Legal Changes Threaten Iconic Protected Areas

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Legal Changes Threaten Iconic Protected Areas

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1. INTRODUCTION

National parks and other protected areas (PAs) are key components of the conservation toolbox. The global PA estate has grown from a handful of sites in 1900 to more than 200,000 PAs today, covering approximately 14.8% of terrestrial areas and inland waters, and 5.1% of marine and coastal areas (UNEP-WCMC & IUCN 2016). Throughout the modern history of PAs, their creation has been motivated by the need to protect spectacular landscapes and wildlife, to conserve biodiversity, to support ecosystems services (Watson et al. 2014). PA effectiveness varies by geography, PA characteristics, socio-ecological context, and by management capacity (Joppa & Pfaff 2010; Pfaff et al. 2014; Gill et al. 2017).

PAs with UNESCO designations are the "jewels in the crown" of area-based conservation measures. United Nations Educational, Scientific, and Cultural Organization (UNESCO) recognizes Natural World Heritage Sites for their unique natural landscapes, biological diversity, or species, as well as their integrity and effectiveness for biodiversity conservation (UNESCO 2017a). UNESCO also recognizes Biosphere Reserves, whose management strives to reconcile biodiversity conservation and sustainable use and integrates biodiversity and cultural diversity (UNESCO 2018).

Despite the net growth in protected lands and waters, recent research (Mascia et al. 2014; Forrest et al. 2015; Pack et al. 2016; Cook et al. 2017) reveals widespread, albeit underreported, protected area downgrading, downsizing, and degazettement (PADDD). Downgrading is a decrease in legal restrictions on the number, magnitude, or extent of human activities within a PA; downsizing is a decrease in the size of a PA as a result of excision of land or sea area through a legal boundary change; and degazettement is a loss of legal protection for an entire PA (Mascia & Pailler 2011). To date, more than 2,300 PADDD events have been documented in 56 countries, affecting over 1 million km^2 from 1892 to 2016 (Mascia et al. 2014; Forrest et al. 2015; Golden Kroner et al. 2016; Pack et al. 2016; Cook et al. 2017). Proximate causes of PADDD include industrial-scale resource extraction and development, local land pressures and land claims, and to a much lesser extent, conservation planning (Mascia et al. 2014). While the Convention of Biological Diversity calls for 17% of terrestrial area under protection, PADDD not only hinders national progress toward Aichi Target 11 (Mascia et al. 2014) but may also accelerate tropical deforestation and carbon emissions (Forrest et al. 2015), and exacerbate habitat fragmentation (Golden Kroner et al. 2016).

Emerging evidence indicates that even iconic PAs, including PAs with UNESCO recognitions, are vulnerable to PADDD (see Table 1; Mascia et al. 2014; Allan et al. 2017; Jones et al. 2018). More than a quarter of UNESCO World Heritage Sites worldwide are under threat from existing or proposed oil and gas extraction (Osti et al. 2011, Veillon 2014), an activity incompatible with World Heritage status (UNESCO 2017a). Many Natural World Heritage Sites also experience increased human pressure and deforestation (Allan et al. 2017). Here, we explore the context, proximate causes, and impacts of PADDD events in five PAs with UNESCO designations, each representing a different socio-ecological context: Yosemite National Park (United States), Arabian Oryx Sanctuary (Oman), Yasuní National Park (Ecuador), Virunga National Park (Democratic Republic of Congo), and the Great Barrier Reef Marine Park (Australia). In light of these findings, discussions in the published literature, workshop discussions, and personal experience, we propose priorities for research, policy, and capacity building to advance the understanding of PADDD, and to improve the transparency of PADDD governance.

Table 1. Enacted and proposed PADDD events in UNESCO World Heritage Sites*

Country	UNESCO World Heritage Site	Year PADDD enacted (proposed)	PADDD Type	Proximate Cause	Year PADDD reversed
Australia	The Great Barrier Reef Marine Park	2013	Downgrade	Industrialization	2014
Brazil	Iguaçu National Park	(1998)	Downsize	Infrastructure	
	Iguaçu National Park	(2010)	Downgrade	Infrastructure	
Bulgaria	Pirin National Park	2012	Downgrade	Industrialization	2012
DRC	Virunga National Park	2010	Downgrade	Oil and Gas	2014
	Virunga National Park	2015	Downgrade	Oil and Gas	
	Virunga National Park	(2018)	Downgrade	Oil and Gas	
	Salonga National Park	(2018)	Downgrade	Oil and Gas	
Ecuador	Sangay National Park	2004	Downsize	Multiple Causes	
Guinea	Mount Nimba National Park	1993	Downsize	Mining	
Oman	Arabian Oryx Sanctuary	2007	Downsize	Oil and Gas	
Tanzania	Selous Game Reserve	(2010)	Downgrade	Infrastructure	
	Selous Game Reserve	2012	Downsize	Mining	
	Serengeti National Park	(2010)	Downgrade	Infrastructure	
	Serengeti National Park	(2012)	Downsize	Infrastructure	2012
USA	Yellowstone National Park	(2014)	Downgrade	Other (recreation)	
	Everglades National Park	(2011)	Downgrade	Infrastructure	2012
	Olympic National Park	(2011)	Downgrade	Infrastructure	2013
	Olympic National Park	(2015)	Downgrade	Infrastructure	2017
	Yosemite National Park	1892**	Downgrade	Infrastructure	
	Yosemite National Park	1901**	Downgrade	Infrastructure	
	Yosemite National Park	1905**	Downsize	Forestry	
	Yosemite National Park	1906**	Downsize	Forestry	
	Yosemite National Park	1913**	Downgrade	Infrastructure	

* As documented in PADDDtracker.org (WWF & Conservation International 2018) and in this paper

** PADDD events enacted before UNESCO designation.

2. PADDD CASES

2.1 Yosemite National Park

First protected as a Land Grant in 1864 and then as a National Park in 1890, Yosemite National Park is one of the oldest national parks in the world. Currently covering more than 3,000 km^2, Yosemite National Park is home to over 400 vertebrate species (Walden-Schreiner et al. 2017) and is best known for its distinctive landscape features which attract more than 4 million visitors annually (USNPS 2018). UNESCO recognized Yosemite National Park as a World Heritage Site in 1984 for both its geological and ecological values (UNESCO 1984).

