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Political dynamics and governance of World Heritage ecosystems

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Political dynamics across scales are often overlooked in the design, implementation and evaluation of environmental governance. We provide new evidence to explain how interactions between international organizations and national governments shape environmental governance and outcomes for 238 World Heritage ecosystems, on the basis of a new intervention–response–outcome typology. We analyse interactions between the United Nations Educational, Scientific and Cultural Organization and 102 national governments responsible for implementing ecosystem protection under the World Heritage Convention between 1972 and 2019. We combine data on the reporting, deliberation and certification of individual ecosystem-level threats, with data on national governance quality, economic complexity and key stakeholder perspectives. We find that the extent of threatened ecosystems is seriously underestimated and that efforts to formally certify threatened ecosystems are often resisted by national governments. A range of responses to international intervention, including both productive and counterproductive responses, generates material impacts at the ecosystem level. Counterproductive responses occur in nations dependent on limited high-value natural resource industries, irrespective of overall level of economic development. We identify new political approaches to improve environmental governance, including how to overcome the problem of regulatory capture. Our findings inform how we can better anticipate and account for political dynamics in environmental governance.

Iconic ecosystems, such as the Galapagos Islands, the Three Parallel Rivers of Yunnan and the Great Barrier Reef, are ecosystems of outstanding socio-economic, environmental and cultural value. Many of these high-value ecosystems are protected to ensure their current and future conservation and use. Because of the substantial investment and attention that international protection requires, it is reasonable to expect more effective conservation of these iconic ecosystems relative to other less-protected ecosystems. Yet hidden threats are causing us to underestimate how these protected ecosystems are diminishing, in both function and extent[1–4]. The Great Barrier Reef, for example, is an ecosystem that successive Australian governments continue to shield from World Heritage (WH) in Danger listing by the United Nations Educational, Scientific and Cultural Organization (UNESCO), despite the system's highly threatened condition[5].

Here, we report the findings of a global longitudinal study of the UNESCO WH in Danger system[6–8]. We show the underestimation of threatened ecosystems and document how political dynamics cause some governments to preference rhetorical adoption, passive resistance or appropriation over compliance or negotiation with UNESCO. In studying these relationships, our primary purpose is to explain dynamics that are often overlooked or deliberately concealed by governance actors and to use this systematic understanding to identify a broader set of solutions for enhancing environmental governance. We comprehensively assess how the UNESCO WH system is addressing ongoing threats to ecosystem governance across multiple scales and time.

Governance threats are the risks to WH sites that stem from political dynamics (such as industrial lobbying) and ultimately limit or reduce site protection. It is well known that local lobbying and political trade-offs can limit the effectiveness of many protected areas, including those in the WH system[7–11]. At the local scale, expertise in managing such political dynamics has risen sharply over the past few decades[12]. We now understand how disputes about natural resource extraction can be resolved, for example, through community deliberation, local rules and incentives[13–15]. Informational strategies such as environmental reporting and eco-certification can also assist in depoliticizing local conflict[16,17]. Yet the strategic politics of iconic ecosystem governance at higher scales is barely understood[18,19]. Indeed, UNESCO's own management-focused threat reporting tends to either overlook multiscale governance threats altogether or aggregate them to broad stereotypes about poor governance in developing economies.

International relations theory suggests that governments often avoid strategies of negotiation and compliance with international directives in favour of alternative strategies such as manipulation and resistance[20,21]. Such strategies can reflect a conflict in priorities between a principal (an international organization) and an agent (a national government). This is known as the principal–agent problem[22]. The theory of social-ecological systems suggests that political and socio-ecological dynamics can interact to produce atypical responses, surprise and uncontrollability[23,24]. Such outcomes are problematic because they can tip an ecosystem into a new political and ecological state from which it is very difficult to return[25]. However, beyond local snapshot studies of individual ecosystems, these insights are yet to widely inform our understanding of the governance of iconic ecosystems[26,27].

