are under way to develop an international legally binding solution to address the problem[15].

Scientists have tracked marine predators for decades[3,4,12]. It is time to pool all these existing data sets to address pressing conservation challenges on a global scale. To succeed, a worldwide movement is needed within the community of animal-tracking researchers, to drive the sharing of these data and to combine them with information about human activities at sea. Combining such information will deliver much-needed evidence of the extent of existing threats, to inform managers and policymakers in a timely manner. As Hindell and colleagues state, the Southern Ocean has the potential to provide an example of how "science, policy and management can interact to meet the challenges of a changing planet", and their work highlights a pathway for how best to direct policy efforts.

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This article was published online on 18 March 2020.