Biodiversity risks and safeguards of China's hydropower investments in Belt and Road Initiative (BRI) Countries

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Article

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Abstract

The imperative of a global transition to renewables to achieve net-zero emissions by 2050 calls for an examination of the associated biodiversity risks. Hydropower is the biggest source of renewable energy globally, and its remaining untapped potential is concentrated in low and lower-middle income countries which are also among the world's most biodiverse. China has emerged as a major overseas financier of hydropower dams under its flagship Belt and Road Initiative (BRI). We assess the biodiversity risk posed by planned or under-construction hydropower dams being funded by China in BRI countries and compare it with that of dams being funded by Multi-lateral Development Banks (MDBs) – the other key overseas financiers of hydropower. We find that 48 hydropower dams are being financed by China in 18 BRI countries, likely impacting 14 free-flowing rivers and the ranges of 11 critically endangered freshwater fish species, and 130 km^2 of critical terrestrial habitat(within a 1-km buffer distance). When compared to dams funded by MDBs, Chinese-funded dams are not located in riskier areas for biodiversity, but the total risk is higher due to their preponderance. We find that Chinese regulators and hydropower companies do not specify any enforceable biodiversity impact mitigation requirements. And while MDBs do specify binding safeguards, impacts on river connectivity do not form a part of the mitigation requirements, except in the case of the European Investment Bank (EIB). China is uniquely positioned to adopt a leadership role in specifying safeguards that will help BRI countries adopt an optimum renewable energy mix that minimizes biodiversity risks.

Main

Electricity generation is the leading contributor to carbon emissions globally[1]. Decarbonization of the power sector is seen as imperative to keeping global warming below 2°C, in alignment with the goals of the Paris Agreement[2]. This will require substantial deployment of renewable energy capacity. The International Energy Agency (IEA)'s paradigm-shifting roadmap for net-zero, envisions an 88% contribution of renewables to global power generation by 2050[3,4]. Renewable energy, however, can be associated with significant risks to biodiversity - existing and under-development hydro, wind and solar power plants overlap with hundreds of areas important for conservation[5].

While all renewables can be associated with biodiversity risks[6], hydropower warrants particular attention as it remains the single largest source of renewable energy globally (accounting for 47% of the total installed capacity)[7]. Construction and operation of hydropower dams pose risks to both freshwater and terrestrial biodiversity (Fig. 1). The 10,000+ large hydropower dams that exist in the world today[8] (accounting for 80% of the total reservoir capacity of all dams globally[9]) have dramatically reduced the number of world's Free Flowing Rivers (FFRs), imperiling the biodiversity they support. Over 63% of rivers longer than 1000 km no longer remain free flowing[10]. Also, more than 50% of the world's 397 freshwater eco-regions have been fragmented by dams[11]. In addition, approximately 340 000 km^2 of terrestrial habitat (equivalent to the area of Germany) has been inundated by reservoir impoundment[12].

In their Nationally Determined Contributions (NDCs) under the Paris Agreement, countries have pledged to add 110 GW of cumulative hydropower capacity by 2030[13]. The biodiversity impacts of hydropower are likely to intensify in the future given that most untapped techno-economically feasible hydropower potential[14,15] and most of the 3700+ hydropower projects upcoming globally are concentrated in low and lower-middle income countries (LICs and LMICs) [as classified by the World Bank][16], home to many of the world's biodiversity hotspots[17].

Financiers of hydropower projects are responsible, even if indirectly, for the biodiversity risks posed by the projects they choose to fund[18]. At the same time, they can influence their clients (project developers) to avoid, minimize or mitigate these risks by requiring safeguards as a pre-condition to their investments[19]. Traditionally, investment in hydropower projects in LICs and LMICs was a preserve of western-backed multilateral development banks (MDBs) led by the World Bank Group (WBG)[20]. In the 1990s, MDBs all but retreated from large-scale hydropower in response to mounting civil society concerns over its environmental and social impacts[14,20]. The hydropower financing of the WBG, for example, declined by 90% between 1992 and 2002[21]. Investment from national development banks of upper-middle income countries (UMICs) such as China and Brazil has since replaced MDB financing (in combination with host country government financing) as the predominant mode of hydropower financing in LICs and LMICs[14]. For example, the total overseas hydropower investments by China Development Bank (CDB) and China Exim Bank (CHEXIM) (China's two national development banks, also referred to as policy banks) between 2005 and 2019 was US$25.7 billion[22], which is at least an order of magnitude higher than the hydropower investments of western-backed MDBs during the same period[23]. Although MDBs have re-engaged with hydropower since the turn of the century, it has been with a more guarded approach and a renewed focus on sustainability (Supplementary Information Table 1) – a shift resulting from years of international deliberations through initiatives such as the World Commission on Dams[24] (by the World Bank and IUCN), Dams and Development Project (by UNEP)[25] and Sustainability Assessment Protocol (by International Hydropower Association)[26]. MDBs now have codified good-practice environmental and social safeguards for all the projects they finance[27].

China's overseas hydropower financing was propelled first by its 'Going Out' strategy of 1999 and since 2013, by its flagship overseas infrastructure investment programme, the Belt and Road Initiative (BRI)[28-30]. China's official Belt and Road Portal lists 144 countries as its BRI partners (hereinafter BRI countries)[31]. More recently, some of the investments in BRI countries are also being routed as clean energy funding under South to South climate cooperation initiatives[32]. According to a 2019 Tsinghua University study[33], BRI countries could account for 66% of global GHG emissions by 2050 (up from 28% in 2015), which alone could catapult the world on a 2.7 degree rise pathway. For their emissions to align with a 2-degree scenario, a shift to renewables with an investment of US $1.1. trillion is needed[33]- a transition that Chinese financing can catalyse[34]. Mimicking global trends, China's renewable energy financing in BRI countries has hitherto been dominated by hydropower (being eight times that of wind and solar combined)[22], necessitating an examination of the inherent risks. It is crucial also to examine the safeguards that are applied to mitigate these risks.

China's hydropower investments in BRI countries are potentially governed by a complex landscape of environmental regulation, with several layers of applicable policies, each potentially a source of biodiversity safeguards (Supplementary Information Fig. 1). Policies and laws put in place by host country governments, for example, can act as an important source of biodiversity safeguards. An additional layer of safeguards can also come from Chinese regulators either through BRI-specific policies or through policies regulating overseas financing in general[35]. The environmental policies or broader Corporate Social Responsibility (CSR) policies of hydropower companies sponsoring the projects can also incorporate provisions for biodiversity protection, as can standards or policies adopted by project financiers. A 2020 assessment found that no biodiversity safeguards have been put in place by China's state-owned banks, the key financiers of BRI[19]. However, other potential sources of biodiversity safeguards are yet to be examined.

In this study, we assess the risk (potential impact) to biodiversity posed by future (i.e., planned or under-construction as of 2021) hydropower dams funded by China in BRI countries, and compare the risk with that posed by dams funded by MDBs. Previous risk assessments of China's overseas infrastructure investments (e.g., Narain et al., 2020[19] Hughes 2019[36]and Yang et al., in print[37]) have focused exclusively on terrestrial habitat. We focus on hydropower as a sector, and on impacts on freshwater systems, with a view to inform the global discourse around the renewable energy mix for a net-zero transition. In making an assessment of the biodiversity safeguards being applied to the hydropower projects, our study looks at hydropower-specific impact mitigation measures, setting it apart from previous assessments.

