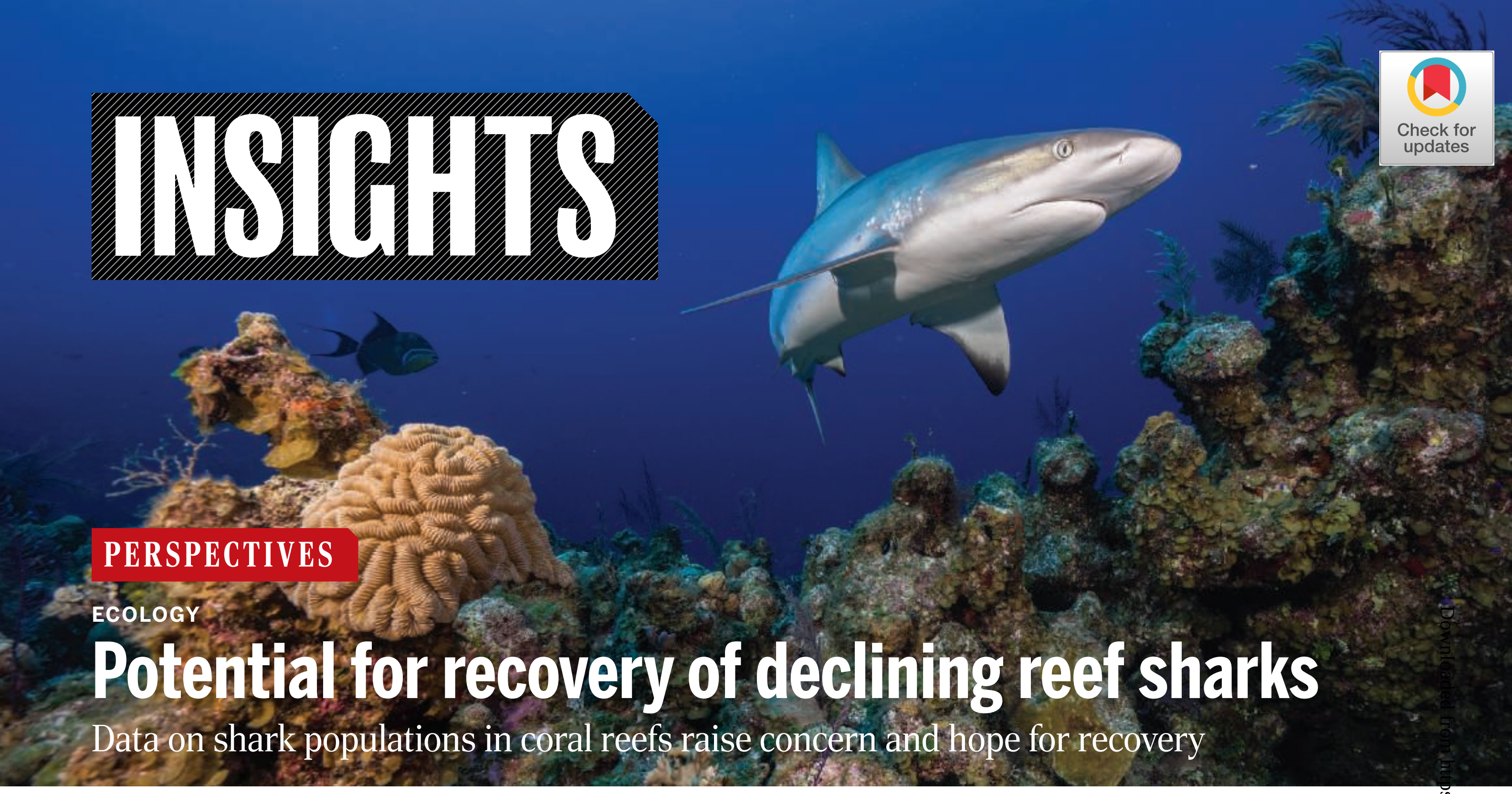

INSIGHTS

PERSPECTIVES

ECOLOGY

Potential for recovery of declining reef sharks

Data on shark populations in coral reefs raise concern and hope for recovery

By **David S. Shiffman**[1,2]

