Energy development reveals blind spots for ecosystem conservation in the Amazon Basin

Elizabeth P Anderson[1*], Tracey Osborne[2], Javier A Maldonado-Ocampo[3†], Megan Mills-Novoa[2], Leandro Castello[4], Mariana Montoya[5], Andrea C Encalada[6], and Clinton N Jenkins[7]

Energy development – as manifested by the proliferation of hydroelectric dams and increased oil and gas exploration – is a driver of change in Amazonian ecosystems. However, prevailing approaches to Amazonian ecosystem conservation that focus on terrestrial protected areas and Indigenous territories do not offer sufficient insurance against the risks associated with energy development. Here, we explore three related areas of concern: the exclusion of subsurface rights on Indigenous lands; the absence of frameworks for freshwater ecosystem conservation; and downgrading, downsizing, degazettement (loss of protection), and reclassification of protected areas. We consider these issues from the perspectives of multiple countries across the Amazon Basin, and link them directly to energy development. Finally, we offer suggestions for addressing the challenges of energy development for Amazon ecosystem conservation through existing policies, new approaches, and international collaboration.

Front Ecol Environ 2019; doi:10.1002/fee.2114

For much of the latter half of the 20th century, new road systems, large-scale mining, and agricultural expansion were major drivers of deforestation and ecosystem degradation throughout the Amazon Basin. Designation of federal and state protected areas has long been the principal conservation response to these drivers, with 1.7 million km^2 (roughly 22% of the Amazon Basin) now under some form of protected area status (RAISG 2016). In addition, a vast network of at least 2344 Indigenous territories are legally recognized within the Amazon and are known to benefit ecosystem conservation and carbon storage (Walker *et al*. 2014). While approximately 27% of national protected areas intersect to some extent with Indigenous lands in South America, the designation of Indigenous territories represents the culmination of decades of struggle for the formal recognition of the customary land rights of Indigenous peoples (Cisneros and McBreen 2010). Cumulatively, Indigenous territories comprise >2.2 million km^2, about 30% of the Amazon Basin (Gullison and Hardner 2018).

In a nutshell:

- Hydropower dams, along with increased oil and gas exploration, represent major threats to ecosystems in the Amazon Basin
- Most existing conservation frameworks do not fully address these challenges
- New approaches to Amazonian conservation need to be developed that recognize subsurface land rights and protect freshwater systems

However, recent trends in energy development have created unanticipated areas of concern – or "blind spots" – for Amazon ecosystem conservation. Beyond roads and agriculture, an additional driver of change is expanding energy development: specifically, the proliferation of new hydropower dams and increased oil and gas exploration, which has already transformed many areas of the Amazon. These new energy development projects are motivated by several factors. Many large infrastructure projects are part of the Initiative for the Integration of Regional Infrastructure of South America (IIRSA), a plan proposed in 2000 by the Union of South American Nations to transform the Amazon River into a source of hydropower and multimodal transportation (Walker and Simmons 2018). Other projects have been proposed or developed as ways to meet the increasing energy demands in Amazonian countries (Colombia, Ecuador, Peru, Bolivia, Brazil, Venezuela, Guyana, Suriname, French Guyana), as tools for political gains, or as opportunities for foreign investment. New energy development could trigger irreversible alterations to protected areas and Indigenous territories, and has highlighted the need to strengthen or modify prevailing conservation strategies in the Amazon (Fraser 2017; Anderson *et al*. 2018; Harfoot *et al*. 2018).

[1]*Department of Earth and Environment and Institute for Water and Environment, Florida International University, Miami, FL *(epanders@fiu.edu);* [2]*School of Geography and Development, University of Arizona, Tucson, AZ;* [3]*Unidad de Ecología y Sistemática, Laboratorio de Ictiología, Departamento de Biología, Facultad de Ciencias, Pontificia Universidad Javeriana, Bogotá, Colombia* [†]*(deceased);* [4]*Department of Fish and Wildlife Conservation, Virginia Polytechnic Institute and State University, Blacksburg, VA;* [5]*Wildlife Conservation Society, Lima, Peru;* [6]*Instituto BIOSFERA, Colegio de Ciencias Biológicas y Ambientales, Universidad San Francisco de Quito, Quito, Ecuador;* [7]*IPÊ-Instituto de Pesquisas Ecológicas, Nazaré Paulista, Brazil*

We examine three "blind spots" in Amazon ecosystem conservation that are linked directly to new energy development. First, we describe how the exclusion or limitation of subsurface rights on Indigenous lands, driven primarily by energy exploration interests, presents a challenge for ecosystems and native Amazonian peoples. We then build on previous studies that have highlighted the vulnerability of Amazonian freshwater ecosystems to energy-related activities and the absence of frameworks for their protection (Castello and Macedo 2016). We emphasize the role of energy development in protected area downgrading, downsizing, and degazettement (PADDD), and in reclassification of Amazonian reserves and Indigenous territories (Pack *et al.* 2016). Finally, we provide recommendations for addressing the challenges of energy development to Amazonian ecosystems and the people that depend on them (Figure 1) through existing policies, new opportunities, and international collaboration.