We conducted spatial analysis to assess potential dam impact on three biodiversity indicators: river connectivity status, geographic ranges of threatened freshwater fish species, and critical and natural habitat for terrestrial species (as defined by the International Finance Corporation or IFC[38]). To put this impact into perspective, we assessed if Chinese-funded dams pose higher risk to biodiversity than MDB-funded dams. We then carried out policy analysis to examine the biodiversity impact mitigation measures required by Chinese regulators, hydropower companies and by host country governments, and compared them with those required by MDBs.

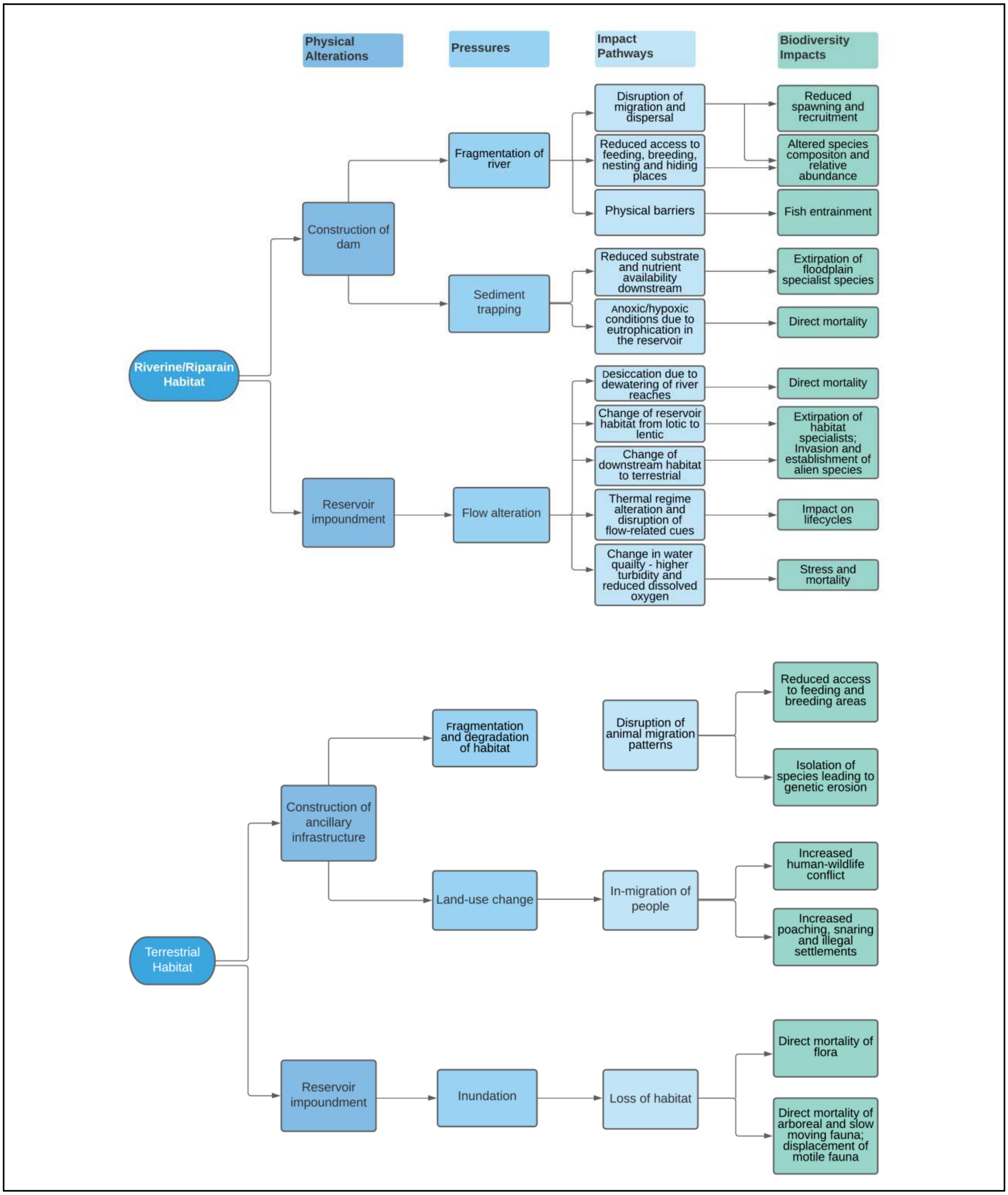

Fig. 1. Impacts of Hydropower Dams on riverine and terrestrial biodiversity [6,9,10]. Figure made by authors

Results

China and MDB funded dams in BRI Countries

We identified a total of 48 future (planned or under-construction as of 2021) hydropower dams funded by China in BRI countries (Fig. 2, Table 1 and Supplementary Information Table 2) and 16 dams funded by the six western-backed MDBs (Fig. 3, Table 1 and Supplementary Information Table 3). Fewer than half (43%) of the identified Chinese-funded dams were financed by its state-owned banks (including both policy banks and commercial banks such as ICBC) and the remainder by Foreign Direct Investment (FDI) from China's hydropower companies. More than 70% of identified Chinese-funded hydropower projects were found to be concentrated in Myanmar, Laos and Pakistan and more than 60% on the Irrawaddy, Mekong and Indus rivers. From a regional perspective, the Chinese-funded dams were found to be concentrated in northern mainland South East Asia, the Tibetan plateau and Himalayas, each region overlapping with several biodiversity hotspots[17]. A total of 18 hydropower companies were identified as the sponsors of the Chinese-funded dams through FDI (Supplementary Information Tables 10 & 16).

