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Biodiversity Risks from Fossil Fuel Extraction

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Despite a global political commitment to reduce biodiversity loss by 2010 through the 2002 Convention on Biological Diversity, declines are accelerating and threats are increasing (*1*). Major threats to biodiversity are habitat loss, invasion by exotic species and pathogens, and climate change, all principally driven by human activities. While fossil fuel (FF) extraction has traditionally been seen as a temporary and spatially limited perturbation to ecosystems (*2*), even local or limited biodiversity loss can have large cascade effects on ecosystem function and productivity. We explore the overlap between regions of high marine and terrestrial biodiversity and FF reserves to identify regions at particular risk of ecosystem destruction and biodiversity loss from exposure to FF extraction.

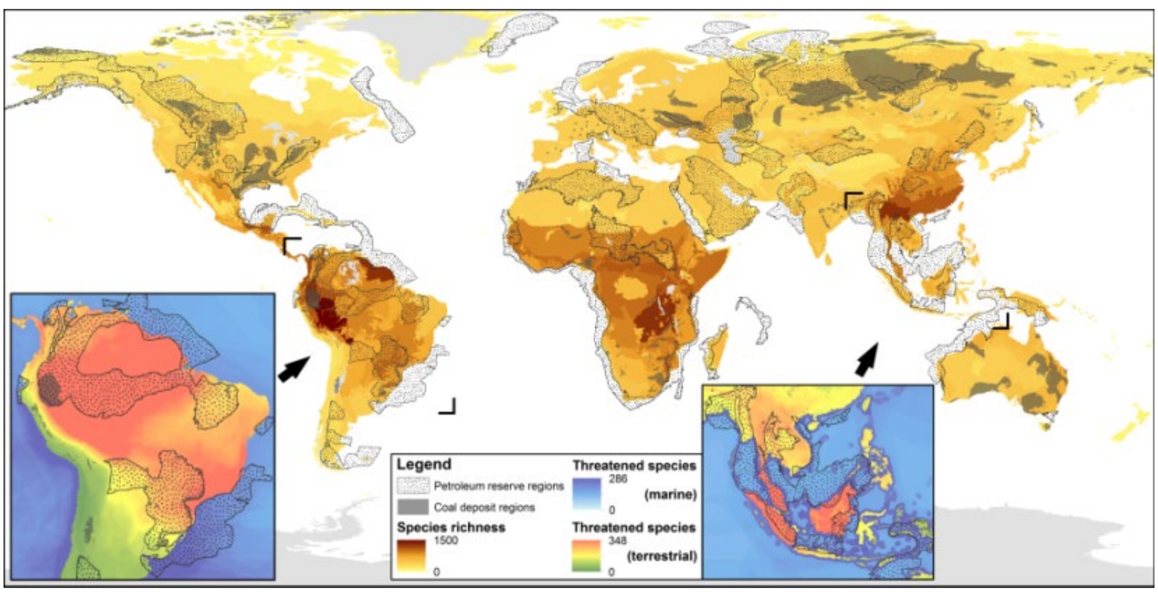

Figure 1: Distribution of fossil fuel reserves and species biodiversity. Large map reflects terrestrial species richness (number of species in each ecoregion). Insets highlight two regions where many threatened terrestrial and marine species may be affected by fossil fuel extraction (background map depicts counts of threatened species ranges at the center of each 0.1° grid cell). Limitations in available data on FF reserves and extraction (e.g., coal reserves in Europe and India) suggest our analyses may underestimate the extent of overlap between FF reserves and regions of high biodiversity. See SM for details.

Consumption of FF (oil, natural gas, and coal) grew from 26200 million barrels of oil equivalent (MBOE) in 1965 to 80300

MTOE in 2012 (*3*). By 2035, oil demand is projected to increase by over 30%, natural gas by 53% and coal by 50% (*4*). It is often assumed that legally mandated restoration after extraction (which includes drilling and all forms of mining) will return an area to close to its pre-disturbance state (*2*). Extraction activities have therefore been considered trivial disruptors of natural systems in comparison with other human activities, such as agricultural land clearing (*5*).

Ecosystem disturbance and degradation resulting from direct or indirect effects of extraction, however, have profound and enduring impacts on systems at wider spatial scales (*6*). Direct effects include local habitat destruction and fragmentation, visual and noise disturbance, and pollution (*7*). Indirect effects can extend many kilometers from the extraction source and include human expansion into previously wild areas, introduction of invasive species and pathogens, soil erosion, water pollution, and illegal hunting (*7*). Combined, these factors lead to population declines and changes in community composition (*8*). Gas and oil transportation can also be environmentally damaging, particularly in countries with weak governance, leading to deforestation, water contamination, and soil erosion (*9*). Spills in marine environments can have severe environmental impacts over wide areas (*10*). However, the main impact of FF extraction on biodiversity may be through facilitating other threats, such as deforestation driven by road construction.