Protection for Indigenous lands excludes subsurface mineral rights

The lack of subsurface mineral rights often associated with recognized Indigenous territories presents a dilemma for conservation of Amazonian ecosystems, in light of increasing oil and gas development. Areas of the western Amazon region where fossil-fuel reserves overlap with Indigenous territories and protected areas are vulnerable to conflicts caused by the ecological and social impacts of oil development (Figures 2 and 3; Harfoot *et al.* 2018). To varying degrees, Indigenous Amazonian peoples have made gains in acquiring legal land rights, which are defended by the UN Declaration on the Rights of Indigenous Peoples (UNDRIP; Cycon 1991). Previous studies have shown lower rates of deforestation and fires on legally titled Indigenous lands (Nepstad *et al.* 2006; Adeney *et al.* 2009). However, in most national contexts, Indigenous territorial title pertains to surface rights only, with the state often retaining subsurface mineral rights (Davis 2013; Blackman *et al.* 2017). In Ecuador, for example, Indigenous peoples have communal and community land rights but do not hold subsurface rights, which are retained by the state (Bremner and Lu 2006). Similarly, in Brazil, subsurface rights are maintained by the state because mineral extraction is considered relevant to the "public interest" (Davis 2013; Postigo *et al.* 2013). In Peru, property rights are only granted for small areas of agricultural land use or forest; Indigenous peoples largely have use of or access to land owned by the state, which maintains rights to most forests and subsoil minerals (Monterroso *et al.* 2017). Although the right of Indigenous peoples to Free, Prior and Informed Consent (FPIC) is enshrined in the UNDRIP, many Indigenous groups have struggled to prevent oil development within their territories, as the UNDRIP is not legally binding and is therefore difficult to enforce. Furthermore, government interests are often less aligned with the interests of Indigenous peoples than with those of energy development, which generates state royalties (Hite 2004).

A del Campo, The Field Museum

Figure 1. The Amazon River Basin is the world's largest fluvial system and home to more than 30 million people, many of whose lives and livelihoods are influenced by these rivers. However, most legal and institutional frameworks for conservation in the Basin focus on terrestrial areas.

Oil development operations have had major impacts in protected areas and Indigenous territories throughout the Amazon (Figure 4; Harfoot *et al.* 2018). The extraction of oil is associated with spills and wastewater discharge, which are damaging to terrestrial and aquatic systems (Azevedo-Santos *et al.* 2016), often for many years after operations have ceased or following a spill (Fraser 2016, 2018). The flaring of natural gas, which frequently rises to the surface during the oil extraction process, is intended to relieve pressure on drilling equipment but can contaminate air locally and cause forest fires (San Sebastián and Hurtig 2004). Communities living in proximity to oil development also suffer from adverse health impacts. Studies of Indigenous communities along Peru's Corrientes River have documented cases of chemical exposure as a consequence of subsistence diets based on fish or wildlife that consume water or soils contaminated with oil (Orta-Martínez *et al.* 2018; Rosell-Melé *et al.* 2018). Health impacts associated with oil and gas drilling in the Ecuadorian Amazon include elevated rates of miscarriages, diarrhea, gastritis, and various forms of cancer (San Sebastián and Hurtig 2004). In addition, road building, pipeline construction, and infrastructure development facilitate colonization, logging, hunting, and agricultural expansion, which further degrade and destroy forests beyond the site of extraction (Finer *et al.* 2008; Suárez *et al.* 2013; Lessmann *et al.* 2016). Furthermore, most of the current knowledge about the effects of oil spills and remediation measures derives from marine environments and temperate countries; the variable water chemistry, seasonal flooding regimes, and clay soils typical of many Amazonian lowland ecosystems make the research approaches commonly applied elsewhere unsuitable for Amazonian environments (Fraser 2018).

Absence of frameworks for freshwater conservation

Despite being the world's largest freshwater system, there is a lack of specific frameworks for conservation of aquatic environments and their biodiversity in the Amazon River

Basin at regional, national, and international scales (Castello *et al*. 2013). Rivers and freshwater biodiversity have long been neglected in many conservation initiatives, and delineating the boundaries of most Amazonian protected areas has focused on representation of terrestrial ecosystems. As such these boundaries often do not align with those of natural hydrologic units like watersheds (Castello and Macedo 2016). River sources typically lie outside of or form the borders of Amazonian protected areas. Even in protected areas where freshwater ecosystems are included as conservation targets (eg Peru's Tambopata National Reserve), actual protection of those ecosystems is challenged by upstream or downstream threats. Of all Amazonian countries, only Colombia has instituted legal recognition of rivers as conservation objects (as part of its Protected River framework; Andrade 2011). Ecuador established legal recognition of "hydrologic protection areas" under its 2014 Water Law, but no freshwater reserves have been established under the country's national system for protected areas.

To date, none of the Amazonian countries have ratified the UN Convention on the Law of International Watercourses (commonly referred to as the UN Watercourses Convention; UNWC), which applies to non-navigational uses of freshwater and promotes measures of protection and management of international watercourses. Furthermore, although all Amazonian countries are signatories to the Ramsar Convention, as of 2017 only 79,373 km^2 of the estimated 800,000 km^2 of Amazonian lowland wetlands have been designated as Wetlands of International Importance. Of those wetlands designated as Ramsar sites, many lack appropriate management, as illustrated by two examples from the Peruvian Amazon: (1) wetlands in Pacaya Samiria National Reserve continue to be managed using a terrestrial approach despite Ramsar status, and (2) no management actions have been taken by Peruvian authorities for the Abanico del Pastaza – which, though not a protected area, is a Ramsar site – 15 years after its designation (M Montoya, unpublished data).