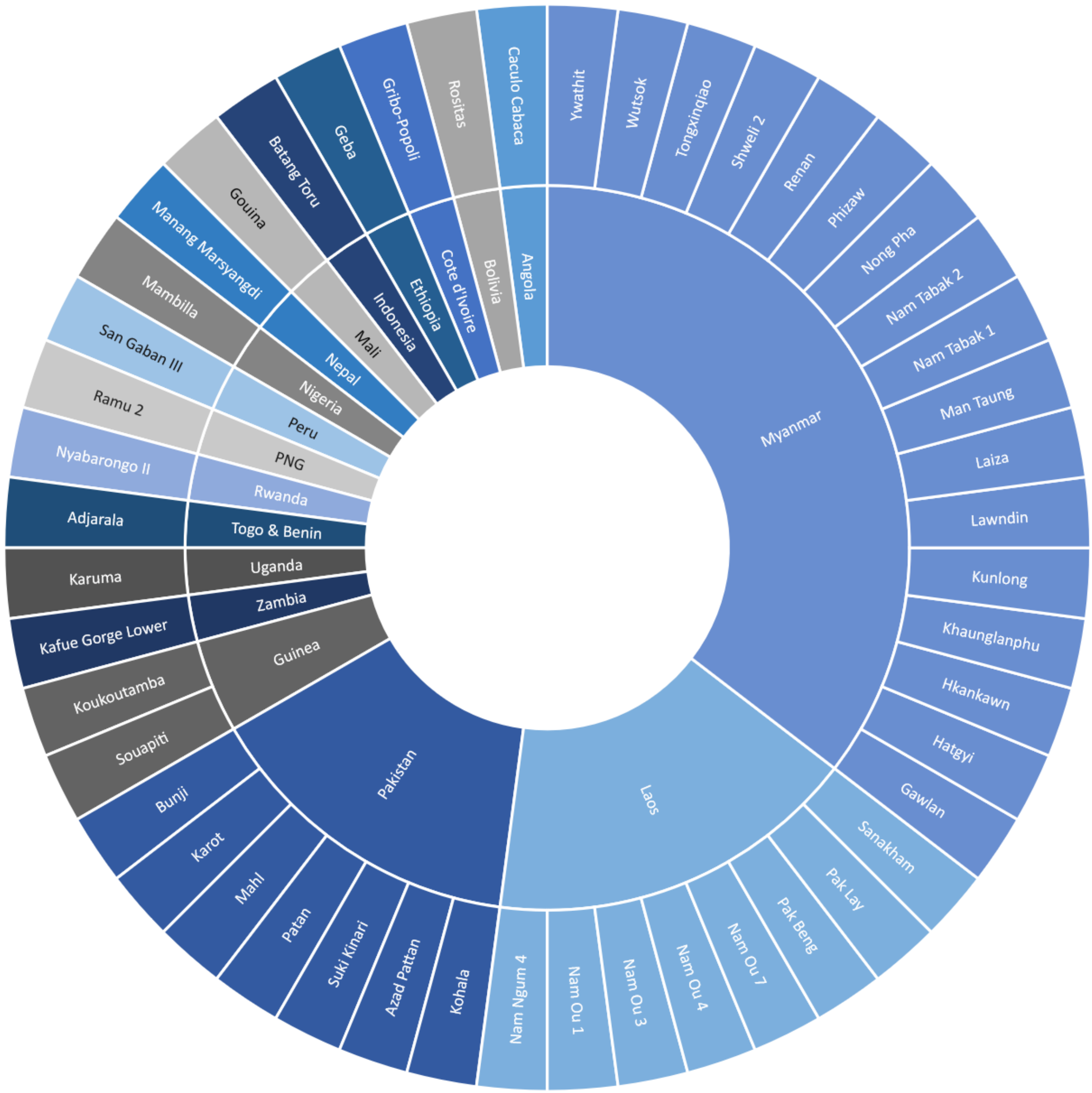

Fig. 2. Future Chinese-funded Dams in BRI Countries. The outermost circle represents names of dams and the inner circle the names of countries where they are being built

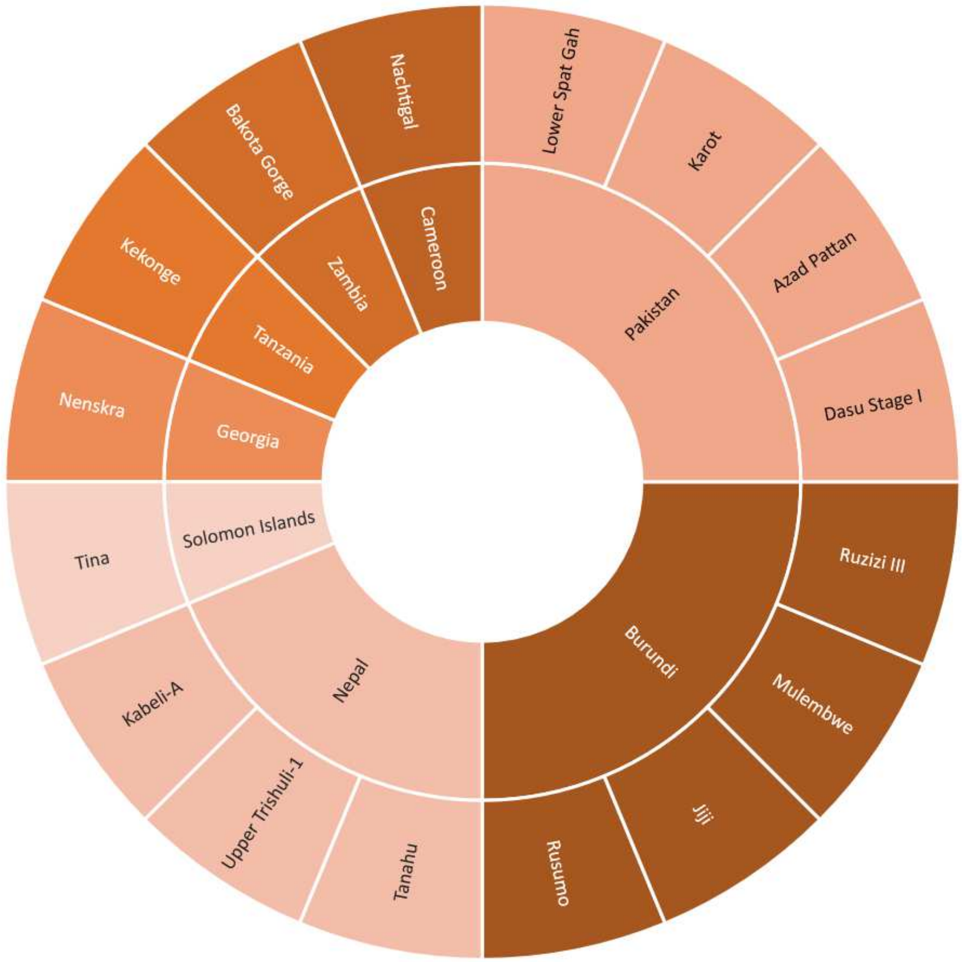

Fig. 3. Future MDB-funded Dams in BRI Countries. The outermost circle represents names of dams and the inner circle the names of countries where they are being built

Biodiversity Risks

Risk to Free-flowing Rivers

The identified Chinese-funded dams were located on (and thereby potentially impact) 26 rivers, of which 14 (54%) are free-flowing. Three of the impacted free-flowing rivers are among those classified as long (500 km to 1000 km) or very long (>1000 km) globally (as per Grill et al., 2019[10]). The 16 MDB-funded dams potentially impact 14 rivers, eight (57%) of which are free-flowing. However, none of the impacted free-flowing rivers are long or very long in case of MDB-funded dams. No statistically-significant difference was found between the average (per dam) number of free-flowing rivers impacted by Chinese-funded dams (0.3) and those impacted by MDB-funded dams (0.5) (Fig. 4, Table 1 and Supplementary Information Tables 2-4).

Risk to Threatened Freshwater Fish

The identified Chinese-funded dams overlapped the geographic ranges of (and potentially impact) 73 threatened freshwater fish species. Eleven (15%) of these species are critically endangered (CR), including the iconic Mekong catfish (*Pangasianodon gigas*) and the giant barb (*Catlocarpio siamensis*), world's largest carp species. The identified MDB-funded dams potentially impact 49 threatened freshwater fish species, 14 of which are critically endangered (CR). No statistical difference was found between the average (per dam) number of threatened species impacted by Chinese-funded dams (0.23) and those impacted by MDB-funded dams (0.88) (Fig. 4, Table 1 and Supplementary Information Tables 4-8).

