Power plant air pollution limits and job creation in coal-producing regions are key to India's clean-energy goals.

is to encourage investment in solar and wind power plants in the coal-producing regions. These energy infrastructure investments will also provide local job opportunities as the regions transition away from fossil fuel–based power generation in the long term (*8*).

India faces the twin challenges of mitigating carbon emissions and meeting an increasing energy demand. Several policies and regulations have been introduced to reduce overall energy demand and increase the supply for zero-carbon electricity. For instance, the government has undertaken large-scale procurement of energy-efficient home and office appliances to decrease their prices. It has also created a market for energy-saving certificates, where businesses saving more energy than their targets can sell the leftover credit to another company, creating a monetary incentive for businesses to meet energy efficiency targets (*9*). In addition, it has introduced competition through bidding by renewable energy companies, targets for each state to purchase renewable energy, exemptions for renewable energy from transmission charges (*10*), and transmission infrastructure for renewable energy (*11*). These policies have since led to some of the world's lowest solar and wind energy prices ($30 to $40 USD per megawatt-hour) (*12*). By 2021, India had become the world's fifth-largest solar power producer, with a capacity of 50 GW, and the fourth-largest wind power producer, with a capacity of 40 GW (*13*).

Although the carbon emissions and gross domestic product per capita of India are still less than half the global average, the country has ambitious plans for mitigating its carbon emissions. At the 26th United Nations Climate Change Conference held in 2021 in Glasgow, UK, the Indian government pledged a net-zero emissions target by 2070 and a near-term target of producing 50% of its electricity from renewable energy by 2030 (*14*). For India, the pursuit of climate and renewable energy targets is important, as is public health, employment, and energy affordability across regions and communities to ensure equitable growth. As India continues to develop its economy, balancing the near-term and long-term effects of its electricity sector policies, as well as their impact on social inequalities, will be critical to ensure a low-carbon transition that is green as well as just. ■

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MARINE CONSERVATION

Good and bad news for ocean predators

Some tunas and billfishes are recovering, but sharks continue to decline

By **Matthew G. Burgess**[1,2,3] *and* **Sarah L. Becker**[1,2]

As human population and economies have grown rapidly over the past 100 years, ecosystems worldwide have faced increasing pressure from overexploitation, habitat destruction, and other threats (*1*). In the oceans, roughly half of all commercially harvested fish and invertebrate stocks became overfished during the 20th century (*2*), and larger predators, such as billfishes and sharks, also dwindled (*3*). The 21st century has seen some marine fish and invertebrate stocks begin recovering owing to management efforts (*4*), whereas poorly managed stocks continued to decline (*2*). On page 617 of this issue, Juan-Jordá *et al.* (*5*) illustrate a similar contrast among ocean predators and introduce an approach for continuously monitoring their conservation statuses. The authors found that the situations for tunas and billfishes have improved over the past decade, but not those for sharks. This contrast owes partly to management, but biological and socioeconomic factors also cause fisheries to affect these species differently.

The International Union for Conservation of Nature (IUCN) (*6*) labels a species as critically endangered, endangered, or vulnerable on the basis of how much its population has declined over the past three generations or 10 years, whichever period is longer. If threats to a species are considered to be poorly understood or managed, then the IUCN applies these endangerment labels when there is a smaller population decline as a precaution. Juan-Jordá *et al.* built upon this classification system, known

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as "Criterion A," and developed indices for assessing the endangerment levels of seven tuna species, six billfish species, and five shark species. Their indices can be used to assess endangerment continuously in time, instead of being limited to fixed IUCN assessment intervals.

The indices define a species as being adequately managed if its mortality rate is less than the mortality rate that can sustain the maximum yield for fisheries. By this measure, the statuses of the tunas and billfishes have improved, on average, during the 2010s, and the mortality rates of several populations have returned to the levels that can support a maximum sustainable yield. By contrast, the statuses of sharks have continued to deteriorate on average during this period, and their mortality rates have remained well above the maximum sustainable rate. Juan-Jordá *et al.* attribute some of this contrast to the improved management of commercial fishing for tunas and billfishes, but not for sharks. For example, the International Commission for the Conservation of Atlantic Tunas has been setting and monitoring catch limits for tunas (*7*). However, the authors also highlight that other biological and fishery factors are needed to explain this difference between shark and tuna and billfish status, which is consistent with previous findings (*8*, *9*). For example, the differences in economic value and population growth rate and how each species is affected by fisheries directly and indirectly are important considerations.