The Amazon is a global center of freshwater diversity, much of which remains understudied and vulnerable to the impacts of human activities. For example, 2258 obligate freshwater fish species have been recorded in the Amazon Basin (www.amazon-fish.com), although an estimated 3000–4000 species may occur there (Reis *et al*. 2016). However, conservation initiatives aimed at freshwater species are relatively limited as compared with those for Amazonian terrestrial fauna, and freshwater species often lack the same degree of protection as terrestrial species under existing legal and institutional frameworks. In Peru and Ecuador, for instance, freshwater fishes are managed under the jurisdiction of the country's Ministry of Production, and are therefore excluded from protections offered to other native flora and fauna considered under the Ministry of the Environment. In Brazil, recent studies have shown that existing protected areas in the Brazilian Amazon do not overlap with areas of high conservation value for freshwater fishes, resulting in inadequate legal protection for freshwater fauna (Frederico *et al*. 2018). Fishes and other freshwater biota within the existing Amazonian protected area network are vulnerable to the influence of activities occurring in upstream or downstream areas beyond the boundaries of the protected areas (Castello and Macedo 2016).

In the absence of adequate frameworks for conservation, the current proliferation of hydropower dams and oil and gas development in the Amazon threatens the integrity of Amazonian freshwater ecosystems and their biodiversity. New dam construction has introduced physical barriers in river channels and altered river flow regimes, which in turn have affected freshwater biota (Figure 5). The Santo Antonio Dam and the Jirau Dam, both on the Madeira River, began operations in 2012 and 2016, respectively, and have already limited the movement of long-distance migratory fish species

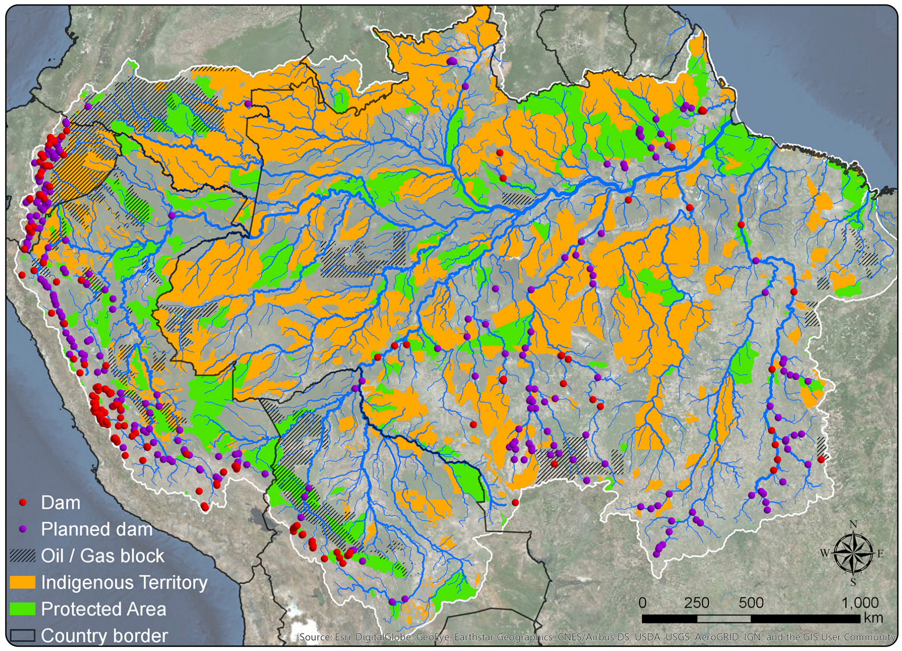
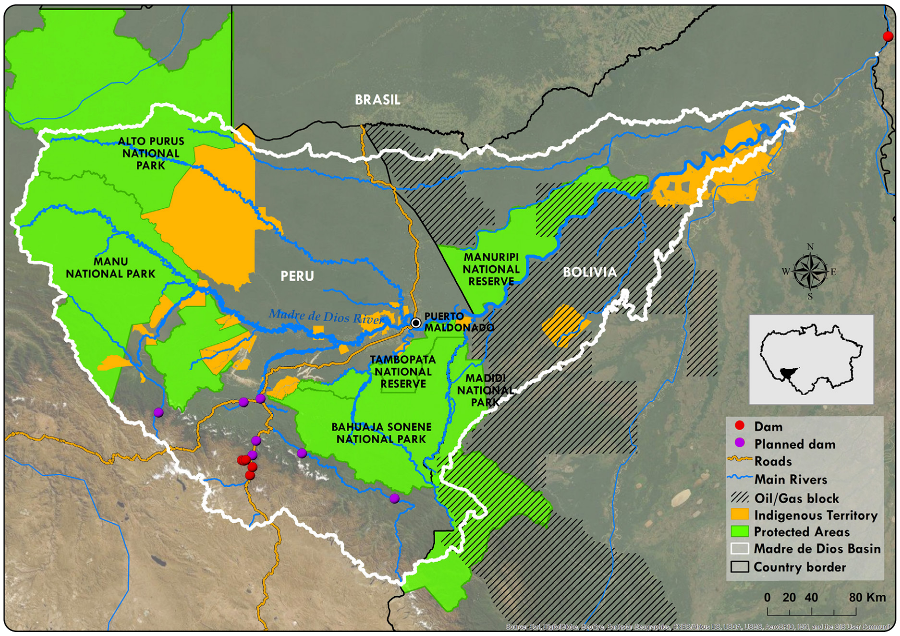


Figure 2. The locations of fossil-fuel reserves in the Amazon often overlap with Indigenous territories or protected areas, especially in the western Amazon. Existing and proposed hydropower projects fragment Amazonian rivers and represent threats to protected areas and Indigenous territories, particularly in the Andean Amazon. Data sources: protected areas (Brazilian Ministry of the Environment, Ecuadorian Ministry of the Environment, Colombian Ministry of Environment and Sustainable Development, SIGOT Colombia, Peruvian Servicio Nacional de Áreas Naturales Protegidas por el Estado [SERNANP], GeoBolivia, and Servicio Nacional de Áreas Protegidas); Indigenous territories (Instituto SocioAmbiental, Rede Amazônica de Informação Socioambiental Georreferenciada [RAISG], GeoBolivia, and SIGOT Colombia); oil and gas blocks (Brazil Agência Nacional do Petróleo, Bolivia Agencia Nacional de Hidrocarburos, SIGOT Colombia, and Finer *et al*. [2015]); dams (Anderson *et al*. [2018] and Brazil Agência Nacional de Energia Elétrica).