Risk to Terrestrial Critical and Natural Habitat

In terms of the terrestrial habitat potentially impacted, the identified Chinese-funded dams have 130 km^2 of critical and 102 km^2 of natural habitat located in close proximity (1-km buffer distance), while MDB-funded dams have only 28 km^2 and 31 km^2 located in close proximity. The difference between the average (per dam) area of critical habitat potentially impacted (2.71 km^2 for Chinese-funded dams and 1.75 km^2 for MDB-funded dams within 1-km buffer distance) however was again found to be statistically insignificant. Similarly, there was no significant difference in the average area (per dam) of natural habitat occurring within 1 km of Chinese-funded dams (2.13 km^2) and of MDB-funded dams (1.94 km^2) (Fig. 4, Table 1 and Supplementary Information Tables 2-4).

Dam-wise Biodiversity Risk

In terms of dam-wise risk, it was seen that out of the 48 Chinese-funded dams identified, 27 are located on free-flowing rivers, 11 overlap the ranges of critically-endangered freshwater fish species and 21 are located in close proximity to critical habitat (1-km buffer distance). While no Chinese-funded dam potentially impacts all three critical indicators, almost 38 impact at least one indicator, while 21 impact two indicators (Supplementary Information Table 2). Out of the 16 MDB-funded dams identified, eight are located on free-flowing rivers, eight overlap the ranges of critically-endangered freshwater fish species and four are located in close proximity to critical habitat (1-km buffer distance). While no MDB-funded dam potentially impacts all three critical indicators, almost 14 impact at least one indicator, while six impact two indicators (Supplementary Information Table 3).

Table 1. Biodiversity risk (potential impact) posed by hydropower dams to various biodiversity measures

	No. of Dams	River Connectivity		Number of threatened freshwater fish species ranges impacted				Terrestrial habitat impacted (within different buffer distances)					
		No. of rivers impacted	No. of free-flowing rivers impacted	Total	CR	EN	VU	Critical Habitat			Natural Habitat		
								Area (km^2)			Area (km^2)		
								1 km	2.2 km	9.2 km	1 km	2.2 km	9.2 km
Chinese-funded (Total)	48	26	14	73	11	11	51	130	555	7577	102	570	10560
MDB-funded (Total)	16	14	8	49	14	12	23	28	88	1037	31	128	2424
Chinese-funded (per dam)		0.54	0.30	1.52	0.23	0.23	1.06	2.71	11.56	157.85	2.13	11.88	220
MDB-funded (per dam)		0.88	0.50	3.06	0.88	0.75	1.44	1.75	5.50	64.81	1.94	8.00	151
p-value			0.84	0.4				0.3	0.07	0.03	0.7	0.15	0.06

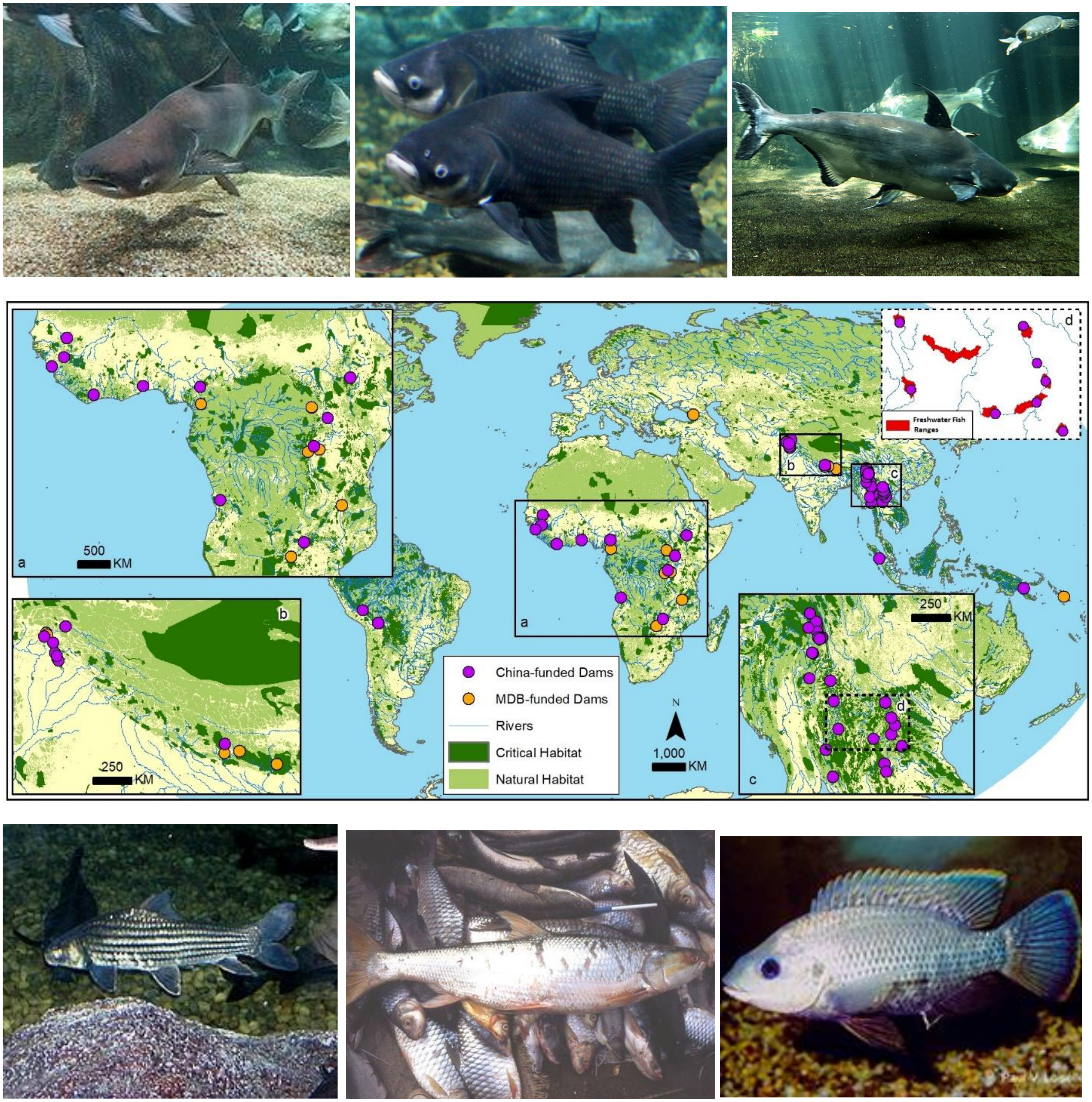

Fig. 4. Chinese and MDB-funded Dams Overlaid on Biodiversity Features. The photographs show critically endangered (CR) freshwater fish species impacted by Chinese-funded dams (clockwise from top left): Mekong catfish (*Pangasianodon gigas*), the giant barb (*Catlocarpio siamensis*), the giant pangasius (*Pangasius sanitwongsei*), Jullien's golden carp (*Probarbus jullieni),* the giant salmon carp (*Aaptosyax grypus*) and Victoria tilapia (*Oreochromis variabilis*) (Images sourced from Wikimedia Commons)

Biodiversity Safeguards

Chinese regulator and hydropower company biodiversity safeguards

We identified 16 Chinese regulator policies that fell in three broad categories: (1) BRI-specific policies, (2) guidelines on overseas investment focused on environmental protection as well as guidelines on green credit applicable to overseas investments, and (3) guidelines issued by industry associations applicable to overseas investments (Supplementary Information Table 9). While out of the 16 identified policies, 11 (70%) included a vision or plan for biodiversity protection, only two policies (12.5%) ("Guidelines on Environmental Protection for Foreign Investment and Cooperation" issued by the Chinese Ministry of Commerce (MOFCOM) and Ministry of Environmental Protection (MEP) and the "Guidelines of Sustainable Infrastructure for Chinese International Contractors" issued by China International Contractors Association) have project-level biodiversity impact assessment and mitigation guidelines. None of the identified policies specify any binding requirements on biodiversity impact assessment and mitigation (Supplementary Information Table 9).

