IFM-GEOMAR

Leibniz-Institut für Meereswissenschaften
an der Universität Kiel

IFM-GEOMAR Report 2002-2004

From the Seafloor to the Atmosphere

- Marine Sciences at IFM-GEOMAR Kiel -

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Preface

For the first time, the Leibniz Institute of Marine Sciences (IFM-GEOMAR) presents a joint report of its research activities and developments in the years 2002-2004. In January 2004 the institute was founded through a merger of the former Institute for Marine Research (IfM) and the GEOMAR Research Center for Marine Geosciences. This report addresses friends and partners in science, politics and private enterprises. It gives an insight into the scientific achievements of IFM-GEOMAR and its predecessor institutes during the last three years.

3.9 Predator Diversity Hotspots in the Blue Ocean

Large oceanic predators such as the bluefin tuna, blue marlin, white shark, barndoor skate and leatherback sea turtle have two traits in common. First, they are fascinating creatures (Fig. 1). And second, they are threatened by extinction. Our fascination comes from their large size (leatherbacks are the largest extant reptiles, second only to dinosaurs), swimming abilities (bluefin tuna are the world's fastest fish, reaching 80 km/h), range (many species regularly migrate across entire ocean basins), and predatory power (white sharks may attack - very rarely - humans). Their endangerment comes mostly from fishing, either directed fishing (bluefin tuna may sell for over 50,000 $US a piece), or unintended bycatch in other fisheries such as longlines and gillnets (leatherbacks turtles are almost extinct in the Pacific because of this, the same goes for barndoor skates in the Atlantic).

Despite our fascination with these creatures we know surprisingly little about them. Only very recently marine scientists have begun to gain deeper insights in the biology and ecology of these fascinating animals. Considering abundance and diversity, the two most fundamental ecological metrics. Large-scale trends in abundance of large predatory fishes were analyzed for the first time on a global basis last year. Our analysis The data revealed that we have only 110% of all large fish - both open ocean species including tuna, swordfish, marlin and the large groundfish such as cod, halibut, skates and flounder - are left in the sea. Most strikingly, the study showed that industrial fisheries take only ten to twenty years to reduce any new fish community they encounter to one tenth of what it was before. This news has invigorated calls to fish more carefully, and let stocks recover to larger size to avoid collapse.

Also last year, we first gained insight into the diversity of large predators, ranging from tuna and sharks to whales and seabirds. Scientific observers on ocean-going longline fishing vessels recorded 145 species that were caught in the Atlantic, North Pacific and South Pacific. When we analyzed these data for species diversity we found some unexpected results. Oceanic predators concentrated in distinct di-