A Mercado, WCS Peru

Figure 3. The Madre de Dios River Basin, located in the tri-national region of Peru, Bolivia, and Brazil in the southwestern Amazon, exemplifies current challenges for conservation. Here, oil and gas blocks partially overlap with both protected areas and Indigenous territories, and hydropower dams influence rivers that flow through or along their borders. Data sources: SERNANP, Peruvian Ministerio de Transportes y Comunicaciones, and RAISG.

(Duponchelle *et al.* 2016; Cella-Ribeiro *et al.* 2017). In the Andean Amazon (the regions of Colombia, Ecuador, Peru, and Bolivia that fall within the Amazon Basin), dams are disrupting critical geomorphological processes such as river meandering and floodplain formation for thousands of kilometers downstream (Latrubesse *et al.* 2017; Anderson *et al.* 2018), with detrimental consequences for floodplain agriculture and fisheries (Coomes *et al.* 2010, 2016). Conversely, while dams disrupt Amazonian hydrologic connectivity, this same property amplifies oil spill impacts, as rivers transport pollutants and thermally altered water far from the source point (Azevedo-Santos *et al.* 2016). With increasing petroleum development, oil spills have become more common in the Amazon, as evidenced by disturbances along the Marañón River in 2014 and 2016 (Fraser 2014, 2016; Mega 2016) and numerous spills in the Ecuadorian Amazon over the past 30 years (Kimerling 2013). These episodes have resulted in massive fish kills, with cascading effects on other organisms through disruptions to food webs and community structure (Kingston 2002; Fraser 2014; Azevedo-Santos *et al.* 2016). Given the possibility of toxin bioaccumulation in food webs, oil spills may have long-lasting (>30 years) effects.

Energy development and PADDD

Another challenge facing conservation of Amazonian ecosystems and biodiversity is the link between PADDD and energy development. In the Brazilian Amazon, for example, PADDD has occurred with greater frequency since 2008, with electricity generation and transmission (especially hydropower) being the primary driver of change (Bernard *et al.* 2014; Pack *et al.* 2016). Between 2010 and 2012, generation and transmission of electricity was the reason for the downsizing/downgrading of 19 *unidades de conservação* (conservation units) or other protected areas (Bernard *et al.* 2014). In addition, few protected areas are immune to the influence of existing or proposed large dams (Ferreira *et al.* 2014). These actions highlight the Brazilian Government's preference for energy generation and transmission over Amazon biodiversity conservation, and could jeopardize Brazil's commitment to international conventions on biological diversity and climate change (Hermoso 2017). Plans to develop infrastructure projects such as hydropower dams have intensified under new Brazilian President Jair Bolsonaro, who has made Amazonian development a core platform of his administration (Artaxo 2019; Walker 2019).

Amazonian countries differ in regard to fossil-fuel extraction in protected areas. Colombia does not permit exploitation within national parks, but oil and gas development blocks have been granted along the borders of protected areas and Indigenous territories. Peru limits fossil-fuel development in national parks, but oil and gas extraction is permitted in national reserves, and the potential for gas development has already led to discussions about downsizing of some of the country's national parks (Sarkar and Montoya 2011), as well as proposed modifications to the Hydrocarbon Law (*Ley de Hidrocarburos*) that would allow for extraction of oil and gas from protected areas characterized by strict levels of protection (García Olano 2017). Oil and gas development is permitted in the national parks of Ecuador and Bolivia (Finer *et al.* 2008). In Ecuador, oil extraction is considered a national priority and therefore supersedes (in legal terms) other laws or international conventions under the nation's 2008 Constitution. There is a long history of oil and gas development in Bolivia (since the 1970s), and the Bolivian government recently passed legislation permitting fossil-fuel extraction in protected areas and national parks (Hindery and Hecht 2013). Fossil-fuel development in the region has resulted in water and soil contamination, with serious health and livelihood implications for local communities (Finer *et al.* 2008), and these impacts have caused disputes about extractive forms of development in protected areas and Indigenous territories.

The recent controversy over Yasuní National Park in Ecuador illustrates the linkage between energy development and PADDD. Yasuní National Park has been designated as a UN Educational, Scientific and Cultural Organization (UNESCO) World Heritage site and is one of the most biodiverse places on Earth (Bass *et al.* 2010). It is also home to several Indigenous groups, mainly the Waorani and Kichwa, as well as those in voluntary isolation, such as the Tagaeri and

Taromenane (Larrea and Warnars 2009). Yasuní also contains one of Ecuador's largest oil reserves. In 2007, Ecuador's then-president Rafael Correa proposed the Yasuní–Ishpingo–Tambococha–Tiputini (Yasuní–ITT) initiative, an ambitious project to keep oil underground in the ITT oil-block region of the park in exchange for half of the opportunity costs of the oil (Finer *et al*. 2010). But in the absence of sufficient financial support from the international community, the Ecuadorian government announced in 2013 that oil development would be permitted in Yasuní–ITT, and oil-related operations were initiated in 2016 (Sovacool and Scarpaci 2016).