Out of the 18 hydropower companies assessed in the study, 11 (60%) have published environmental policies or have environmental provisions in their CSR policies. Out of these, nine hydropower companies including industry heavyweights such as PowerChina, HydroChina, China Three Gorges, China Gezhouba and China Huadian have set out intentions for biodiversity/ecological protections. However, none of the 18 companies offer guidelines or binding requirements on biodiversity impact assessment and mitigation (Supplementary Information Table 10).

Host country policies

The assessed future Chinese-funded dams are being implemented in 18 BRI countries, for which 'stage of biodiversity offsetting policy development' was recorded from the GIBOP database (last updated Nov 2017). Out of 17 BRI countries examined (1 country did not feature in the GIBOP database), four countries had the score of '3' which means that they have provisions in place for regulatory biodiversity offsetting, while six countries had the score of '2', which means they have an enabling regulatory environment for voluntary biodiversity offsetting, while in the remaining seven countries biodiversity offsetting policy was found to be nascent or absent (scores 1 or 0). The top three recipients of China's dam financing (in terms of number of dams financed) Myanmar, Laos and Pakistan each had a score of 2, meaning that they have an enabling environment for policy development (Supplementary Information Table 11).

MDB Biodiversity Safeguards

All six western-backed MDBs except ADB were found to have dedicated biodiversity standards (ADB has biodiversity impact mitigation requirements embedded within its broader safeguard policy) (Supplementary Information Table 12). The biodiversity safeguards of all MDBs, except ADB and AfDB, are aligned with IFC PS6, which itself specifies detailed mitigation requirements centred around the Mitigation Hierarchy and based on whether the proposed project poses a risk to modified, natural and critical habitat. All MDBs (including those that don't follow IFC PS6) only capture impact on broader biodiversity elements such as threatened ecosystems and species, as embodied in the criteria for identifying natural and critical habitat. None of the MDB safeguards, except those of EIB, have requirements specific to impact on river connectivity. The mitigation measures specific to riverine habitat specified by all other MDBs exist in the form of guidelines (Supplementary Information Table 13).

Discussion

Our study found that future Chinese-funded dams in BRI countries are likely to impact 14 free-flowing rivers. Free-flowing rivers flow unimpeded by human alteration, retaining their natural ecosystem function and processes[10], and are the freshwater equivalents of intact forest ecosystems[39]. The proverbial ‘first cut’, into intact ecosystems disproportionately and irreversibly erodes the biodiversity they harbour[40] and therefore must be avoided if intactness is to be preserved[39]. We also found that future Chinese-funded dams in BRI countries are likely to overlap the geographic ranges of 11 fish species that are listed as Critically Endangered (CR) by the IUCN Red List, an indicator of their high degree of ‘vulnerability’ to threatening processes[41]. The disruption of river connectivity caused by dams are likely to push them closer to the brink of extinction. Finally, we found that Chinese-funded dams will likely impact 130 km^2 (equivalent to the area of San Francisco) of critical terrestrial habitat – irreplaceable sites that will be exposed to the threats of inundation and fragmentation triggered by the dams.

In terms of the relative risk of Chinese financing, our results show that China outstrips MDBs as an overseas financier of hydropower projects in BRI countries, having financed three times as many dams. The large number of Chinese-funded dams translates into higher overall biodiversity risk posed by them. However, even though their overall biodiversity footprint is higher, we find that Chinese-funded dams are not, on average, located in riskier locations than are MBD-funded dams. The increasingly stronger presence of China in BRI countries coupled with the global attention BRI has garnered in the recent years could explain the elevated scrutiny that Chinese investments are facing (e.g., [42]).

Concerningly, however, Chinese regulators and hydropower companies were not found to specify any enforceable biodiversity impact mitigation requirements. And while MDB financing is filtered through binding biodiversity safeguards, impact on river connectivity status - an important determinant of the health of riverine ecosystems and species – does not form a part of their mitigation requirements except in the case of European Investment Bank (EIB). In case of all other MDBs, such considerations have been relegated to non-binding guidance. Our results reveal that more Critically Endangered (CR) and Endangered (EN) freshwater species (both absolute and per dam) are at risk from MDB-funded dams than from Chinese-funded dams, while the critical habitat and natural habitat (both absolute and per dam) at risk from MDB-funded dams is less than that at risk from Chinese-funded dams. While the latter finding could be ascribed to the terrestrial habitat-focused safeguard requirements of MDBs, the former finding points to the lack of riverine habitat specific requirements of MDBs.

Domestically, China has experienced first-hand the consequences of development without adequate environmental safeguards, in response to which it has embarked on a new development paradigm of ‘ecological civilization’, which envisions a future in which humanity lives in harmony with nature[43,44]. In 2011, China also launched the Ecological Conservation Red Line (ECRL), an initiative towards protecting ecologically-important areas covering a quarter of its landmass[45]. More recently, in 2020, China made the much-lauded commitment to achieve net-zero carbon emissions by 2060[46]. These commitments throw into sharp relief the risks of

China's overseas hydropower investments and beg the question of whether its domestic environmental policy reforms will also extend to its outbound investments.

As their biggest international hydropower financier, China is uniquely positioned to adopt a leadership role in specifying biodiversity safeguards for the projects it funds in BRI countries and over the long term, to foster such policy adoption by regulators of these countries. With initial exploration of policy options or provisions already in place to facilitate voluntary mitigation (as evidenced by our study), a majority of BRI countries have an enabling regulatory environment for evolving policies on hydropower-specific biodiversity impact mitigation. A wealth of guidance on the siting, design and operations that has emerged from international multi-stakeholder forums can inform such policies.

Aligned with the objectives of EU's Water Framework Directive (WFD)[47], EIB's safeguard requirements offer a useful template. Similar to the objectives of 'no net loss' or 'net gain' of biodiversity in critical and natural habitats embodied in IFC PS6 (and in many other MDB safeguards), EIB (in adherence to WFD) requires a project to achieve for 'good status' for water bodies and to ensure that 'no deterioration in status' has occurred. In addition, EIB requires the consideration of 'not just the footprint of the reservoir or project infrastructure (powerhouses, roads, transmission lines, etc.), but also downstream water and sediment flow and/or water quality effects, aquatic habitats in river reaches upstream and migratory species throughout their range', casting a wider net for the assessment and mitigation of impacts. Project proponents are also required to make provisions for appropriate downstream 'environmental flow' releases (EFR) and mitigation measures such as 'fish passages' for freshwater biodiversity[48].