Addressing these gaps and improving governance requires empirical evidence of how political dynamics play out across ecosystems at multiple scales and over time. We used WH as a model system through which to explore the multiscale politics of the governance of iconic ecosystems. Our central goal was to understand how 'WH

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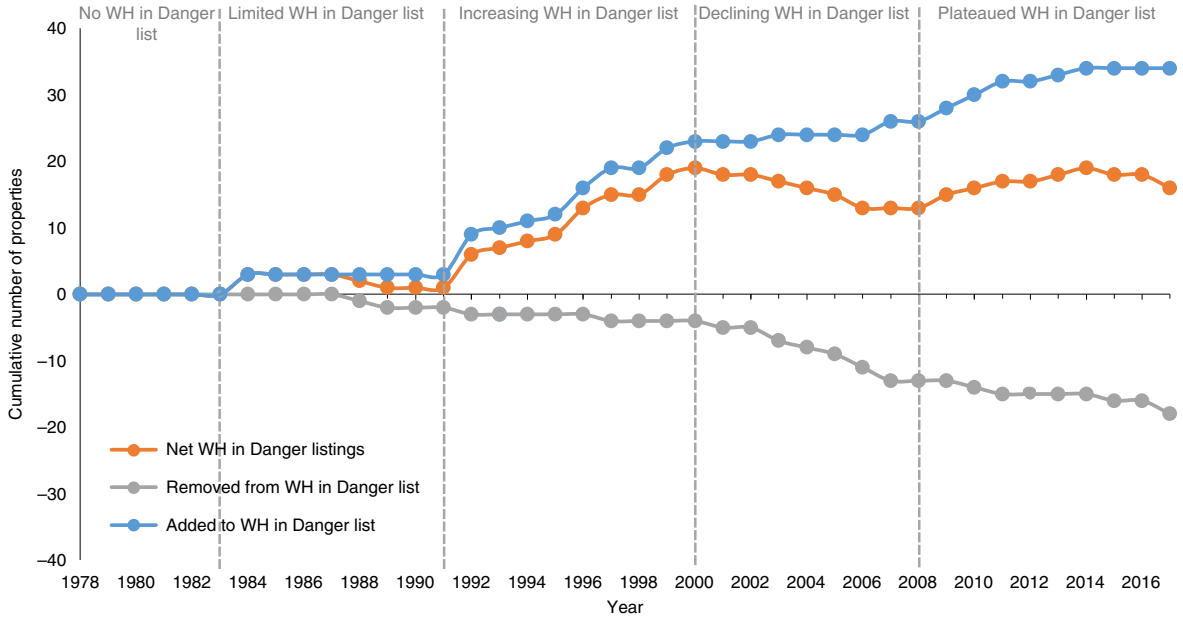

Fig. 1 | Evolution of WH in Danger listings over time for natural WH sites. The net number of WH in Danger listings has plateaued since 2000.

in Danger' designations (or lack thereof) shape, and are shaped by, longitudinal relations between national governments and UNESCO, and the implications for ecosystem governance and outcomes.

Emergence of technically in danger sites

Examination of the use of the WH in Danger list since its inception in 1983 reveals increased resistance to WH in Danger listing, including a 31.6% decline in such listings between 2001 and 2008 (Fig. 1). Interviewees attributed this decline in listings to 'increased politicization' of the process (for example, interview WH01, also WH07, WH10; see Methods). In the subsequent period (2009–2017), WH in Danger listings returned to previous levels, coinciding with, and perhaps because of, increased oversight by the International Union for the Conservation of Nature (IUCN). Indeed, the IUCN advanced its own WH Outlook assessment in 2011 with the stated goals of improving the independence and transparency of decisions of the WH Committee[28,29].