Addressing these blind spots

Recent studies have documented contemporary shifts in deforestation dynamics and identified a potential tipping point for deforestation, beyond which major alterations in Amazonian climatic and ecological systems are expected (Lovejoy and Nobre 2018), underscoring the importance of developing new strategies for Amazonian conservation. As shown above, there is a need for governments, communities, scientists, donors, and non-governmental organizations (NGOs) to view Amazonian ecosystem conservation through a new lens in response to current trends in energy development. To that end, we suggest means to address some of the challenges that energy development represents for the people and ecosystems in the Amazon Basin.

Increase the recognition of Indigenous cultures

There is a widespread need for governments and civil society to better understand the hundreds of Indigenous cultures that inhabit the Amazon, and to strengthen and support alliances with and between Indigenous peoples (with the exception of uncontacted tribes; Fraser 2017). The deep, reciprocal relationships that Amazonian Indigenous cultures have with surrounding ecosystems offer some of the strongest opportunities and assets for achieving conservation goals in the face of energy development, and provide a reason to conserve these ecosystems in the first place. Yet such relationships remain largely unappreciated by outsiders to those cultures. For example, rivers are linked to the cultures and worldviews of many Amazonian Indigenous groups. The Shawi, who live near Peru's Cordillera Escalante, recognize rivers as energizing forces that facilitate connection with and sustain ancestors (Figure 1; Huertas Castillo and Chanchari 2012). The Kukama, who live near the confluence of the Marañon and Ucayali rivers in the western Amazon, believe that underwater cities provide shelter to drowned relatives and view certain freshwater environments, such as oxbow lakes, as sacred. These cultural connections are being leveraged by the Kukama, NGOs, and scientists to call for reconsideration of Chinese–Peruvian plans for the development of an Amazonian Waterway (Hidrovía Amazónica) that would dredge hundreds of kilometers of the Marañón and other rivers (Fraser and Tello Imaina 2015). Similarly, in Brazil, an Indigenous movement led by the Munduruku people – based on their desire to assert tribal rights to natural resources and to cease infrastructure projects threatening those rights – recently helped bring about the suspension of construction plans for the São Luiz do Tapajós Dam (8000 megawatts), which had been proposed as a centerpiece of a major hydroelectric scheme in the Tapajós River (Walker and Simmons 2018). These and other such efforts help illuminate cultural connections to Amazonian ecosystems and demonstrate how they can be used as a tool for conservation.

Figure 4. Oil spills occur frequently in parts of the Amazon, often multiple times a year from a single pipeline. The impacts of these events can affect Amazonian ecosystems and the people that depend on them for many years afterward. Used with permission.

Grant subsurface mineral rights

The territorial rights of Indigenous peoples should be legally strengthened in all Amazonian countries to include subsurface mineral rights, thereby potentially protecting culturally and ecologically important areas from the impacts of fossil-fuel development. Many Indigenous peoples (eg the Kichwa community in Sarayaku, Ecuador) are adamantly opposed to fossil-fuel development in their territory (Riofrancos 2016). Shifts in the political climate in individual countries toward Indigenous peoples – exemplified by Brazilian President Bolsonaro attempting to transfer administrative responsibilities for Indigenous lands from the Ministry of Justice to the Ministry of Agriculture during his first months in office – underscore the importance of international, pan-Amazonian alliances for conservation, and for the recognition and support of Indigenous people and their territorial rights (Artaxo 2019; Walker 2019).

In the absence of subsurface mineral rights for Indigenous peoples, major improvements in consultation processes – with inputs from both government bodies and Indigenous groups – are needed prior to fossil-fuel development, wherein Indigenous people have greater authority to deny advancement of fossil-fuel projects that threaten culturally and ecologically

Figure 5. Hydropower dams have fragmented rivers throughout the Amazon Basin. Dams in the Andean Amazon often operate by diverting water from the channel over several kilometers, effectively leaving a dry or dewatered reach.

important areas. Improved consultation processes should be backed by more stringent enforcement by national governments, in collaboration with civil society. UNDRIP, as an international standard for consultation, requires FPIC in all projects that affect Indigenous peoples' rights to land, territory, and resources (Article 32) and asserts that there is an obligation to obtain consent in cases where there is relocation of Indigenous groups (Article 10) or storage/disposal of hazardous materials on Indigenous peoples' land (Article 29).

Given the rapidly shrinking carbon budget, especially under the stricter Paris Agreement target of limiting global temperature increases to 1.5°C, approximately 83% of economically accessible fossil-fuel reserves must remain unburned and underground (Benedikter *et al.* 2016). Addressing this issue would have important effects not only for Amazon biodiversity conservation, but also for climate-change mitigation through the reduction of carbon emissions resulting from deforestation, forest degradation, and fossil-fuel combustion. Indigenous peoples could be compensated for climate-change mitigation in forest funds like the Green Climate Fund (Brechin and Espinoza 2017), which would provide Indigenous communities with support for sustainable development, thereby reducing incentives to permit oil drilling in their territories and to better ensure that fossil fuels are left underground.

Establish protection for freshwater systems

Governments, donors, scientists, NGOs, and civil society must direct greater attention toward establishing effective protection for freshwater ecosystems at national and international scales, and at the level of individual protected areas (Castello and Macedo 2016). At a minimum, the federal governments of all Amazonian countries should consider becoming signatories to the UNWC, collectively work to increase the extent of Ramsar-designated wetlands in the Amazon, and ensure effective management of existing Ramsar sites. Development of a basin-wide framework for aquatic ecosystem conservation should be a goal for the immediate future, which could make use of the existing Amazon Cooperation Treaty (ACT) as a framework for international collaboration. This framework should specify roles for environment-, fisheries-, and water-related authorities in individual countries, and recognize the multidimensional connectivity of freshwater systems along longitudinal, lateral, and vertical pathways, as well as the importance of Andes-to-Amazon fluvial linkages. Governments of all Amazonian countries could also explore opportunities for creating new legal frameworks for protecting flowing water systems; recent policies in Colombia and Costa Rica that restrict hydropower development on certain rivers could provide models for new legislative frameworks to address potential impacts of proposed hydroelectric dam projects in Amazonian countries (Andrade 2011; MINAE 2015).