However, project-level assessment and mitigation are often not sufficient to fully safeguard biodiversity. When several projects have been planned in a basin or region, which is the case in China's hydropower investments in BRI, a project-centric approach presents many limitations – not only does it fail to take into account cumulative and transboundary impacts, it also limits the options for avoidance (alternative siting or rejection of the project) as most of decisions have already been made [49,50]. To overcome such limitations, international initiatives such as the World Commission on Dams (WCD) (led by World Bank and the IUCN) and EU's Water Framework Directive (WFD) recommend a basin/region-wide planning approach to arrive at a configuration of projects that optimizes risks and benefits across economic, social and environmental values. According to our findings, 38 Chinese-funded dams potentially impact at least one indicator of biodiversity included in the study, while 21 impact two. Being the common denominator across these projects, China is at the vantage point to carry out a system-scale high-level needs and alternatives assessment to determine whether each dam is indeed an appropriate response to a verified need - a key recommendation of WCD's Dams and Development framework - and whether other alternatives such as wind or solar could meet the energy needs with lower risks.

IEA's landmark 'Net Zero by 2050' roadmap positions hydropower as a key 'dispatchable' technology providing the necessary flexibility for a clean-energy transition[4]. While solar and wind account for half of the global power generation in IEA's 2050 scenario, hydropower has been envisaged as the third-largest source, accounting for 12% and requiring a doubling of installed capacity[4]. This doubling of capacity will not come without a cost to global biodiversity – it is likely to further threaten the already-imperilled freshwater biodiversity. According to

WWF's 2018 Living Planet Index Report, between 2007 and 2014, there was an 83% decline in the populations of freshwater vertebrate species, far more precipitous than the drop for terrestrial or marine species during the same period [51]. Freshwater fishes have also had the highest rate of extinctions of all vertebrates over the last century [52]. The 3700+ future (under-construction or planned as of 2015) hydropower dams are likely to impact 25 out of the 120 large river systems [as defined in Nilsson et al., 2005 [53]] [16] and increase the fragmentation of river volume globally from 48% to 93% [54]. They are also likely to reduce the geographical range connectivity of freshwater fishes occurring in the tropics by 20-40%[55]. Moreover, 14% (590) of these future dams are located in Protected Areas[56].

The biodiversity risks posed by hydropower create a conflict between the biodiversity conservation targets the world will likely adopt as a part of the post-2020 Global Biodiversity Framework[57] (during the Convention on Biological Diversity COP 15, hosted by China) and the carbon emissions targets that have been agreed upon in the Paris Agreement[2]. It is only when the focus is shifted from 'building the dams right' to 'building the right dams' in the first place, that an optimal renewable energy mix for BRI countries can be achieved - the one which minimizes biodiversity risks while maximizing avoided emissions, thereby reconciling the competing objectives of biodiversity conservation and climate change mitigation.

Methods

We adopted a step-wise methodology for assessment of biodiversity risks and safeguards of hydropower dams in BRI countries (Fig. 5).

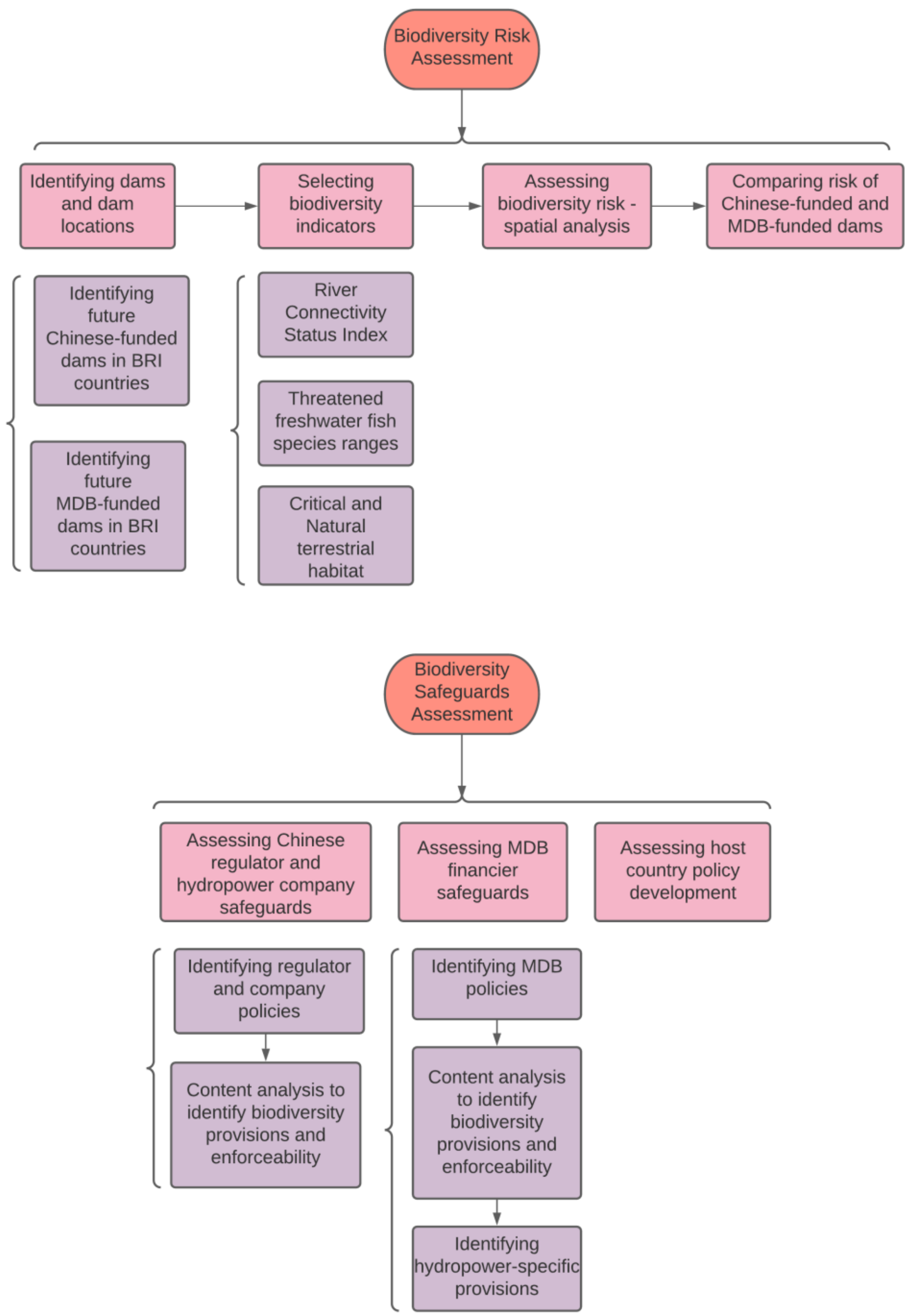

Fig. 5. Step-wise methodology of the study

Biodiversity risk assessment

We first examined the biodiversity risk (potential impact) of future MDB and Chinese-funded hydropower dams. To do this, we collated a list of planned or under-construction hydropower dams funded by China and those funded by MDBs in BRI countries and accessed data on their locations. We then used data on key indicators of biodiversity to identify the spatial overlap of the identified dams with important biodiversity. These steps are described in detail below.