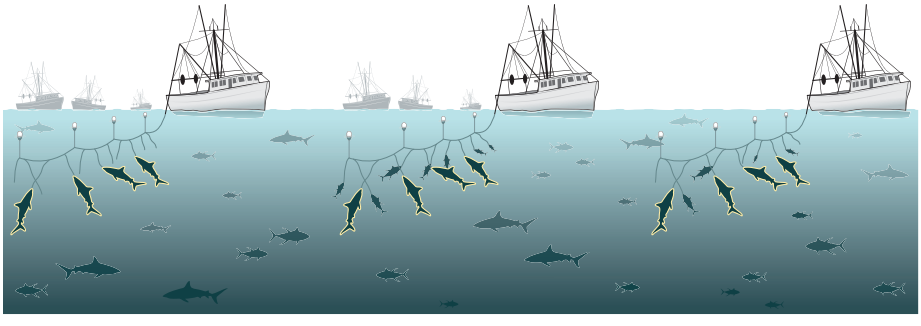
To understand why sharks are faring worse on average than tunas and billfishes, the mechanisms driving unsustainable fishing practices must be considered (see the figure). Without management (*4*), collective action, or community norms that promote cooperation (*10*), fisheries tend to overfish their target species. Commercially valuable species can support profitable fishing even at extremely low population sizes—if the species have high prices, large body sizes, low harvest costs, and/or small geographic ranges, which reduce the costs of catch (*11*). Nontarget species can also be affected by fishing activities, such as those that are caught unintentionally ("bycatch") (*12*) or opportunistically (for example, a fishing crew spotting and deciding to catch a different species than their original target) (*13*). Bycatch species can become threatened if they are frequently caught alongside overfished target species (*14*). They can also become threatened even if the target species are being sustainably caught when the bycatch species has a higher vulnerability—having a lower reproductive rate compared with its catch rate (*15*).

Some of the differences Juan-Jordá *et al.* found among sharks, tunas, and billfishes likely result from their different vulnerabilities to fishing activities. The five shark species studied by the authors all have slow population growth, have high vulnerability as bycatch, and are commonly caught by fisheries targeting tunas and billfishes. Sharks are also sometimes the target themselves. Although there has been some progress in managing fisheries that target sharks, these efforts face challenges posed by the lucrative fin trade and related illegal and unreported fishing (*9*). Marlins also stood out among the studied billfish species as being more endangered, likely because they are highly vulnerable as bycatch in tuna fisheries (*15*). By contrast, tuna species and relatively nonthreatened billfish species, such as swordfish, are mostly caught as targets (*7*). Among tuna species, their conservation statuses are more correlated with their biological and economic characteristics, such as short generation time and low price (which limit overfishing), than with the quality of their management (*8*).

Juan-Jordá *et al.* highlight the stark challenges facing oceanic predators—especially sharks. Successful shark conservation needs to address their specific biological and economic vulnerabilities, in addition to deploying fisheries management tools used for tunas and billfishes, such as science-based catch limits. Moreover, macroscopic ecosystem considerations may pose further challenges, even with well-managed predator fisheries. For example, maintaining sharks' ecosystem services as top predators might require higher shark abundances than is ideal for fishery catch. The conservation statuses of threatened target species can be improved by managing the fishing industry, which can benefit the industry economically in the long run while allowing the threatened species to recover (*2*, *14*). Generating sufficient scientific and governance capacity to implement successful management is often the primary challenge (*4*, *10*). However, the protection of high-vulnerability bycatch and nontarget species is expected to be more difficult because they will require fisheries to invest in better fishing gear and targeting practices, or reduce fishing efforts, without directly benefiting from these changes (*14*). The trade-offs between fishery benefits and ecosystem impacts will demand difficult negotiations and compromises between stakeholders. ■

How fisheries threaten sharks

Slow growth rates and high catch prices have made sharks vulnerable to fisheries, both as a target and as bycatch.



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