Legal changes to Yosemite's regulations and boundaries occurred early in its history. The Park was downgraded in 1892, 1901, and 1913 to allow construction of wagon roads and turnpikes; electrical lines, dams, and pipes; and the construction of O'Shaughnessy Dam in the Hetch Hetchy Valley (Golden Kroner et al. 2016). The Park was also downsized in 1905 and 1906 to accommodate forestry and mining activities, removing legal protections from 1,309.30 km^2 (around 1/3 of its original 3,886 km^2) (Runte 1990; Golden Kroner et al. 2016).

In addition to downgrades and downsizes, parcels of land were added to Yosemite National Park in 1905, 1914, 1930, 1932, 1937, and most recently, in 2016. In 1905, 292.7 km^2 of land selected for its aesthetic beauty was added to the Park to offset the first downsize (Golden Kroner et al. 2016). Notably, with the passage of the Wilderness Act (1964), more than half (57%) of the downsized lands were later established as Wilderness Areas in 1964. Today, Yosemite National Park covers an area equivalent to 77% of its original size, with 19% of the originally protected lands now under other forms of protection (Golden Kroner et al. 2016).

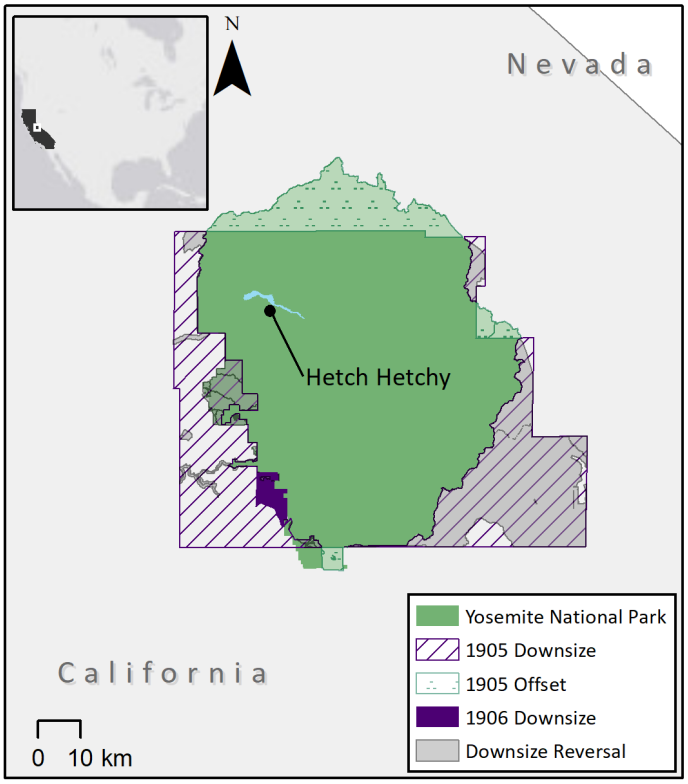

Figure 1. Evolution of Yosemite National Park (USA) boundaries and legal restrictions from 1892 to 2018. Yosemite National Park was repeatedly downgraded (1892, 1901, 1913) to allow construction of roads, facilities, and dams. Yosemite National Park was also repeatedly downsized (1905, 1906) for forestry and mining activities. The downsize in 1905 was partially mitigated by a spatial offset, and partially reversed in 1964. The park was also expanded several times in 1905, 1914, 1930, 1932, 1937, and 2016. From an original size of 3,886 km^2, Yosemite now covers ~2,995 km^2 with another 1,222 km^2 protected (but managed separately) as wilderness areas.

The legacy of the dynamic history of Yosemite National Park is visible on the landscape today. Forests excised from the original Park in 1905 and 1906 and that remain unprotected today are more fragmented by roads than lands within Yosemite National Park or the adjoining Wilderness Areas (Golden Kroner et al. 2016). Conversely, lands that regained protection, even decades later, are less fragmented by roads than lands that remain unprotected today, demonstrating the value of long-term land protection and the potential for reversals of PADDD to contribute to maintaining ecosystem connectivity (Golden Kroner et al. 2016).

2.2 Arabian Oryx Sanctuary

Established in 1994, the Arabian Oryx Sanctuary originally covered 34,000 km^2 of the central desert and coastal hills of Oman (Oman 1994; Al Jahdhami et al. 2011). In the same year, UNESCO designated 27,500 km^2 of the Sanctuary as a World Heritage Site (UNESCO 1994a). The Sanctuary was best known for the free-ranging Arabian oryx (*Oryx leucoryx*) population, which were reintroduced to the region in 1982 following the species' extinction in the wild a decade earlier (Swaisgood et al. 2016). The Sanctuary also sheltered the largest Arabian gazelle (*Gazella arabica*) population (IUCN 2017). Reintroduction of Arabian oryx into the Sanctuary succeeded until the mid-1990s, when poaching severely decreased the wild population (Al Jahdhami et al. 2011).

In 2007, although opposed by the World Heritage Committee, the government enacted a downsizing of the Arabian Oryx Sanctuary by 90% (Oman, 2017).The remaining 2,824 km^2 was renamed as the Al Wusta Wildlife Reserve. Because the downsized area coincided with hydrocarbon concession blocks and the decision did not adequately consider ecological impacts, UNESCO removed the Arabian Oryx Sanctuary from the World Heritage List in 2007 (UNESCO 2007).