By 2019, only 16 of 238 sites were certified on the WH in Danger list, with a total of 30 sites certified at least once in the 1972–2019 period. However, a key finding from our analysis is that 41 sites have never been certified as WH in Danger despite reported threats that are equal to or higher in intensity than those that are certified as WH in Danger (threat intensity ≥23.2) (Fig. 2). This is a new status of site—which we classify as 'technically in danger'—a status that is currently unrecognized by UNESCO. Of these 41 technically in danger sites, 27 have been proposed for a WH in Danger listing more than once by the WH Committee but have never made it to the WH in Danger list. For many of these sites, document analysis confirms divergence between formal WH advisory body (for example, IUCN) recommendations and subsequent WH Committee decisions and inconsistencies between WH classifications and advisory body classifications, such as IUCN classifications. The emergence of technically in danger sites also coincides with a clear plateauing of the net number of WH in Danger listings from 2000 onwards (Fig. 1), in stark contrast to the steady growth of inscription of new WH sites and the increasing frequency of deliberations on threats to individual sites.

Atypical responses to WH in Danger listings

How do we explain the persistence of technically in danger ecosystems over time? Why do sites that are just as threatened or more threatened than those certified as WH in Danger continue to evade the WH in Danger list? A key finding of our analysis is that the threat of a WH in Danger listing by UNESCO drives a range of responses by governments over time. While individual governments can and do change their responses across different places and over time (Supplementary Table 2), we found that analysing responses according to similar threat status, UNESCO intervention characteristics and national response characteristics enabled development of a generalized spectrum of responses (see Methods). At one end of the spectrum, we found sites that had either never been listed as WH in Danger or had been listed at least once as WH in Danger, with government responses characterized by compliance, negotiation or appropriation. At the other end, we found sites that were technically in danger, with government responses that can be best described as rhetorical and resistant to WH intervention (Fig. 3).

Compliance, for example, is associated with full acceptance of WH values, with complying sites never certified as WH in Danger or proposed for a WH in Danger listing, and governance that is characterized by transparent and regular reporting (56% of sites, for example, Ilulissat Icefjord, Denmark). Negotiation responses, by contrast, are associated with at least one WH in Danger listing and substantial dialogue with UNESCO (17% of sites, for example, Galápagos Islands, Ecuador; Tropical Rainforest Heritage of Sumatra, Indonesia; East Rennell, Solomon Islands; Manas Wildlife Sanctuary, India). Appropriation occurs in the rare situation when the responsible government exploits a WH in Danger listing for its own internal purposes, such as to generate votes or wield power over local actors (1% of sites, for example, Everglades, USA; Yellowstone, USA) (Fig. 3).

Rhetorical adoption occurs at the other end of the spectrum, when governments exert their autonomy in an oppositional manner (through partial compliance and symbolic commitments) to repeated WH in Danger proposals to keep a site off the WH in Danger list. Rhetorical adoption characterizes 21% of all sites, including the Great Barrier Reef, Australia; the Three Parallel Rivers of Yunnan Protected Areas, China; and the Western Caucasus, Russia. Australia, for example, avoided a WH in Danger listing for the Great Barrier Reef in 2015 by developing a long-term sustainability plan in 2016. However, the method of financing and implementing the plan was characteristic of rhetorical adoption