In the future, FF will be increasingly extracted from more remote and previously undisturbed areas. Unconventional sources, such as coal seam gas and shale oil, will threaten currently undeveloped regions that are biodiverse and represent important centres of endemism (*8*). Furthermore, the corporations of the FF extraction industry are economically and politically powerful, while many countries in areas of high biodiversity risk under FF exploration are characterized by weak governance and poor implementation of environmental regulations.

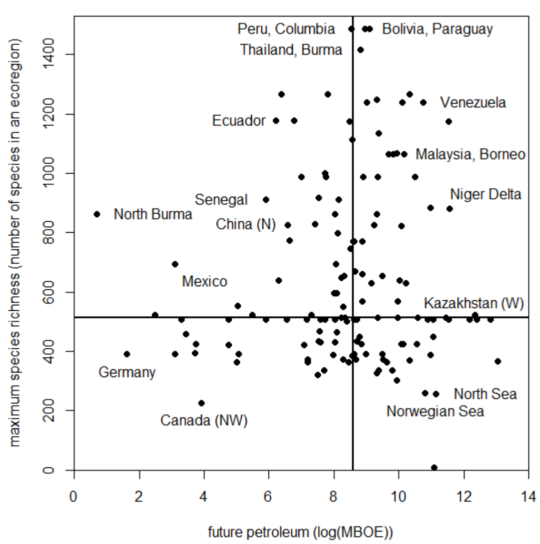

Figure 2: Relationship between ecoregional species richness and petroleum reserves. Quadrants determined by median values for petroleum and species richness by ecoregion. Examples of ecoregions within our identified areas of biodiversity concern include Bolivia, Venezuela, Malaysia and Borneo. See SM for details.

Areas at greatest risk

We suggest that northern South America and the western Pacific Ocean are at particular risk (Figure 1; see Supplemental Materials (SM)). The Western Amazon is one of the most biodiverse regions of the planet and contains large reserves of oil and gas (*11*). Potential impacts from FF extraction in this region include deforestation, contamination, and wastewater discharge. Increased accessibility to previously remote areas via oil industry roads and pipeline routes is one of the primary causes of habitat fragmentation and facilitates further logging, hunting, and deforestation (*11*).

The Coral Triangle in the western Pacific Ocean is one of the most biodiverse marine areas of the world, containing 76% of the world's coral species and 37% of the world's coral reef fish species (*12*). In Papua New Guinea, terrestrial FF development will likely be accompanied by maritime extraction and transport of FF, posing increasing risk to globally-important mangroves (*13*), and possibly compounding existing threats to coral reefs (*14*). An oil well failure analogous to the Deepwater Horizon spill, or a tanker spill comparable to that of the Exxon Valdez, could have devastating consequences for biodiversity in the Gulf of Papua.

Utilizing available data, we explored the spatial coincidence of terrestrial species richness with petroleum reserves (Figure 2). Extraction and processing costs, and the size and quality of reserves may strongly influence the prioritization of different regions for exploitation. In principal, however, jurisdictions with large reserves and high biodiversity (e.g. Bolivia, Venezuela, Borneo) are of particular concern. Developments in these countries are likely to cover a greater spatial extent, thereby posing threats to numerous species. Regions with large petroleum deposits but low species richness, such as the North Sea, are expected to experience ecosystem degradation, but as species richness is low, the net impact on biodiversity may be relatively small.

Policy implications and solutions.

Our results highlight opportunities where international FF extraction corporations and conservation organizations can have important impacts on biodiversity protection. We propose that industry regulation, monitoring, and conservation should be targeted where FF reserves and regions of high biodiversity overlap. We suggest that, in general, regions or countries in the high risk areas with weak governance and low levels of environmental protection may not attract or allow international scrutiny, and so environmental damage caused in these areas may remain both undetected and unaddressed (*15*). There is a risk, therefore, of non-compliance with best environmental and safety practices. By contrast, where high environmental standards are enforced, such as the construction of the 3,150 km Gasbol pipeline in Brazil and Boliva, impacts on biodiversity can be minimized (*16*).

Biodiversity and environmental monitoring is crucial for effective implementation of both industry regulations and conservation management. It is critical that environmental organizations play an active role in ensuring that FF extraction takes place according to best practices, ideally avoids areas of high biodiversity, and that trade-offs between biodiversity and development are assessed critically (*17*). Greater international collaboration between governments, FF extraction corporations, research bodies and NGOs is needed.

With increasing global demand for energy, the location, extent and methods of extraction are changing rapidly, but the effect on biodiversity of these changes is largely unknown. We speculate, based on best available but incomplete data, that northern South America and the western Pacific Ocean are two critical regions at risk from increasing FF development. Thus far, there has been little research into potential mitigation measures (*8*). Recognition of the direct and indirect threats to biodiversity from FF extraction in these regions, and of their complex interactions, is essential in the establishment of suitable norms and processes which can guide development to minimise environmental damage.

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