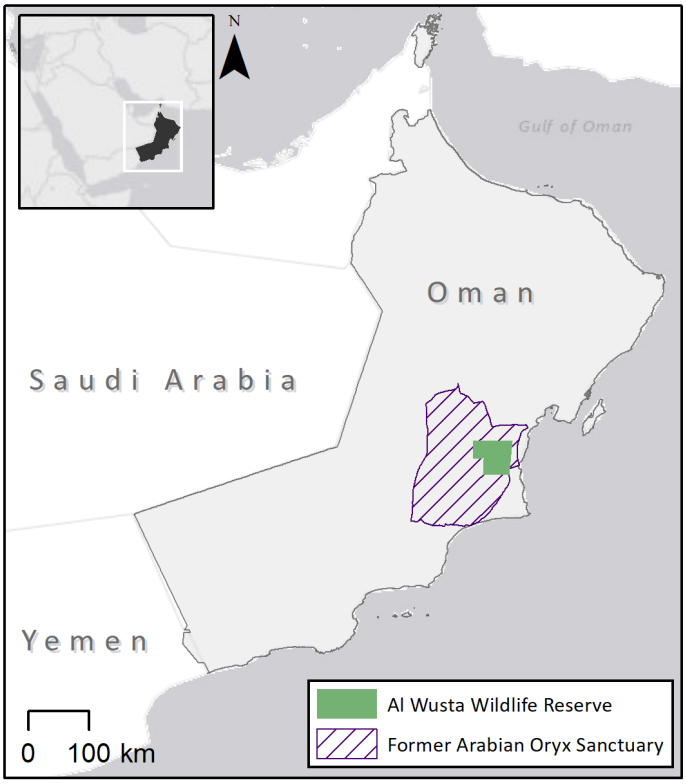

Figure 2. Evolution of Arabian Oryx Sanctuary (Oman) boundaries from 1994 to 2016. The Arabian Oryx Sanctuary was downsized in 2007 for hydrocarbon activities and poaching control. From the original size of 34,000 km^2, the Arabian Oryx Sanctuary (renamed Al Wusta Wildlife Reserve in 2011) now covers 2,824 km^2.

Hydrocarbon activities began in the downsized area after the boundary change (UNESCO 2007; Osti et al. 2011). However, because the wild population of Arabian oryx had already been depleted by poaching, it is unclear whether the downsizing had further negative impacts on the species. The PA management authority later fenced Al Wusta Wildlife Reserve to prevent poaching. Fences also restrict the migration of the wild Arabian oryx population, preventing it from identifying new water sources during drought (Al Jahdhami et al. 2011). Although the total number of Arabian oryx has increased globally, the current wild population in Oman is only around ten individuals. The population density of Arabian gazelle has also declined, likely due to poaching and ranching in the PA (Jahdhami et al. 2017). The future of this PA and the species that it protects remain uncertain.

2.3 Yasuní National Park

Established in 1979, Yasuní National Park (Ecuador) is the most biodiverse place on the planet (Bass et al. 2010). Over the years, the area of the Park has increased from 6,330 km^2 to nearly 10,000 km^2 of Amazonian rainforest (Bass et al. 2010; Figure 3). Estimates show that Yasuní National Park contains over

2,700 vascular plant species, 150 amphibian species, 121 reptile species, 382 fish species, and 596 bird species (Bass et al. 2010). The Park is also home to several indigenous tribes (Finer et al. 2008). Given the global importance of Yasuní for ecological and cultural preservation, UNESCO recognized the Park as a Biosphere Reserve in 1989.

The interplay between demand for oil and both ecological and cultural conservation had shaped the boundaries of Yasuní National Park (Finer et al. 2008). In 1990, the Ecuadorian government downsized the Park by approximately 2,088 km^2 to grant land ownership rights to the Waorani indigenous group (see SI). The downsized area, however, largely overlaps with an oil concession; land titles came with restrictions on indigenous peoples' rights to interfere with oil exploitation (Espinosa 2013). In 1992, the government expanded the boundary of Yasuní to include another 5,985 km^2 (Figure 3).

Rules governing oil and gas exploration and exploitation within the Park have also shifted over time. The Ecuadorian government downgraded the Park at least six times through Ministerial Accords and Resolutions (SI) that authorized oil development-related infrastructure (e.g., seismic lines, exploration platforms, and heliports) within oil concession blocks 16 and 31, both of which partially overlap with Yasuní National Park (Figure 3). In 1999, the President of Ecuador upgraded the protection to the southern part of the Park by designating the 7,000 km^2 Tagaeri-Taromenane Intangible Zone, which legally prohibits industrial-scale resource extraction (Ecuador 1999). In 2007, the government initiated the Yasuní-ITT initiative, which proposed to forgo drilling in Block 31 and the Ishpingo-Tambococha-Tiputini (ITT) oil blocks in exchange for monetary compensation from the international community, given the region's global climate and biodiversity values (Espinosa 2013). However, in 2013, Ecuador repealed the initiative, downgrading 1% of Yasuní National Park to authorize oil drilling. A later amendment reduced the area of drilling to 0.1% of Yasuní National Park (around 10 km^2) (see SI). Subsequently, in 2014, the government signed permits for drilling (Keyman 2015) and, in 2016, the first wells in the ITT block started producing oil (Vidal 2016).