Identifying dams and dam locations

<u>Identifying future Chinese-funded dams in BRI countries</u>

China has not released an official list of BRI projects[58]. Therefore, we included all future hydropower projects financed by China in BRI countries in our study. To identify these projects, we used secondary databases of China's overseas finance (listed in Supplementary Information Table 14) developed by centres of China studies at prominent universities such as Boston University and Johns Hopkins University. These databases (e.g., China's Global Energy Finance Database[22] and China's Global Power Database[59]) list overseas infrastructure projects (including hydropower projects) financed by China.

Using these databases, we collated a universal list of overseas hydropower dams funded by China (Supplementary Information Table 15). Next, for each dam in the universal list, we searched information on seven attributes: name of country, name of river, name of basin (river system), Chinese financier or hydropower company sponsor, completion status (planned, under-construction or complete) and feasibility evaluation status (for planned dams) using Google (example search string: <dam name> AND (feasibility study OR report)). These attributes were used to shortlist ‘future Chinese-funded dams in BRI countries’ (Supplementary Information Table 16). Dams meeting the following criteria were included in the shortlist:

1) ‘future dams’ – as per the definition of future dams used in Zarfl et al., 2015[16], we included dams (> 1 MW) under-construction or planned as of 2021, with planned dams having at least finished the ‘feasibility evaluation stage’. Joint Venture projects that had finished the Memorandum of Agreement (MoA) stage were included. An MoA is made only after feasibility evaluation is completed[60]. Dams that were in an early stage of development e.g., MoU or pre-feasibility were not included as per Zarfl et al., 2017[16]. Dams already completed were excluded as most of the biodiversity impact in such cases would already have accrued.
2) ‘Chinese-funded dams’ i.e., those funded either by Chinese banks (policy banks or commercial) or by Chinese hydropower companies (through FDI involving Joint Ventures with local firms) were included. Dams where Chinese companies acted only as Engineering Procurement Construction/Built-Operate-Transfer (EPC/BOT) contractors were excluded as this study focuses only on dams financed by China.
3) ‘dams in BRI countries’ i.e., dams located in one of the 144 partner countries listed on China’s official Belt and Road portal (as of end of Oct 2020)[31] were included

Next, for each of the shortlisted ‘future Chinese-funded dam in BRI countries’, the spatial coordinates were obtained from their respective Wikipedia pages as well as from two geolocated databases: ‘Future Hydropower Reservoirs and Dams (FHReD) Database[61]’ and ‘AidData's Geocoded Global Chinese Official Finance, Version 1.1.1[62]’.

Identifying future MDB-funded dams in BRI countries

For identifying dams funded by MDBs, we used the project disclosure websites of all six western-backed MDBs[63] i.e., the World Bank Group (including IFC), African Development Bank (AfDB), Asian Development Bank (ADB), Inter-American Development Bank (IADB), European Investment Bank (EIB), European Bank for Reconstruction and Development (EBRD)[64-70]. Each disclosure website has a searchable list of all the projects financed by the MDB. Searches with keywords 'hydropower' and 'dams', yielded a list of hydropower dams funded by the MDB. The exercise was carried out for all six MDBs and the names of dams and other metadata such as 'name of country' and 'status (i.e., completed or active)' were recorded. Only dams which are located in BRI countries and are 'active' were shortlisted. Next, the dams that had not completed the feasibility stage were excluded from this shortlist. The information on the feasibility assessment status of each dam was searched using Google (search string used: <dam name> AND (feasibility study OR report)). Dams where both China and MDBs were acting as co-financers were included in both the Chinese-funded and the MDB-funded lists.

Biodiversity Indicators

To examine the risk posed by dams, we used three indicators of biodiversity: river connectivity status, geographic ranges of threatened freshwater fish species, and critical and natural terrestrial habitat (Table 2).

Table 2. Biodiversity Indictors for Risk Assessment of Hydropower Dams and associated spatial datasets			
	Indicator	**Measure of Biodiversity Impact**	**Spatial Dataset**
Riverine/ Riparian Biodiversity	River Connectivity Status Index (CSI)	No. of rivers on which dams are located	Map of the World's Free Flowing Rivers [10]
		No. of free-flowing rivers on which dams are located	
	Threatened Fish species ranges	No of CR species whose ranges coincide with dam locations	Geographic range maps from IUCN Red List [71]
		No of EN species whose ranges coincide with dam locations	
		No of VU species whose ranges coincide with dam locations	
Terrestrial Biodiversity	IFC Critical Habitat	IFC Critical Habitat occurring within circular buffers of radii 1 km, 2.2 km and 9.2 km	Global map of terrestrial Critical Habitat [72]
	IFC Natural Habitat	IFC Natural Habitat occurring within circular buffers of radii 1 km, 2.2 km and 9.2 km	Global map of terrestrial Natural Habitat [73]

River Connectivity Status Index

Dams (and associated reservoirs) can imperil riverine biodiversity by affecting river connectivity[10]. Dams fragment rivers, and impoundment of water in reservoirs alters downstream flow (Fig. 1). We used river Connectivity Status Index (CSI) to assess the potential impact of dams on river connectivity. Developed by Grill et al.[10], river CSI captures five pressure factors (1) river fragmentation (2) flow regulation (3) sediment trapping (4) water consumption and (5) infrastructure development in riparian areas and floodplains (four of these correspond to pressures outlined in Fig. 1). CSI values range from 0% to 100% and are used to classify rivers as free-flowing (CSI≥ 95% over the entire length) and non-free flowing (CSI < 95% over the entire length). Grill et al., 2019[10] have carried out a high-resolution spatial assessment of CSI for 12 million km of rivers globally. We used these data from Grill et al. 2019, to assess the potential impact of dams.

Threatened freshwater fish species ranges

The second indicator we used for the assessment of potential impact of dams was the geographic ranges of threatened freshwater fish species. Freshwater fish are the most diverse and the most threatened of freshwater taxa[74]. We used geographic range maps of fish species of class Actinopterygii (the class that covers 99% of described fish species) in all threat categories viz., vulnerable (VU), endangered (EN) and critically endangered (CR) from the IUCN Red List website[71].

IUCN fish species ranges have been mapped to WWF's HydroBASINS, which is a series of polygon layers depicting river basin and sub-basin boundaries at the global-scale[75,76]. We converted the IUCN maps to sub-basin (level 8) of the hierarchically-nested HydroBASINS layer as per He et al., 2018[75] and Jaric et al., 2019[77]. We used IUCN's range maps (despite criticisms of their limited certainty[75]) because of the granularity they provide (sub-basin level) instead of other fish distribution datasets (e.g., Tedesco et al.,2017[74]) which are coarser in resolution (river basin level).

Critical and natural terrestrial habitat

We used critical and natural terrestrial habitat as described by the International Finance Corporation (IFC)[38] as indicators for assessing potential impact of dams on terrestrial biodiversity. IFC's widely-applied biodiversity safeguard standard, Performance Standard 6 (PS6), requires borrowers to determine whether the project poses a risk to modified habitat, natural habitat or critical habitat. Areas that largely retain the main characteristics of its native ecosystem qualify as 'natural habitat' whereas areas that have been substantially altered by human activities are classified as ‘modified habitat’. ‘Critical habitat’ is defined as that containing high biodiversity values such as threatened, endemic, congregatory and migratory species, threatened or unique ecosystems, and key evolutionary processes[38] and is considered an irreplaceable element of biodiversity[78]. Critical habitat is a subset of natural and modified habitat i.e., areas of natural and modified habitat that contain high biodiversity values are classified as critical (referred to as ‘critical natural’ and ‘critical modified’ habitat, respectively). (Supplementary Information Figure 2). Critical habitat encompasses sensitive areas such as Protected areas, Key Biodiversity Areas, ranges of threatened terrestrial species and key threatened ecosystems[72]. Projects impacting on natural and critical habitat are subjected to mitigation requirements by IFC[38].