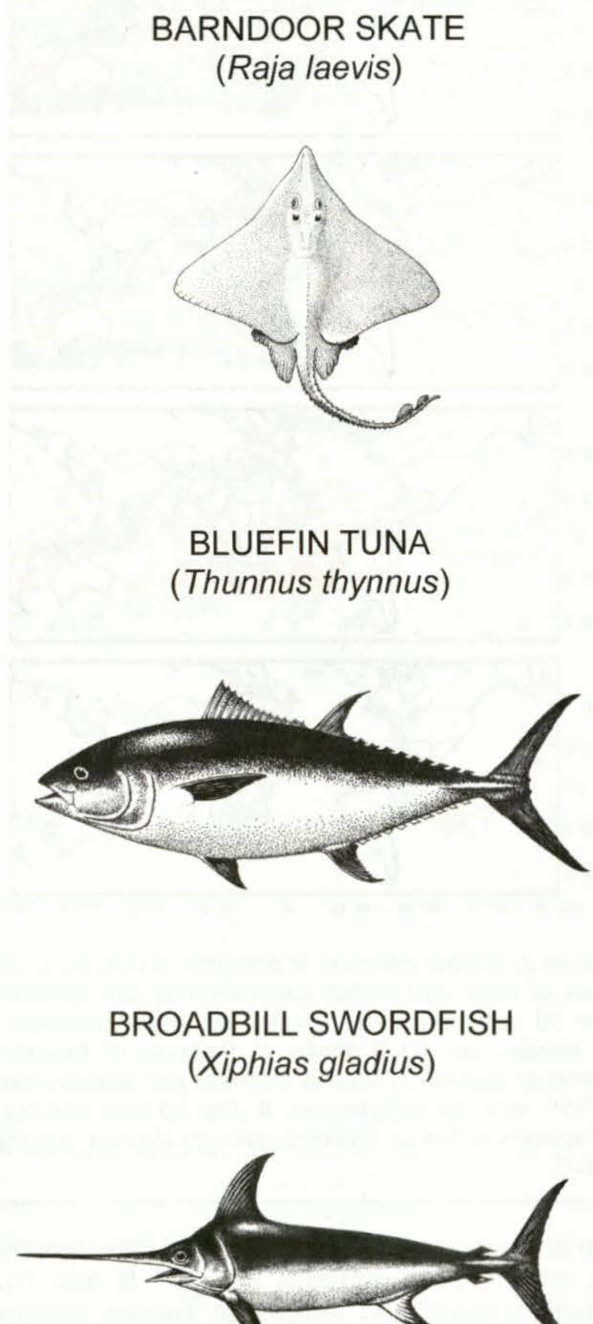

Figure 1: Large marine predators such as the barndoor skate, bluefin tuna and broadbill swordfish have become rare in the world oceans. Illustrations by Richard Ellis from "The empty ocean" (Island Press/Shearwater Books 2003). Reprinted with permission.

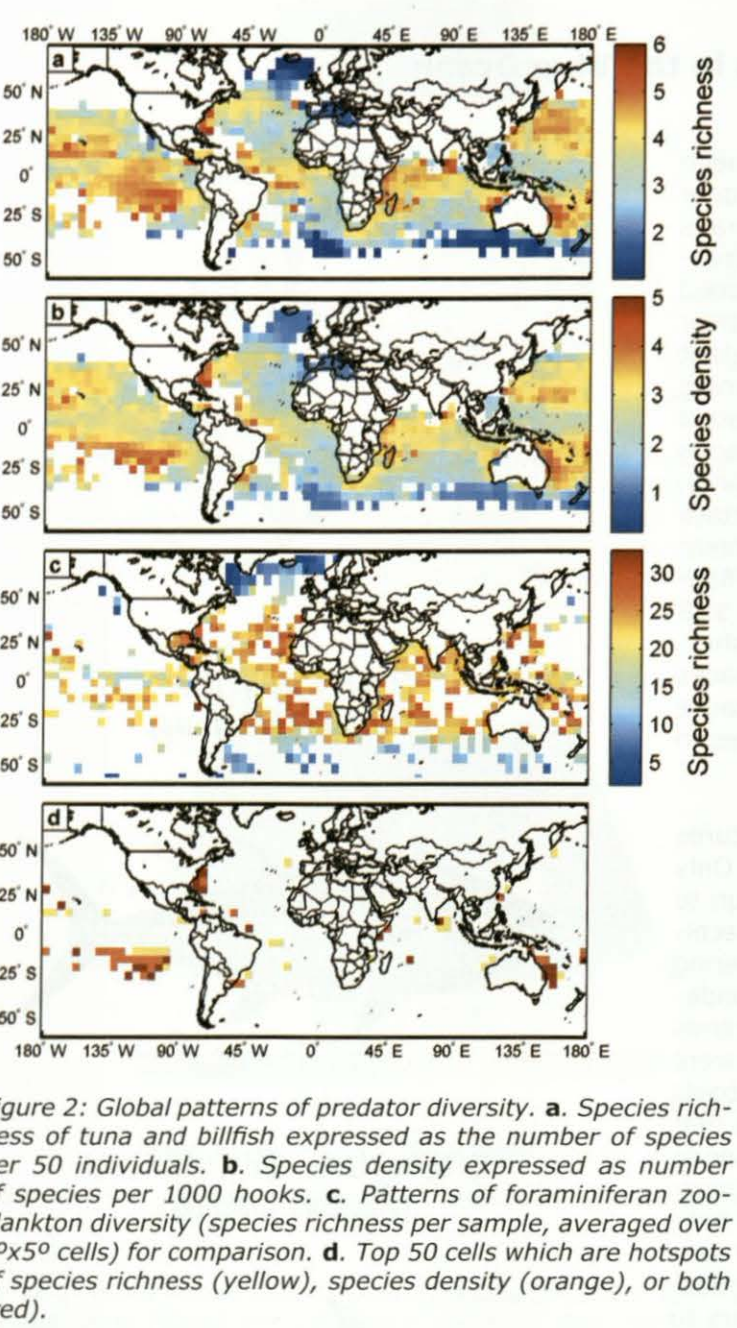

Figure 2: Global patterns of predator diversity. **a**. *Species richness of tuna and billfish expressed as the number of species per 50 individuals.* **b**. *Species density expressed as number of species per 1000 hooks.* **c**. *Patterns of foraminiferan zooplankton diversity (species richness per sample, averaged over 5°x5° cells) for comparison.* **d**. *Top 50 cells which are hotspots of species richness (yellow), species density (orange), or both (red).*