Sharks and their relatives are some of the most threatened vertebrates on Earth, with approximately one-third estimated or assessed as threatened with extinction (*1*). This is a major problem because as predators that help keep the food web in balance, these animals play a variety of vitally important ecological roles (*2*) and in doing so help to keep healthy many ecosystems that humans depend on. Coral reefs provide homes for countless fish species that are vital for fisheries and are therefore an especially important ecosystem for humans—and one where the decline of shark populations seems to be especially acute (*3*). On page 1155 of this issue, Simpfendorfer *et al.* (*4*) report the results of a species-level and reef-level analysis of common resident reef sharks across the world. They show startling declines of once-common reef shark species but also signs of hope that these populations can recover with the right protection.

The study by Simpfendorfer *et al.* is the result of a worldwide collaboration called the Global FinPrint project. The data analyzed include more than 20,000 hours of standardized underwater video taken at nearly 400 reefs in 67 countries and territories around the world—that is nearly 3 years of raw video. The baited remote underwater video stations (BRUVSs) used by FinPrint are a simple but powerful tool. They are essentially underwater camera traps that consist of a small quantity of bait suspended in front of a camera. In addition to being good at documenting the presence and absence and the behavior of different marine organisms (*5*), they also generate high-definition images and video of marine life that are tailor-made for public education about what lives in the threatened habitats off our coastlines.

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The results of Simpfendorfer *et al.* reveal declines of 60 to 73% of once-abundant coral reef shark species at reefs around the world. This adds to a large and growing volume of similarly alarming conclusions about the global conservation status of sharks and their relatives. The global conservation status of sharks and rays is worse than a decade ago (*6*) and is even more concerning for some groups of sharks (*7*). Sharks caught as bycatch in global tuna fisheries are declining in population even as those same tuna are rebounding (*8*).

However, the findings of Simpfendorfer *et al.* include signs of hope and a clear path forward. Their results show that although shark populations in many reefs had declined, some healthy reef shark populations remained. The reefs with healthier shark populations had some important similarities: They tended to be in the waters of high-income countries with stronger natural resource management regulations, participatory natural resource management (where citizens have the right to petition the government about changes in natural resource management policy), and resources for enforcing the rules. Unfortunately, such countries are relatively rare, and lower-income countries tend to have fewer resources for sustainable management and enforcement. These observations show that conservation problems involve solving human problems as well as those associated with ecology; a country that lacks the resources to feed its people is less able to sustainably manage and protect its biodiversity.

Science-based, well-enforced marine protected areas—in which harmful fishing practices are restricted or banned—also tended to have healthier reefs. However, Simpfendorfer *et al.* suggest that some highly touted shark conservation solutions were enacted in places where there were not many threats to the shark population to begin with and advise caution in interpreting the success of those solutions. For example, the British Virgin Islands shark sanctuary bans all commercial shark fishing in its territorial waters, but between 1950 and the 2014 establishment of the sanctuary, only 3 tons of shark were fished from those waters (*9*, *10*), suggesting that there was not much of a shark fishery to ban. Another sanctuary was established in the Bahamas in 2011 but decades after the most common shark fishing gear was already banned, suggesting that the country's relatively high shark population is most likely due to the older, less-hyped regulation (*11*).

The most unexpected result of the study by Simpfendorfer *et al.* is that a decline or complete loss of shark species in one reef was not always associated with similar changes

PHOTO: ANDY MANN

Numbers of reef sharks, such as this Caribbean reef shark (*Carcharhinus perezi*) in the Bahamas, have fallen overall, but some healthy populations remain.

in nearby reefs. They found that one reef can be overfished so badly that a once-common reef shark species is totally gone, but another reef a short distance away can have healthy populations of that same species. Strong, effective management (including but not limited to no-fishing-allowed marine protected areas) on one reef protected local species, even while their populations on neighboring reefs faced collapse. The presence of these possible future "source" populations—that is, healthy populations that can eventually help repopulate nearby areas—gives hope that if the threats that led to population decline are resolved, then these important and threatened animals may recover.