For spatial data on critical habitat, we used the global map of terrestrial critical habitat developed by Brauneder et al., 2018[72]. This layer has been developed using spatial datasets of 12 biodiversity features (e.g., Protected Areas, Key Biodiversity Areas, Red List Threatened Species etc.) corresponding to the relevant IFC PS6 criteria for critical habitat. For spatial data on natural habitat, we used the natural habitat map developed by Gosling et al., 2020.[73] The map is based on five spatial datasets corresponding to IFC PS6 criteria for natural habitat combined with the Human Footprint layer[79]. Gosling et al., 2020 take areas with human footprint <4 as ‘natural’ or ‘low disturbance’ to capture the criterion of level of anthropogenic modification (habitat state) embodied in IFC’s definition of natural habitat.

Assessing Potential Impact: Spatial Analysis

We took the overlap with or proximity of dam locations with spatial data of the identified indicators as a measure of the potential biodiversity impact of future Chinese-funded and MBD-funded dams (Table 2).

For each identified dam, we extracted:

1) The CSI of the river on which a dam is located – to determine whether the river potentially impacted is free-flowing or non-free-flowing
2) The number of threatened fish species (VU, EN and CR) occurring in (and potentially impacted) the sub-basin in which a dam is located
3) The area of critical and natural terrestrial habitat occurring in three buffer zones (concentric circles around point locations) of dams, representing the estimated area potentially impacted by each dam both by reservoir inundation and by fragmented/degradation caused by ancillary infrastructure. The buffer distances were based on actual data on reservoir areas from Global Reservoir and Dam Database (GRanD) v 1.3[80], a global database of 7000+ existing dams. We took 10th percentile, 50th percentile, and 90th percentile of the reservoir areas (after excluding small dams i.e., <15m and small reservoirs < 2 km^2 to ensure parity with dams being assessed in this study). This gave us reservoir areas of 3.2 km^2, 15.9 km^2, and 265 km^2, equating to buffer radii of 1 km, 2.2 km, 9.2 km (10th, 50th and 90th percentile were taken instead of 25th, 50th and 100th percentiles to ensure that buffers were sufficiently different in size).

Assessing relative risk of MDB and Chinese funded dams

We used different statistical tests to compare the potential impact of Chinese and MDB-funded dams. Pearson's Chi-squared (χ^2) test for independence was used to compare the free-flowing rivers potentially impacted. Unequal variance T-tests (Welch's t-test) were used to compare the number of threatened freshwater fish species and areas of critical and natural habitat potentially impacted.

Biodiversity Safeguards assessment

We assessed the environmental policies being applied to the identified Chinese-funded hydropower projects by Chinese regulators and Chinese hydropower companies for presence of biodiversity impact mitigation requirements. For comparison, we assessed the biodiversity safeguards that are being applied by the six western-backed MDBs to the projects they fund. We also assessed the extent to which regulatory biodiversity impact mitigation policies in the host countries had evolved. Each of the assessments are described below.

Chinese regulator and hydropower company biodiversity safeguards

We began by identifying Chinese regulator policies applicable to overseas hydropower investments. For this, we carried out English and Chinese language Google searches. For the Google search in English language, the following search string was used: (Environment* OR Green OR Biodiversity OR Ecolog*) AND (Polic* OR Safeguard* OR Standard* OR Framework OR Guideline* OR Strateg* OR Plan*) AND (“Belt and Road” OR “One Belt One Road”) OR (China OR Chinese) AND (Overseas OR International OR Foreign) AND (Investment* OR Project OR "Green Credit"). The Chinese language equivalent was used for Chinese language Google: (生态 OR 环

境 OR 环保 OR 生物多样性) AND (政策 OR 体系 OR 指导 OR 保障 OR 计划) AND “一带一路” OR 中国 AND (对外 OR 海外 OR 国际) AND (投资 OR 项目 OR "绿色信贷").

Next, we identified hydropower company policies applicable to the Chinese-funded hydropower projects. For this, first we identified the Chinese hydropower companies that have sponsored the Chinese-funded dams assessed in the study (EPC/BOT contractors were not included). Next, English and Chinese language Google searches were carried out to identify the environmental policies as well as the broader CSR policies of each of these companies. For the Google search in English language, the following search string was used: <Hydropower Company Name> AND (Environment* OR Green OR Biodiversity OR Ecolog*OR CSR) AND (Polic* OR Safeguard* OR Standard* OR Framework OR Guideline* OR Strateg* OR Plan*). The Chinese language equivalent was used for Chinese language Google: <Hydropower Company Name> AND (生态 OR 环境 OR 环保 OR 生物多样性 OR 社会责任) AND (政策 OR 体系 OR 指导 OR 保障 OR 计划). The respective websites of the identified hydropower companies were also examined for presence of any environmental/CSR policies.

For the identified Chinese regulator and hydropower policies, we examined whether they had any biodiversity-related provisions, and if so, whether they appeared to be binding project-level operational requirements on biodiversity impact mitigation, non-binding guidelines, or simply a high-level vision/plan for biodiversity protection. For this, content analysis was used. The policy documents were reviewed for any text that indicated the presence of provisions on biodiversity impact mitigation. The entire text was read with particular attention to terms such as ‘biodiversity’, ‘conservation’, ‘ecosystems’, ‘ecological’, ‘flora and fauna’, ‘nature’ or ‘natural environment', 'species' and 'protected areas' to look for biodiversity-specific requirements and terms such as 'mandatory' and 'non-compliance' to ascertain the binding nature. A similar exercise was conducted with the Chinese-language documents.

MDB safeguards

To assess MDB safeguards, we identified the biodiversity policies of all six western-backed MDBs (WBG + five regional MBDs) from their respective websites, including both dedicated standards on biodiversity, as well as biodiversity-related provisions within their broader environmental policies. For each MDB, we also searched for any policies/provisions specific to hydropower projects. Thereafter, content analysis of their biodiversity policies was carried out on the same lines as for the Chinese regulator and hydropower company policies to examine the presence of project-level operational requirements on biodiversity impact mitigation.

Host country policies

To assess the national-level biodiversity policy/regulation in the BRI countries where Chinese-funded dams are implemented, we used IUCN's Global Inventory of Biodiversity Offset Policies (GIBOP) database[81]. The GIBOP database brings together information on status, scope and implementation of biodiversity offsetting policy and regulation in 198 countries around the world. For each country, the database lists provisions (if any) on biodiversity offsetting in the relevant national policy/law as well as gives the country a score from 0-3 based on the stage of biodiversity offset policy development, with 0 standing for 'no provisions', 1 for 'provisions under development', 2 for 'provisions on voluntary offsetting' and 3 for 'provisions on regulatory offsetting'. We used the 'stage of biodiversity offsetting policy development score' from the GIBOP database as an indicator of the presence and maturity of biodiversity impact mitigation policy in each country.

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