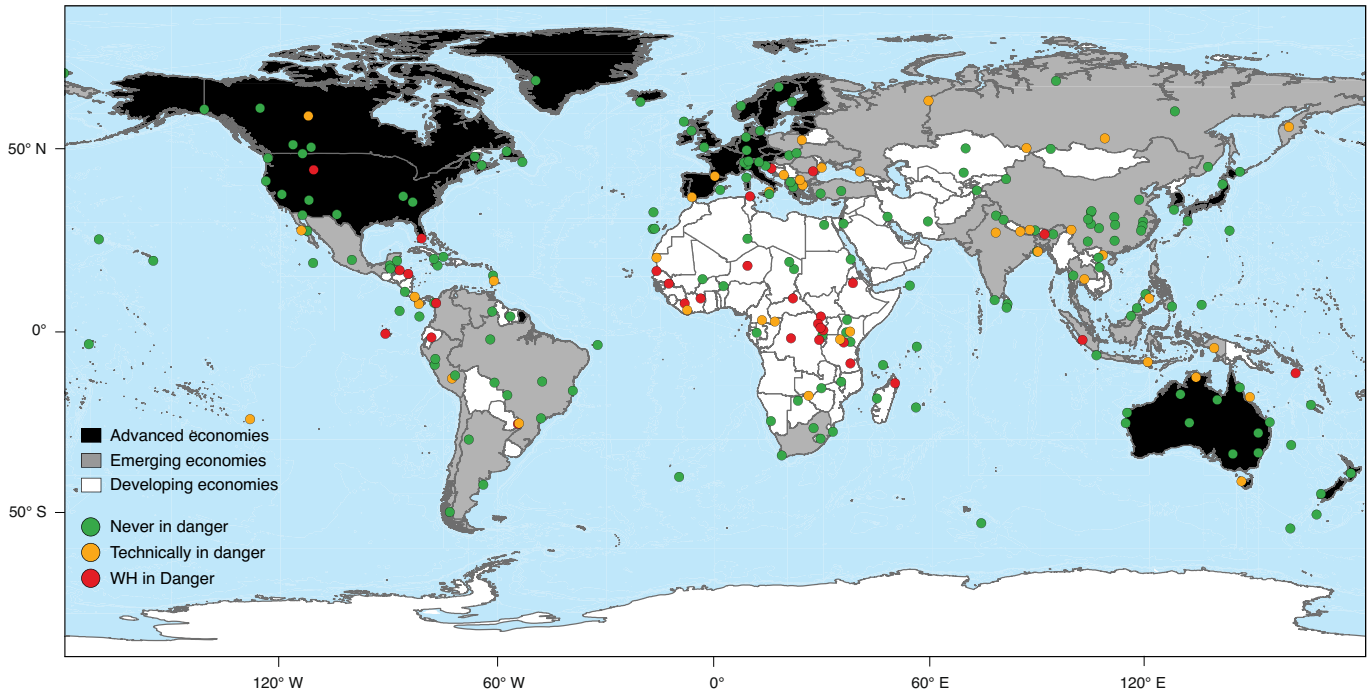

Fig. 2 | Unrecognized extent of threats for natural WH sites. Reporting, deliberation and certification patterns[6] for 238 natural and mixed (natural and cultural) sites were assessed; 41 sites have never been certified as WH in Danger despite reported threats that are equal to or higher in intensity than those certified as WH in Danger (threat intensity ≥23.2).

rather than a clear display of compliance. For example, in 2018, an Australian national audit and Senate inquiry found that a substantial portion of finance for the plan was delivered in a non-compliant (non-competitive and non-transparent) process to a private organization with limited capacity and expertise, thereby jeopardizing the ability to achieve the key actions and outcomes set out in the agreed plan[30–32] (Fig. 3 and Supplementary Table 1).

Passive resistance (5% of sites), by contrast, occurs when threats are high but the site attracts limited attention and effort from both the responsible government and UNESCO. Seven sites fall into this category, including geographically remote sites such as Tubbataha Reefs (Philippines) and Henderson Island (United Kingdom) as well as institutionally complex sites, including Banc d'Arguin (Mauritania), Mount Athos (Greece), Halong Bay (Vietnam), Komodo (Indonesia) and the Danube Delta (Romania) (Fig. 3).

Counterproductive governance outcomes

Do different responses to UNESCO intervention result in distinct environmental governance outcomes? Scientists and policymakers assume that UNESCO interventions will result in either a predictable or a controllable governance outcome. Here, however, we show that different types of responses generate different outcomes, ranging from predictable to uncontrollable and invisible (Fig. 3).

Predictable outcomes, for example, occur when an intervention (for example, inscription of a location on the WH list) results in the expected strengthening of site governance (such as a compliance response characterized by positive certification and regular monitoring and reporting). The Danish government, for example, has consistently advanced the management of Greenland's Ilulissat Icefjord since inscription in 2004, including a 2018 management plan that explicitly addresses the effects of climate change on the fjord's glacier (Supplementary Table 1).