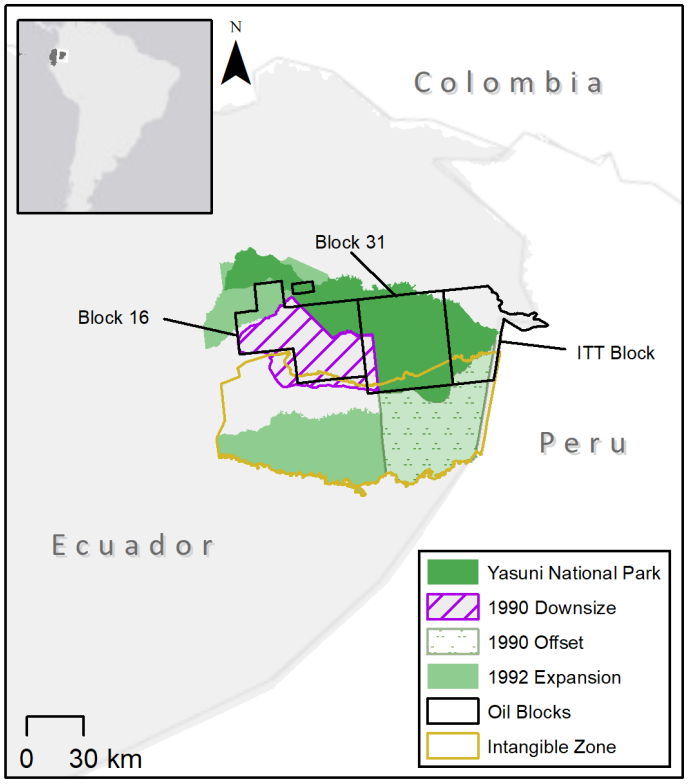

Figure 3. Evolution of Yasuní National Park (Ecuador) boundaries and legal restrictions from 1990 to 2018. Yasuní National Park was repeatedly downgraded in 1992, 1993, 1995, 1997, 2005, and 2006 to authorize oil development-related infrastructure in blocks 16 and 31, and in 2013 to authorize oil drilling affecting 10 km2 of the Park area in the ITT block. The Park was also downsized to remove 2,088 km2 in 1990. The downsizing event in 1990 was mitigated by a spatial offset (adding 2,460 km2) in the same year. An additional 3,177 km2 was added to the Park in 1992. The downgrade events in 1995 and 1997 were reversed in 2007 and 2000. From an original size of 6,331 km2, Yasuní National Park now covers 9,820 km2 (area figures are not reported in any legal documents for Yasuní; values reported are measured in GIS).

Negative environmental impacts have been observed within and adjacent to areas downsized and downgraded for oil extraction and related infrastructure. Demonstrated environmental impacts include contamination from oil and wastewater spills (Finer et al. 2008), deforestation and fragmentation along access roads that enabled new human settlements (Finer et al. 2015), and unsustainable harvest of wildlife fueled by easier access to the market (Suarez et al. 2009). Although the newest downgrade only authorized drilling to occur in 0.1% of the Park, the environmental impact is likely to extend beyond the extraction area (Finer et al. 2008, 2015; Suarez et al. 2009) and may have negative social impacts – including the fragmentation of traditional indigenous territories, health problems, and societal destabilization (Swing et al. 2012). Despite the concerns, new oil drilling activities continue in the recently downgraded areas (Watts 2018). To date, deforestation caused by oil extraction and introduced

settlements in Yasuní National Park is estimated at 4.17 km^2, exceeding the deforestation limit of 3 km^2 as voted upon in a recent Ecuadorian referendum (Thieme et al. 2018).

2.4 Virunga National Park

Virunga National Park, the oldest national park in Africa, was established in 1925. Located on the eastern edge of the Democratic Republic of the Congo (DRC; Figure 4), Virunga National Park covers over 8,000 km^2 of forests, savannas, rivers, lakes, marshlands, active and dormant volcanoes, and permanent glaciers (Inogwabini et al. 2005). The Park is also known for its megafauna, notably elephants (*Loxodonta africana*), buffalo (*Syncerus caffer*), and the largest concentration of hippopotamuses (*Hippopotamus amphibius*) in Africa (Plumptre et al. 2007), as well as more than 200 mammal and 700 bird species (UNESCO 2017b). Within the Park, Lake Edward benefits 50,000 people who directly or indirectly depend upon the fishing industry. (WWF 2013). Virunga National Park earned World Heritage status in 1979 (UNESCO 1979) and joined the Ramsar List of Wetlands of International Importance in 1996 (Ramsar 1996).

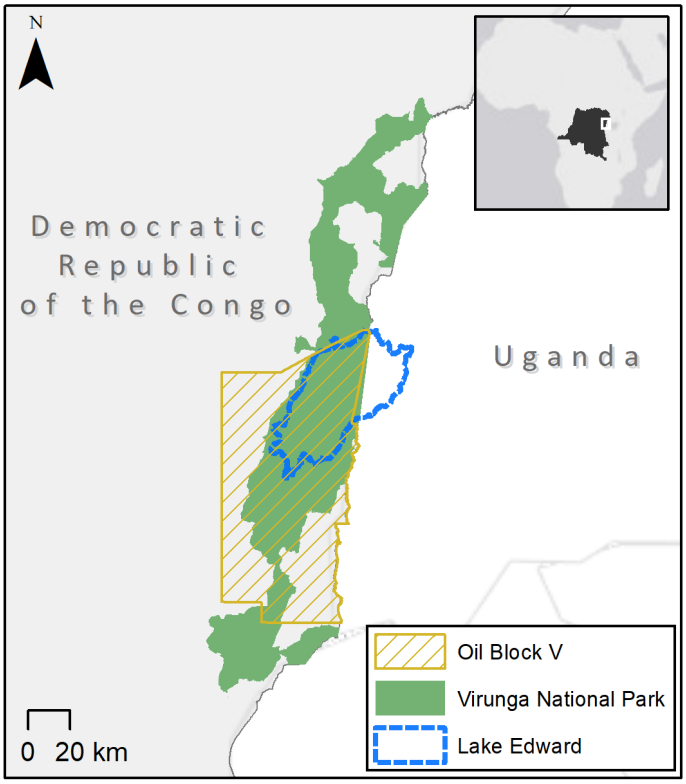

Figure 4. Evolution of Virunga National Park (DRC) legal restrictions from 1925 to 2018. Virunga National Park was partially downgraded (2010), authorizing SOCO International to perform oil exploration activities in oil block V, which overlaps with 3,897 km2 of the Park area. The PADDD event was reversed in 2014 when SOCO International declared that it would cease further involvement with oil block V. In 2015, the Park was downgraded again when the new Hydrocarbon Law made it legally possible to

permit oil exploration or downsize the park for oil exploitation. In 2018, a downgrade covering 1,720 km2 to authorize oil development (location unknown) was proposed.