The study by Simpfendorfer *et al.* also demonstrates the growing importance of global collaboration. Global problems require huge multidisciplinary teams because scientists or laboratories working by themselves simply cannot generate or analyze data on this scale. In many ways, FinPrint has been a model for international collaboration. Such studies have documented how the decline of sharks leads to increasing abundance of mesopredatory fishes such as moray eels (*12*), what aspects of marine protected area design are most effective for sharks (*13*), and much more—and there is more to learn.

The problem is clear—animals that provide ecosystem services that are vital for human food security and livelihoods are disappearing at an alarming rate, overwhelmingly owing to bad management practices that allow unsustainable overfishing of these ecologically important and biologically vulnerable creatures. The loss of sharks and the ecosystem services they provide represents an ecological disaster that can cause substantial harm to humans. Action must be taken to prevent further population declines and allow rebuilding of depleted populations before it is too late. ■

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NEUROSCIENCE

Epigenetic changes in astrocytes make sense

Serotonin induces gene expression changes in astrocytes to regulate olfactory behavior

By **Flora Vasile**[1,2] and **Nathalie Rouach**[1]

The ever-changing nature of the world requires the brain to constantly adapt to its environment to optimize behavioral output at different spatial and temporal scales. Although short-term synaptic and circuit plasticity materializes as changes in synaptic transmission, longer-term plasticity can be supported by transcriptional and epigenetic modifications. This process has been well described in neurons, but whether and how non-neuronal cells also undergo such modifications to promote flexible neuronal circuits underlying behavior is unknown. On page 1146 of this issue, Sardar *et al.* (*1*) report a newly identified role for the monoamine neurotransmitter serotonin in inducing epigenetic histone modifications in astrocytes that alter inhibitory neurotransmitter signaling and ultimately sculpt olfactory processing and behavior in mice.

Astrocytes are an integral part of brain circuits: They undergo intracellular calcium fluctuations in response to physiological sensory-driven neuronal activity (*2*) that elicit the calcium-dependent release of neuroactive molecules that affect neural activity, plasticity, and behavior (*3*). It is becoming evident that the influence of astrocytes on neurons is multifold (*4*) and is specific to developmental stages, brain regions, activity regimes, and pathophysiological states. Hence, the regulation of neuronal activity by astrocytes is remarkably specific yet flexible. Transcriptional modifications have recently been identified as a mechanism for long-lasting adaptations in the modulatory program of astrocytes. Building on the first astroglial transcriptome database (*5*), studies have since characterized the development-, region-, and activity-dependent properties of the astrocyte transcriptome. Additionally, specific transcription factors that are involved in supervising astrocyte gene expression and ultimately neuronal functions have been revealed. Yet the intricacies of neuronal activity–dependent transcriptomic plasticity in astrocytes and the mechanisms underlying downstream neuronal circuit and behavioral alterations have remained obscure.

Sardar *et al.* identify a mechanism through which neuronal activity induces transcriptomic changes in astrocytes, which in turn drive epigenetic changes and regulate olfactory sensory processing in mice. They show that neuronal activity, artificially evoked using chemogenetics or physiologically triggered through olfactory stimulation, induces widespread changes in gene expression in astrocytes in a brain region–dependent manner. The expression of immediate early genes—a set of genes that are rapidly and transiently expressed in response to various stimuli—were specific to astrocytes and included transcription factors such as SOX9. The evoked neuronal activity increases binding of SOX9 to the promoter of the solute carrier family 22 member 3 (*Slc22a3*) gene. This gene encodes the monoamine transporter organic cation transporter 3 (OCT3), which contributes to the uptake of serotonin. SOX9-mediated up-regulation of *Slc22a3* expression was specific to the olfactory bulb; deleting *Sox9* did not affect *Slc22a3* expression in the cortex or hippocampus. This up-regulation in OCT3 expression increases levels of astroglial serotonin, which enters the nucleus to drive histone serotonylation (see the figure). Because SOX9 regulates the expression of various genes, it would be interesting to further investigate the downstream effects of SOX9-mediated gene regulation.

What is the role of such histone modification? Using conditional deletion of *Slc22a3*, Sardar *et al.* show that *Slc22a3* up-regulation

"...a newly identified role for the monoamine neurotransmitter serotonin in inducing epigenetic histone modifications in astrocytes..."

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