Because the borders of most of the protected areas in the Amazon do not align with river basin boundaries, the majority of freshwater species are vulnerable to upstream or downstream threats. Therefore, where possible, existing protected areas could be expanded to cover greater extents of river basin area, or at least to include areas of importance for freshwater species (Abell *et al.* 2017). For existing protected areas, we recommend that relevant government authorities (eg environment-related ministries and agencies) revisit management plans to better consider freshwater ecosystems through identification of specific conservation targets, development of monitoring plans, and increased coordination with other government authorities (eg fisheries, water, transportation, and energy-related agencies). Finally, an integrated, multisectoral, and multiscale management approach is needed for all protected areas to improve conservation of freshwater ecosystems (Castello and Macedo 2016).

Limit energy and infrastructure development in protected areas

Governments of Amazonian countries should declare all or most categories of protected areas in the Amazon off-limits for energy and large-scale infrastructure development. Decades of research have shown that well-managed protected areas in the Amazon can reduce deforestation, buffer against potential climate change, and achieve biodiversity conservation goals (Walker *et al.* 2009; Soares-Filho *et al.* 2010). In contrast, decades of scientific study have also documented the detrimental effects of oil and gas development, and of hydroelectric dams, on Amazonian terrestrial and aquatic biodiversity (Finer *et al*. 2008; Castello and Macedo 2016). PADDD, whether as a consequence of energy development or other factors, needs to be governed by stringent policies similar to those that guide the initial establishment of protected areas. Examples of new computational approaches – through the nascent field of computational sustainability – show promise for the development of robust, multicriteria decision-support tools that can be applied at the scale of the Amazon Basin to optimize future energy projects while supporting the conservation for protected areas (Wu *et al.* 2018).

Proclaim the importance of freshwaters and Indigenous communities to conservation

Finally, there is an urgent need for a widespread, global campaign to acknowledge the importance of Amazonian freshwater systems and the uniqueness of Amazonian Indigenous communities. The case for Amazon forest conservation and the concept of intact, standing forests as conservation objects are well-recognized worldwide, including legal frameworks in support of their conservation in all Amazonian countries. Support from governments of Amazonian countries and the international conservation community – including large influxes of donor funds – helped double the size of Amazonian protected areas since 2000 (RAISG 2016; Gullison and Hardner 2018). Similar advocacy for the importance of Indigenous territories and for strengthening those communities that are vulnerable to the pressures created by energy development is necessary from all levels of society in light of current trends in energy development (Gullison and Hardner 2018). Several networks of South American and international scientists have recently formed to examine the implications of energy development for Amazonian people and ecosystems, particularly freshwater systems; examples include the Amazon Dams Network (www.amazondamsnetwork.org), the Amazon Computational Sustainability working group (https://impactsofdams.wordpress.com), and the Amazon Waters Initiative (www.amazonwaters.org). These scientists are well placed to advise governments on conservation strategies for Amazonian freshwater systems, drawing upon the latest science and the strengths and assets of human populations in riparian areas.

Conclusion

Addressing these challenges to Amazon conservation is essential for securing the future of the Amazon's biological and cultural diversity, and for maintaining critical, global-scale processes of carbon storage and sequestration provided by Amazonian ecosystems. Destruction of the Amazon is not a solution to economic or political problems. Lovejoy and Nobre (2018) called for strict limitation of Amazonian deforestation to less than 20% of the original extent of the forest area as a margin of safety against a tipping point for deforestation-generated degradation of the hydrologic cycle. Similar analyses are underway to determine potential thresholds or tipping points for fragmentation of Amazonian freshwater ecosystems. The risks associated with energy development in the Amazon Basin must be considered if we are to meet these globally important conservation goals.

Acknowledgements

We are grateful to many colleagues for discussions that inspired this manuscript, especially those leading the Amazon Dams Network (S Athayde, D Kaplan, and B Loiselle), the Amazon Computational Sustainability project (A Flecker and C Gomes), and the Amazon Waters Initiative. LC acknowledges the Interdisciplinary Research in Earth Sciences program (grant #NNX14AD29G). EPA, ACE, and JAM-O acknowledge The MacArthur Foundation for financial support under the Living Andean Rivers initiative (#16-1607-151053-CSD). We thank B Kays for assistance with the references. This is #928 contribution from the Southeast Environmental Research Center in the Institute of Water and Environment at Florida International University. This manuscript is dedicated to the memory of our Colombian colleague J Maldonado-Ocampo.

References

Abell R, Lehner B, Thieme M, and Linke S. 2017. Looking beyond the fenceline: assessing protection gaps for the world's rivers. *Conserv Lett* **10**: 383–93.

Adeney JM, Christensen NL, and Pimm SL. 2009. Reserves protect against deforestation fires in the Amazon. *PLoS ONE* **4**: e5014.

Anderson EP, Jenkins CN, Heilpern S, *et al*. 2018. Fragmentation of Andes-to-Amazon connectivity by hydropower dams. *Science. Advances* **4**: eaao1642.

Andrade G. 2011. Río Protegido. Nuevo concepto para la gestión de conservación de sistemas fluviales de Colombia. *Gestión y Ambiente* **14**: 65–72.

Artaxo P. 2019. Working together for Amazonia. *Science* **363**: 323.

Azevedo-Santos VM, Garcia-Ayala JR, Fearnside PM, *et al*. 2016. Amazon aquatic biodiversity imperiled by oil spills. *Biodivers Conserv* **25**: 2831–34.