Since the early 1990s, armed conflicts in and around Virunga National Park have led to poaching and deforestation (UNESCO 1994b). PADDD emerged as a concern in the 2000s, when the government considered allowing access to petroleum resources in the Park. In 2006, the DRC government granted an oil concession for block V to SOCO International (SOCO International 2014). A Presidential Decree in 2010 ratified the contract and approved exploration activities, subsequently downgrading 3,897 km^2 of the Park area that overlapped by the oil block (WWF 2013; SOCO International 2014). SOCO International subsequently conducted a bathymetry survey, a seismic survey, and several geological studies within the Park (SOCO International 2014).

In response to opposition from UNESCO and civil society, SOCO halted oil exploration in Virunga in 2014 and advised the DRC government to downsize the park (Gouby 2015). In 2015, DRC parliament passed the new Hydrocarbon Code (DRC 2015) which states that oil exploration can be authorized within PAs; this constitutes a systemic downgrade of all PAs in the country. The Hydrocarbon Code also made the decommissioning ("déclassement") of PAs legally possible for oil & gas extraction (DRC 2015). In 2018, the government proposed to decommission 21% (1,720 km^2) of Virunga, as well as Salonga National Park, another World Natural Heritage site, to allow oil drilling (Mwarabu & Ross 2018). The future risk of ecological impacts due to PADDD in Virunga National the Park is highly uncertain.

2.5 The Great Barrier Reef Marine Park

Established in 1975, the Great Barrier Reef Marine Park covers an area of 344,400 km^2 along the northeastern coast of Australia. The Park is home to the largest coral reef ecosystem in the world, protecting over half of all hard coral species, one-third of all soft coral species, half of all mangrove plant species, 23% of global seagrass diversity, and six of the world's seven species of marine turtles (GBRMPA 2014). The Park also generates $6 billion annually through fishing, tourism, and other coastal industries, while supporting approximately 69,000 jobs (GBRMPA 2014; Benham 2017). In 1981, UNESCO designated the Park as a World Heritage Site (UNESCO 1981).

In 2004, the Australian government expanded no fishing zones from 5% to 33% of the Great Barrier Reef Marine Park. This upgrade of protection led to substantial gains in fish stocks (Emslie et al. 2015). However, coastal biodiversity in the Great Barrier Reef Marine Park has been threatened by runoff from agricultural and coastal development (De'ath et al. 2012; Benham 2017), including new port developments in response to increased demand for coal exports. In 2013, the Australian government downgraded the Park, allowing dredge spoil from the Abbot Point coal terminal expansion to be dumped within the Park (Department of the Environment 2013). In 2015, after significant opposition from scientists, and civil society, including the possibility that UNESCO would include the Park on the register of World Heritage Sites in Danger, the Australian Government reversed the downgrade and committed to prohibiting future dumping of dredge spoil within the Park (UNESCO 2015). In 2017, the World Heritage Committee decided not to include the Park among the World Heritage Sites in Danger, but noted serious concerns about the health of the reef (UNESCO 2017c).

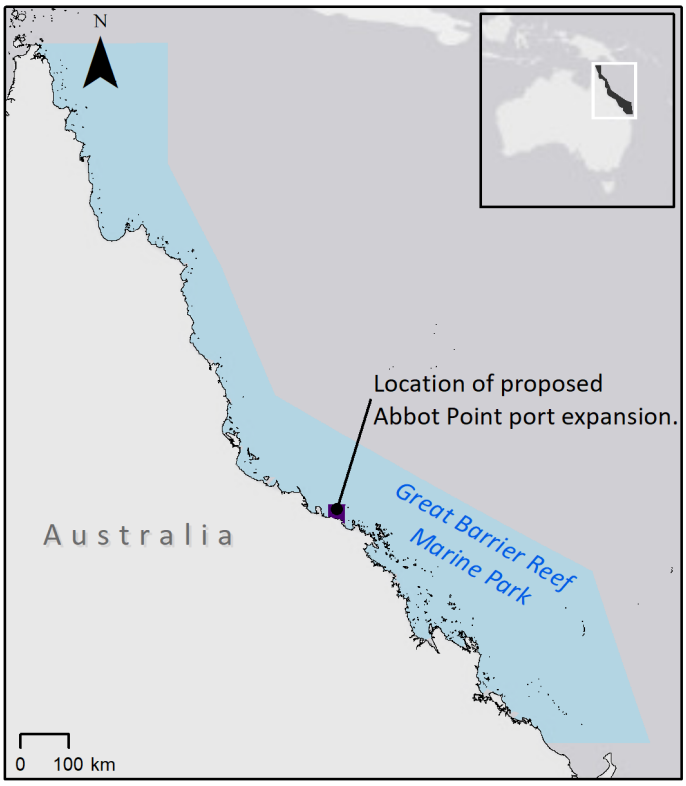

Figure 5. Evolution of The Great Barrier Reef Marine Park (Australia) legal restrictions from 1975 to 2018. The Great Barrier Reef Marine Park was downgraded (2013) to authorize the dumping of dredge spoil from the Abbot Point terminal inside the Park area. The downgrade event was reversed in 2014.

Nevertheless, expansion of the Abbot Point port was approved in 2015 (Australian Government 2015), with dredge spoil to be dumped offshore. An assessment by the Australian Coral Reef Society (Ward et al. 2015) concluded that the process of dredging would have considerable negative impacts on the surrounding seagrass, corals, soft corals, as well as turtles and dugongs (*Dugong dugon*). Given that the health of the Great Barrier Reef is already significantly impacted by coral bleaching and poor water quality (UNESCO 2017c), the expansion of the port could magnify the additional pressures associated with dredging.