Likewise, controllable outcomes occur when improved governance is dependent on periodic pulses of interventions (such as a negotiation response characterized by negative certification or technical and financial assistance). Many negotiating governments receive technical and financial assistance to move towards compliance—this pathway is one of the stated intentions of the WH in Danger listing and a strategic action by some governments. The Ecuador government, for example, has received repeated technical and financial assistance and a WH in Danger listing to shift the Galápagos system towards compliance (Supplementary Table 1).

When site governance is immune to conventional interventions, such as certification and technical or financial assistance, the outcome is only potentially controllable. The US government, for example, has alternately rejected and appropriated intervention in the Everglades[2] system in direct association with national political sentiment, resulting in a continuous cycle of multiple policy reversals. Under both the Clinton (1993) and Obama (2010) (Democrat) administrations, for example, the US federal government requested that UNESCO certify the Everglades[2] as WH in Danger to wield power over lower levels of government, other federal agencies and private actors. Under the G. W. Bush (2007, Republican) administration, by contrast, the US government requested that UNESCO remove the site from the WH in Danger list despite advisory board recommendations and stakeholder criticism (Supplementary Table 1).

When site governance is not only robust to conventional intervention strategies but also subject to rhetorical adoption, the governance outcome becomes even less controllable. The Australian Government, for example, has implemented symbolic and partially compliant policies to avoid a WH in Danger listing for the Great Barrier Reef[30–33], locking in a new political and ecological state for the reef that concerned stakeholders have found difficult to comprehend (Supplementary Table 1).

Finally, invisible or hidden outcomes occur when site governance appears to be passive in the face of intervention. To understand the Ha Long Bay system, for example, additional research strategies would need to uncover drivers such as poverty, World Bank intervention, proximity to China and cultural resistance to intervention, among others[34] (Supplementary Table 1).