versity hotspots which were found consistently at intermediate latitudes (20-30° N and S), where tropical and temperate species ranges overlap. This is very different from the land, where diversity is typically peaks around the equator, most prominently in rain forests. In the ocean, sub-tropical hotspots were often found close to prominent habitat features such as reefs, shelf breaks or seamounts. These underwater slopes and mountains are obviously special places, where many species aggregate.

Despite these advances worldwide patterns of predator diversity, as well as their underlying causes, have remained elusive so far. This changed when we founded a small interdisciplinary research group at the IFM-GEOMAR. In a 10-month effort Andreas Oschlies (oceanographic modeling), Marcel Sandow (bioinformatics), Heike Lotze (historical ecology), and myself in collaboration with Ransom Myers (a fishery scientist at Dalhousie University, Canada) constructed the first global maps of tuna and billfish diversity from longline fishing data (Fig. 2). Two different measures of diversity, predator species richness (Fig. 2a) and species density (Fig. 2b) both showed a consistent and surprisingly well-defined global pattern. Again peaks of diversity were found at sub-tropical latitudes and lower diversity towards the poles and at the equator. Remarkably, this general pattern closely resembles that seen for foraminiferan zooplankton, which is small single-cell plankton that accumulates in deep sea sediments (Fig. 2c). Distinct hotspots of predator diversity are seen off the U.S. and Australian east coasts, south of the Hawaiian Islands chain and most prominently in the southeastern Pacific (Fig. 2d). All these areas lie in the subtropics, as do the peaks in foraminiferan zooplankton diversity (Fig. 2c, d). Good correlation with the zooplankton data suggests that the global pattern of diversity shown here could be very valid generally for very different organisms. This would also mean that patterns of diversity in the open ocean are fundamentally different from those on land or on the sea floor which tend to peak around the equator.

Can oceanographic variables explain geographic patterns of predator diversity? Marine biologists have observed that sharp temperature fronts and whirling eddies associated with meso-scale oceanographic variability attract diverse species from plankton to whales. In contrast many oceanographers believe that large-scale patterns of temperature, productivity and climate determine the distribution of life in the ocean. We found that both were right. For example, mean temperature had a very large effect on diversity, which increased over most of the observed range (5-25°C), but declined again at high temperatures >27°C. Fronts and eddies were also important and often showed a distinct concentration of species. But also oxygen was important, as predator species are fast and active swimmers with a high metabolism. Areas with low oxygen levels (less than 2 ml per liter) clearly had fewer species than nearby regions with normal oxygen concentrations.

Finally, our analysis revealed a disturbing historic trend. We found that in the wake of industrial fisheries, predator species density has declined significantly (on average by 20%) during the last 40 years, particularly in the Atlantic and Indian Oceans. If continued, this trend may reduce the ability of communities to adapt to environmental change, and undermine the sustainability of fishing. We conclude that the seemingly monotonous landscape of the open ocean shows rich structure in species diversity, but that diversity has been declining for some time. These results could be important for the management of oceanic predators as they confirm concerns about the ecosystem-wide effects of fishing. At the same time we are offering a partial solution. Knowledge of global diversity patterns, when combined with detailed information on species biology, migration patterns, and fishing pressure, makes it possible for the first time to clearly define priority areas for open ocean conservation.

Current efforts to establish marine protected areas in the open ocean could use this information to place protected areas where most of the species are - and thereby protect many species at once.

IFM-GEOMAR Contributions

Hillebrand, H., 2004: On the generality of the latitudinal diversity gradient. *Am. Nat.*, **163**.

Myers, R.A., and Worm, B., 2003: Rapid worldwide depletion of predatory fish communities. *Nature*, **423**, 280-283.

Worm, B., Lotze, H.K., and Myers, R.A., 2003: Predator diversity hotspots in the blue ocean. *Proc. Natl. Acad. Sci. USA*, **100**, 9884-9888.

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