Table 2. The history and current status of the five iconic protected areas and the PADDD events

	Yosemite National Park	Yasuní National Park	Arabian Oryx Sanctuary	Virunga National Park	Great Barrier Reef Marine Park
Country	United States	Ecuador	Oman	Democratic Republic of the Congo	Australia
Year Recognized by UNESCO	1984	1989	1994	1979	1981
Year PADDD Enacted (Proposed)	1905, 1906, 1892, 1901, 1913	1990, 1992, 1993, 1995, 1997, 2005, 2006, 2013	2007	2010, 2016, (2018)	2013
Year PADDD Reversed	1964[1]	2000, 2007	NA	2014	2014
Proximate Cause	mining & forestry, roads, transmission lines, dam	oil extraction	oil extraction, poaching control	oil extraction	port development, dredge spoil dumping
Area Gazetted	3,886 km^2	6,331 km^2	34,000 km^2	7,800 km^2	344,400 km^2
Area Removed	1,445 km^2	~2,088 km^2	~31,176 km^2	NA	NA
PADDDed by	Legislation	Ministerial Accords, Ministerial Resolutions, Legislative Resolution, Executive Decree	Royal Decree	Presidential Decree, Hydrocarbon Code	Approval
Re-protected + extended	1,116 km^2	5,577 km^2	NA	NA	NA
Current Size	~2,995 km2	9,820 km2	2,824 km^2	7,800 km^2	344,400 km^2
Example Impacts	higher level of habitat fragmentation in areas PADDDed	oil spills, water contamination, deforestation, fragmentation, social conflicts	limited migration range of Arabian oryx during droughts	threats to biodiversity and local livelihoods	water pollution, high exposure and pressure on seagrass meadows
Current status	expanded in 2016 by 1.62 km^2	oil drilling started on <1% of the park, and may affect larger range	hydrocarbon activities in the downsized areas; remaining area fenced	hydrocarbon law allows PADDD; government considering downsizing for drilling	dumping banned; port expansion next to park approved

[1] Partial reversal of downsizes that occurred in 1905 and 1906. 57% of lands downsized were re-protected as Wilderness Areas.

3. DISCUSSION

PAs are established to "achieve the long-term conservation of nature" (Dudley 2008), yet the five cases (Table 2) demonstrate that even iconic PAs are not immune to PADDD. Notwithstanding ongoing efforts, strategic investment in further research, policy, and capacity development are essential to ensure that PAs can realize their full potential.

3.1. Research priorities

First, more regional and country-level descriptive studies are needed to understand the full extent and history of PADDD. Current efforts, covering 70 countries, provides relatively comprehensive PADDD profiles for only 12 countries (Forrest et al. 2015; Pack et al. 2016; Cook et al. 2017; WWF & Conservation International 2018). Simple comparison of historical versions of PA databases may lead to a large number of false positives (Cook et al. 2017; Lewis et al. 2017), highlighting the need for systematic, in-country archival research. In addition, archival research generate absence data with high confidence, which are essential to understanding PA survivorship rates, impacts, and risks. Further examination of marine PADDD is especially timely in light of a recent wave of PADDD proposals targeting marine protected areas in Australia (Rebgetz 2017; Roberts et al. 2018) and the USA (Milman 2018).

Secondly, gaining a better understanding of the risk of PADDD, including contextual factors that increase or decrease its probability, is a critical area of inquiry. Existing national-level legal frameworks likely affect the rates and causes of PADDD, as they define the activities that are authorized and what changes are legally possible. International laws, such as the West Hemisphere Convention (OAS 1940; Gillespie 2007) may further constrain domestic legal processes on PADDD. Geography, history, and PA characteristics may also shape the vulnerability of PAs to PADDD. For example, larger PAs closer to population centers (Symes et al. 2016) and PAs with higher deforestation rates appear more vulnerable to PADDD (Tesfaw et al. 2018). Other contextual factors, including PA ownership, governance, management objectives, and funding, may play a role in PADDD decisions, which often reflect bargaining between different interests (e.g. PADDD in Virunga NP and Yasuní NP, Tesfaw et al. 2018).

The third key area for research centers on the social and ecological impacts of PADDD. Initial studies indicate that PADDD may accelerate rates of deforestation, carbon emissions, and habitat fragmentation (Forrest et al. 2015, Golden Kroner et al. 2016), but key questions remain unanswered. How does PADDD affect biodiversity outcomes other than forest loss, as well as the surrounding landscapes beyond affected areas? What are the impacts of PADDD on human well-being? How does impact vary by PADDD process and context? Who benefits from PADDD decisions and who loses? For PADDD aiming to address historical conflicts and grant rights to local communities (e.g., Cook et al. 2017), researchers should engage communities living in areas affected by PADDD to examine livelihoods and human rights impacts of PADDD. Future studies may also consider the conservation and development-related costs and benefits of PADDD.

Lastly, further research to understand the impermanence of other conservation interventions (e.g. indigenous reserves, privately protected areas, etc.) can support better design and implementation of

conservation strategies. For example, rates of degazettements of privately protected areas (PPAs) in Australia were lower when approval was required from multiple parties instead of a single party (Hardy et al. 2017). Adapting the PADDD framework to other conservation interventions will broaden our understanding of risks, generate a more complete picture of their durability, and help design more durable and effective conservation strategies.

3.2. Insights for Conservation Legislation and Policy

Although further research is required to more fully explain the patterns, trends, causes, risks, and impacts of PADDD globally, available evidence is sufficient to inform evidence-based policies to address PADDD.