Bass MS, Finer M, Jenkins CN, *et al*. 2010. Global conservation significance of Ecuador's Yasuní National Park. *PLoS ONE* **5**: e8767.

Benedikter R, Kühne K, Benedikter A, and Atzeni G. 2016. "Keep it in the ground". The Paris Agreement and the renewal of the energy economy: toward an alternative future for globalized resource policy? *Challenge* **59**: 205–22.

Bernard E, Penna LAO, and Araújo E. 2014. Downgrading, downsizing, degazettement, and reclassification of protected areas in Brazil. *Conserv Biol* **28**: 939–50.

Blackman A, Corral L, Lima ES, and Asner GP. 2017. Titling indigenous communities protects forests in the Peruvian Amazon. *P Natl Acad Sci USA* **114**: 4123–28.

Brechin SR and Espinoza MI. 2017. A case for further refinement of the Green Climate Fund's 50:50 ratio climate change mitigation and adaptation allocation framework: toward a more targeted approach. *Climatic Change* **142**: 311–20.

Bremner J and Lu F. 2006. Common property among indigenous peoples of the Ecuadorian Amazon. *Conserv Soc* **4**: 499–521.

Castello L and Macedo MN. 2016. Large-scale degradation of Amazonian freshwater ecosystems. *Glob Change Biol* **22**: 990–1007.

Castello L, McGrath DG, Hess LL, *et al*. 2013. The vulnerability of Amazon freshwater ecosystems. *Conserv Lett* **6**: 217–29.

Cella-Ribeiro A, Rodrigues da Costa Doria CR, Dutka-Gianelli J, *et al*. 2017. Temporal fish community responses to two cascade run-of-river dams in the Madeira River, Amazon basin. *Ecohydrology* **10**: 1–11.

Cisneros P and McBreen J. 2010. Superposición de territorios indígenas y áreas protegidas en América del Sur. Quito, Ecuador: IUCN-DFID Department for International Development.

Coomes OT, Lapointe M, Templeton M, and List G. 2016. Amazon River flow regime and flood recessional agriculture: flood stage reversals and risk of annual crop loss. *J Hydrol* **539**: 214–22.

Coomes OT, Takasaki Y, Abizaid C, and Barham BL. 2010. Floodplain fisheries as natural insurance for the rural poor in tropical forest environments. *Fisheries Manag Ecol* **17**: 513–21.

Cycon DE. 1991. When worlds collide: law, development, and indigenous peoples. *New England Law Rev* **25**: 761–94.

Davis DC. 2013. Land in the second decade: the evolution of indigenous property rights and the energy industry in the US and Brazil. *Energy Law J* **34**: 667–86.

Duponchelle F, Pouilly M, Pécheyran C, *et al*. 2016. Trans-Amazonian natal homing in giant catfish. *J Appl Ecol* **53**: 1511–20.

Ferreira J, Aragão LEOC, Barlow J, *et al*. 2014. Brazil's environmental leadership at risk. *Science* **346**: 706–07.

Finer M, Babbitt B, Novoa S, *et al*. 2015. Future of oil and gas development in the western Amazon. *Environ Res Lett* **10**: 024003.

Finer M, Jenkins CN, Pimm SL, *et al*. 2008. Oil and gas projects in the western Amazon: threats to wilderness, biodiversity, and indigenous peoples. *PLoS ONE* **3**: e2932.

Finer M, Moncel R, and Jenkins CN. 2010. Leaving the oil under the Amazon: Ecuador's Yasuní–ITT initiative. *Biotropica* **42**: 63–66.

Fraser B. 2014. Oil spill in Amazon sickens villagers, kills fish. *Sci Am* **Jul**; www.scientificamerican.com/article/oil-spill-in-amazon-sickens-villagers-kills-fish. Viewed 1 Apr 2019.

Fraser B. 2016. Oil in the forest. *Science* **353**: 641–43.

Fraser B. 2017. Maps reveal how Amazon development is closing in on isolated tribes. *Science* **Aug**; doi.org/10.1126/science.aao7079.

Fraser B. 2018. Peru plans oil clean-up. *Nature* **562**: 18–19.

Fraser B and Tello Imaina L. 2015. Culture, ecology get short shrift in river plan. *EcoAméricas* **Jan**: 6–8.

Frederico RG, Zuanon J, and de Marco P. 2018. Amazon protected areas and its ability to protect stream-dwelling fish fauna. *Biol Conserv* **219**: 12–19.

García Olano E. 2017. Perupetro pide revisar restriccion par apoder explotar petroleo y gas en zonas protegidas. *Gestíon, Economía* **Dec**: 14.

Gullison RE and Hardner J. 2018. Progress and challenges in consolidating the management of Amazonian protected areas and indigenous territories. *Conserv Biol* **32**: 1020–30.

Harfoot MBJ, Tittensor DP, Knight S, *et al*. 2018. Present and future biodiversity risks from fossil fuel exploitation. *Conserv Lett* **11**: 1–13.

Hermoso V. 2017. Freshwater ecosystems could become the biggest losers of the Paris Agreement. *Global Change Biol* **23**: 3433–36.

Hindery D and Hecht B. 2013. From Enron to Evo: pipeline politics, global environmentalism, and Indigenous rights in Bolivia. Tucson, AZ: University of Arizona Press.

Hite K. 2004. Back to the basics: improved property rights can help save Ecuador's rainforests. *Georgetown Environ Law Rev* **16**: 763.

Huertas Castillo B and Chanchari M. 2012. Mitos Shawi sobre el agua. Lima, Peru: TerraNova.

Kimerling J. 2013. Oil, contact, and conservation in the Amazon: indigenous Huaorani, Chevron, and Yasuni. *CO J Int Environ Law Policy* **24**: 43–115.

Kingston PF. 2002. Long-term environmental impact of oil spills. *Spill Sci Technol B* **7**: 53–61.

Larrea C and Warnars L. 2009. Ecuador's Yasuni–ITT initiative: avoiding emissions by keeping petroleum underground. *Energy Sustain Dev* **13**: 219–23.

Latrubesse EM, Arima EY, Dunne T, *et al*. 2017. Damming the rivers of the Amazon basin. *Nature* **546**: 363–69.

Lessmann J, Fajardo J, Muñoz J, and Bonaccorso E. 2016. Large expansion of oil industry in the Ecuadorian Amazon: biodiversity vulnerability and conservation alternatives. *Ecol Evol* **6**: 4997–5012.

Lovejoy TE and Nobre C. 2018. Amazon tipping point. *Science Advances* **4**: 1–2.

Mega ER. 2016. Oil spills stain Peruvian Amazon. *Sci Am* **Mar**; www.scientificamerican.com/article/oil-spills-stain-peruvian-amazon. Viewed 1 Apr 2019.

MINAE (Ministro de Ambiente y Energia). 2015. Salvaguarda ambiental para el cauce principal de los Ríos Pacuare y Savegre. San Jose, Costa Rica: MINAE. No 39199-MINAE.

Monterroso I, Cronkleton P, Pinedo D, and Larson AM. 2017. Reclaiming collective rights: land and forest tenure reforms in Peru (1960–2016). Bogor, Indonesia: Center for International Forestry Research. Working paper 224.

Nepstad D, Schwartzman S, Bamberger B, *et al*. 2006. Inhibition of Amazon deforestation and fire by parks and indigenous lands. *Conserv Biol* **20**: 65–73.

Orta-Martínez M, Rosell-Melé A, Cartró-Sabaté M, *et al*. 2018. First evidences of Amazonian wildlife feeding on petroleum-contaminated soils: a new exposure route to petrogenic compounds? *Environ Res* **160**: 514–17.

Pack SM, Ferreira MN, Krithivasan R, *et al*. 2016. Protected area downgrading, downsizing, and degazettement (PADDD) in the Amazon. *Biol Conserv* **197**: 32–39.

Postigo JC, Montoya M, and Young KR. 2013. Natural resources in the subsoil and social conflicts on the surface: perspectives on Peru's subsurface political ecology. In: Bebbington A and Bury J (Eds). Subterranean struggles: new dynamics of mining, oil, and gas in Latin America. Austin, TX: University of Texas Press.

RAISG (Rede Amazônica de Informação Socioambiental Georreferenciada). 2016. Cartografia histórica de areas naturales protegidas y territorios indigenas en la Amazonia. Quito, Ecuador: EcoCiencia.

Reis RE, Albert JS, Di Dario F, *et al*. 2016. Fish biodiversity and conservation in South America. *J Fish Biol* **89**: 12–47.

Riofrancos TN. 2016. Proleptic protest: local resistance to new extractive projects in Ecuador. Notre Dame, IN: University of Notre Dame.

Rosell-Melé A, Moraleda-Cibrián N, Cartró-Sabaté M, *et al*. 2018. Oil pollution in soils and sediments from the northern Peruvian Amazon. *Sci Total Environ* **610–611**: 1010–19.

San Sebastián M and Hurtig A-K. 2004. Oil exploitation in the Amazon basin of Ecuador: a public health emergency. *Rev Panam Salud Publ* **15**: 205–311.

Sarkar S and Montoya M. 2011. Beyond parks and reserves: the ethics and politics of conservation with a case study from Perú. *Biol Conserv* **144**: 979–88.

Soares-Filho B, Moutinho P, Nepstad D, *et al*. 2010. Role of Brazilian Amazon protected areas in climate change mitigation. *P Natl Acad Sci USA* **107**: 10821–26.

Sovacool BK and Scarpaci J. 2016. Energy justice and the contested petroleum politics of stranded assets: policy insights from the Yasuní–ITT Initiative in Ecuador. *Energ Policy* **95**: 158–71.

Suárez E, Zapata-Ríos G, Utreras V, *et al*. 2013. Controlling access to oil roads protects forest cover, but not wildlife communities: a case study from the rainforest of Yasuní Biosphere Reserve (Ecuador). *Anim Conserv* **16**: 265–74.

Walker RT. 2019. Amazon deforestation, already rising, may spike under Bolsonaro. *The Conversation*. http://theconversation.com/amazon-deforestation-already-rising-may-spike-under-bolsonaro-109940. Viewed 5 May 2019.

Walker R and Simmons C. 2018. Endangered Amazon: an indigenous tribe fights back against hydropower development in the Tapajós Valley. *Environ Sci Policy Sust Develop* **60**: 4–15.

Walker R, Moore NJ, Arima E, *et al*. 2009. Protecting the Amazon with protected areas. *P Natl Acad Sci USA* **106**: 10582–86.

Walker W, Baccini A, Schwartzman S, *et al*. 2014. Forest carbon in Amazonia: the unrecognized contribution of indigenous territories and protected natural areas. *Carbon Manag* **5**: 479–85.

Wu X, Gomes-Selman J, Shi Q, *et al*. 2018. Efficiently approximating the Pareto frontier: hydropower dam placement in the Amazon Basin. Proceedings of the Thirty-Second Association for the Advancement of Artificial Intelligence (AAAI) Conference on Artificial Intelligence; 2–7 Feb 2018; New Orleans, LA. Palo Alto, CA: AAAI.