One fundamental area for policy reform is PADDD tracking and reporting. At present, no requirements exist at national or international level to track or report PADDD. Existing tracking systems either overlook PADDD (e.g., World Database of Protected Areas) or have limited capacity or authority for data collection (e.g., PADDDtracker.org). International (e.g. the Convention on Biological Diversity) and national policies that require standardized PADDD monitoring and reporting would be the first step, establishing consensus on tracking PADDD systematically. Governments should report PADDD decisions and proposals at least annually and make historical and proposed PADDD data publicly accessible. Such data would allow development and application of key indicators (e.g. the number and proximate causes of PADDD events, and the number and total area (km^2) of PAs affected by PADDD) for tracking progress towards environmental targets established by CBD and other international conventions.

Another area for reform is the policy processes governing PAs and PADDD. As illustrated in our case studies, PADDD occurs through a variety of mechanisms, including executive orders, judicial actions, PA legislation, and other natural resource legislation (e.g. Hydrocarbon Code). These diverse – and often opaque and ill-defined – procedures can create challenges for reporting and tracking and may lead to decisions perceived as illegitimate. To achieve science-based, transparent, and legitimate decisions, PADDD procedures may mirror the processes for PA establishment. Elements of such procedures may include: 1) approving PADDD through the same or higher legal mechanism or instrument, by the same or higher government body, and 2) requiring comparable levels of scientific assessment and stakeholder consultation as are required to gazette, upsize, or upgrade PAs (Lausche & Burhenne-Guilmin 2011). Meanwhile, restructuring to ensure consistency of other natural resource legislation (e.g., Mining Code, Forest Code, Land Law) and non-legislative mechanisms (e.g., regional zoning plans and development plans) with PA designations and regulations may substantially avoid conflicting decisions on PA status, boundaries, and management criteria. When working with governments to create new PAs, international funding institutions could consider reviewing current legislation for legal threats to the PA system.

The mitigation hierarchy (avoidance, minimization, restoration, and offsetting) can serve as a useful framework for PADDD governance (ten Kate & Crowe 2014). Decision makers could prohibit PADDD for extractive activities in World Heritage Sites (IUCN 2016). When PADDD decisions are unavoidable, it is possible to limit the negative impact by limiting the area PADDDed, adopting low-impact technology, and monitoring approved activities and impacts. Re-protecting PADDDed areas may prevent further damage

(Golden Kroner et al. 2016) and allow restoration. Finally, upgrading, expanding, or creating new PAs with comparable conservation value could be another option to offset the loss of habitat and biodiversity (Lausche & Burhenne-Guilmin 2011; Pringle 2017).

3.3. Capacity Building

Further standardization of methods will enhance capacity to ensure consistent documentation, reporting, and interpretations of PADDD through cases, which enables integrated study and comparative analyses using data collected by different researchers. Examples include several case studies and regional analyses (Bernard et al. 2014; de la Cruz-Hernández et al. 2016; Cook et al. 2017; Mancheno et al. 2017; Rebgetz 2017) following the technical guidelines for PADDD reporting (Mascia et al. 2012).

Comprehensive and interactive training with local researchers will expand the expert network for knowledge sharing and collaboration and help identify research and policy priorities pertinent to the local context. Integrating PADDD training within regional capacity-building workshops on PA management is also an option to deliver important information to PA managers.

Making PADDD data available to the public will facilitate research and engage civil society to link local decisions with the global context (WWF-Australia 2017). Raising awareness of PADDD can enhance the capacity to plan conservation interventions with uncertain futures (Cook et al. 2014) and may help secure PAs under threat of PADDD by exposing proposals to public scrutiny (Correia et al. 2018). Integration of the PADDD concept further into conservation communities will engage more PADDD data providers and users, contributing to expert capacity to report and review PADDD data via PADDDtracker.org and other platforms (e.g., www.ProtectedPlanet.net). Documenting proposed and enacted PADDD events could also shape the risk and impacts of PADDD; public opposition has prevented (e.g., damming of the Franklin River in Australia [Kellow 1989]) or helped reverse (e.g., Great Barrier Reef Marine Park, Virunga National Park) PADDD events.

4. CONCLUSION

PADDD is a global phenomenon affecting even iconic protected areas. With the expansion of PA networks and growing development pressures (Lambin & Meyfroidt 2011; Geldmann et al. 2014; Pouzols et al. 2014; UNEP-WCMC & IUCN 2016; Jones et al. 2018), future conservation success will depend not only on how quickly we conserve new areas, but also on how we maintain the existing conservation estate. PADDD research has provided a more holistic and accurate view of PA conservation progress and has identified emerging conservation challenges. Good governance of PADDD is achievable if we can understand offs implication of PADDD, increase transparency of PADDD decisions, raise awareness, and ensure the accounting of PADDD in reporting processes. Finally, several of our case studies highlight the importance of public engagement around PADDD. Collaboration between academics, policymakers, and civil society is essential to achieve the long-term conservation of nature and sustainable development in a dynamic world.

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APPENDICES

Table S1. Enacted and proposed PADDD events to Yosemite National Park, Arabian Oryx Sanctuary, Yasuní National Park, Virunga National Park, and the Great Barrier Reef Marine Park.

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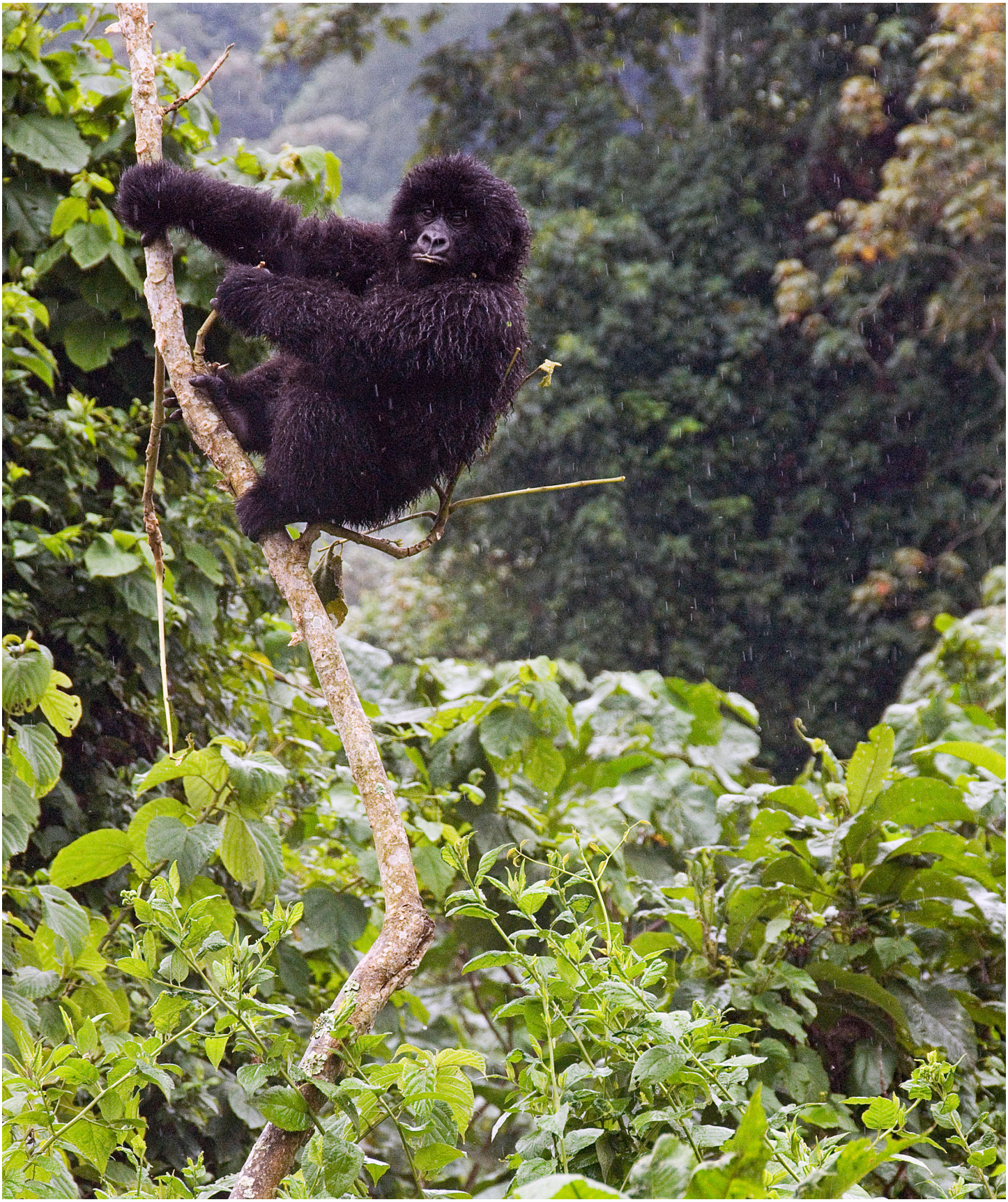
Table S1. Enacted and proposed PADDD events to Yosemite National Park, Arabian Oryx Sanctuary, Yasuní National Park, Virunga National Park, and the Great Barrier Reef Marine Park.

Protected Area	Event Type	Status	Year PADDD	Proximate Cause	Area (km^2) Affected	Year of Reversal	Legal Document
Yosemite National Park (USA)	Downgrade	Enacted	1892	Infrastructure	unknown	N/A	U.S. Statutes at Large, Vol. 27, Chap. 205, pp. 235-36. "An act granting to the County of Mariposa, in the State of California, the right of way for a free wagon road or turnpike across the Yosemite National Park, in the said state."
	Downgrade	Enacted	1901	Infrastructure	unknown	N/A	H.R. 11973 of 1901
	Downsize	Enacted	1905	Forestry	1,403.8	N/A	H.R. 173 of 1905
	Downsize	Enacted	1906	Forestry	41.4	N/A	H.J.R. 118 of 1906; Public Resolution 27 of 1906
	Downgrade	Enacted	1913	Infrastructure	unknown	N/A	H.R. 7207 of 1913
	Downgrade	Proposed	2013	Forestry	unknown	N/A	H.R. 3188 of 2013
Arabian Oryx Sanctuary (Oman)	Downsize	Enacted	2007	Oil and Gas	31,176	N/A	Royal Decree 11/2007
Yasuní National Park (Ecuador)	Downsize	Enacted	1990	Land Claims	2,088.0	N/A	Acuerdo Ministerial No 0191
	Downgrade	Enacted	1992	Oil and Gas	582.8	N/A	Resolución INEFAN No 002, 14 Dec 1992
	Downgrade	Enacted	1993	Oil and Gas	582.8	N/A	Acuerdo Ministerial 153
	Downgrade	Enacted	1995	Oil and Gas	1,049.0	2007	Resolución INEFAN No 005, 08 June 1995
	Downgrade	Enacted	1997	Oil and Gas	582.8	2000	Resolución INEFAN RD No 001, 20 Oct 1997
	Downgrade	Enacted	2005	Oil and Gas	582.8	N/A	Resolución Ministerial No 042, 06 July 2005
	Downgrade	Enacted	2006	Oil and Gas	1,740.0	N/A	Resolución Ministerial No 099, 28 Nov 2006
	Downgrade	Enacted	2013	Oil and Gas	9.8	N/A	Decreto Ejecutivo No 71/2013, Decreto Ejecutivo No 84/2013
Virunga National Park (DRC)	Downgrade	Enacted	2010	Oil and Gas	3,897.0	2014	Ordonnance No. 10/044, 18 June 2010
	Downgrade	Enacted	2015	Oil and Gas	unknown	N/A	Loi n° 15/012 du 1er août 2015 portant régime général des hydrocarbures
	Downsize	Proposed	2018	Oil and Gas	1,720.8	N/A	unknown
The Great Barrier Reef Marine Park (Australia)	Downgrade	Enacted	2013	Industrialization	unknown	2014	DoE Approval (12 Oct 2013) for EPBC 2011/6213



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