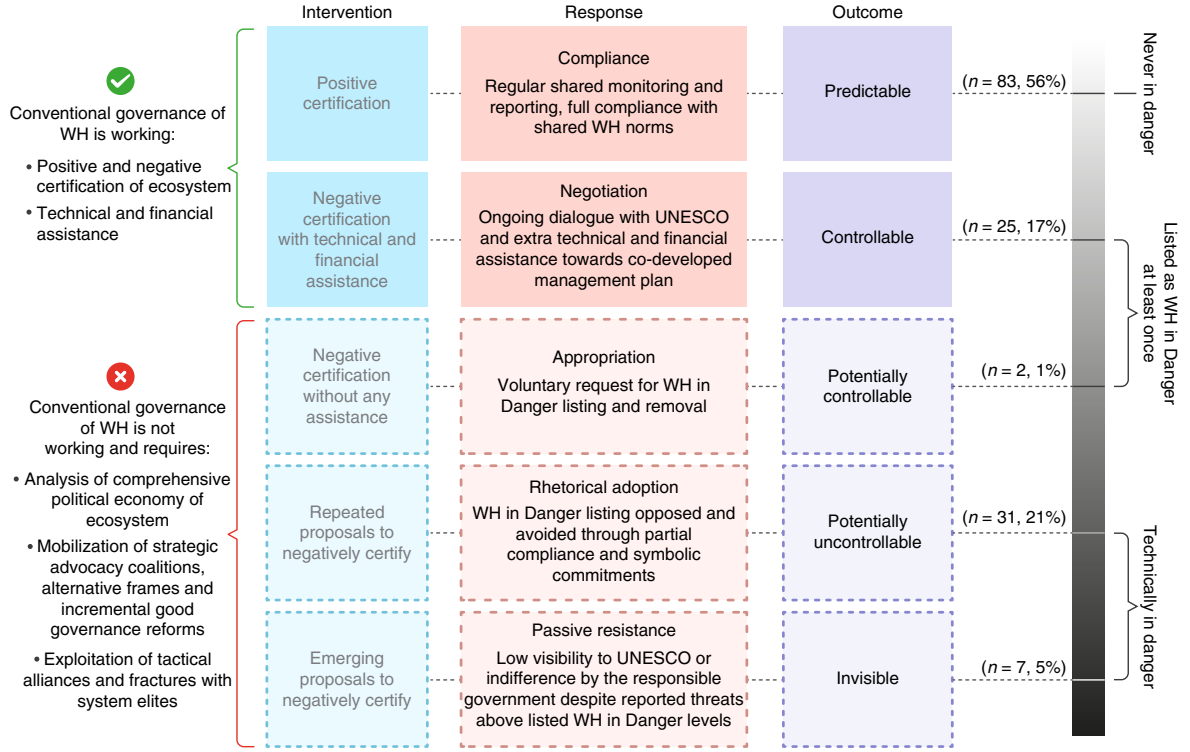

Fig. 3 | Governance of WH-listed ecosystems is a function of UNESCO intervention and national response. Most studies of WH governance focus on interventions that address proximate socio-environmental threats, generating compliance and negotiation responses and predictable or controllable governance outcomes (top of diagram). A critical challenge to empirical research is to internalize how political dynamics mediate interventions to generate alternative national responses and less-controllable governance outcomes (bottom of diagram).

These different governance outcomes are important because they have a material impact at the ecosystem level. In the case of the Great Barrier Reef, for example, the lack of a WH in Danger listing has facilitated the approval of harmful developments on and adjacent to the reef and made it easier for the Australian government to convince the public of the necessity to wind back national climate commitments[5]. The 2019 Great Barrier Reef Outlook Report assessed the overall outlook for the reef as 'very poor,' and in 2020, corals on the Great Barrier Reef bleached again for the third time in five years, generating grave concerns about the ecosystem's future ability to recover before yet another bleaching event.

Natural resource dependency and rhetorical responses

To explain counterproductive responses, such as appropriation, rhetoric and resistance, governance analysis must move beyond the study of original motivations and local rules and processes[35]. The original motivations for a WH listing provide little insight into WH in Danger listings due to the considerable length of time and divergence of interests between many WH listings and WH in Danger listings (up to 40 years). UNESCO's own reporting system also does not explain this spectrum of responses. Indeed, UNESCO's reporting system reports 'governance' threats only when they relate to developing and emerging economies (Fig. 4).

Whether a nation's economy is developed, emerging or developing also does not solely explain this spectrum of responses. Rather, broader drivers, such as wealth, governance quality, economic complexity and dependence on natural resources, lead to differential responses (Fig. 5a). We use gross domestic product (GDP) as a proxy for wealth[36]. For governance quality, we refer to control of corruption, government effectiveness, political stability and absence of violence or terrorism, regulatory quality, rule of law, and voice and accountability[37]. By economic complexity, we mean the diversified capability of a nation's economy (see https://oec.world/). Regarding natural resource dependency, we examine the dependency of a country's exports and services on primary resources (such as agriculture, forestry, mining and environmental tourism)[38–43].

WH sites characterized by compliance and appropriation responses are often, but not exclusively, located in advanced economies (45% for compliance, 100% for appropriation) that have limited dependence on natural resources and high levels of GDP, governance quality and economic complexity. Sites characterized by negotiation responses, by contrast, are primarily located in developing economies (84%) with lower values in all social and political indices, such as GDP per capita and governance quality. Negotiation responses also correlate with lower economic complexity and higher levels of dependence on natural resource industries (for example, mining, forestry and environmental tourism) (Fig. 5a). These results reflect common stereotypes about the relative challenges of achieving ecosystem sustainability in developed versus developing economies.

However, we also found results that challenge such stereotypes. WH sites characterized by rhetorical adoption responses, for example, include many in the advanced (for example, Australian) and emerging (for example, Chinese and Russian) economies (Fig. 5b). These countries exhibit high levels of GDP and natural resource dependence but lower levels of economic complexity and governance relative to those countries with compliance responses (Fig. 5a). In these countries, high levels of GDP and natural resource dependence are mutually reinforcing, reflecting the direct influence of industrial-scale resource development over efforts to sustainably govern protected areas[1,2]. Put simply, when a country is dependent on limited high-value natural resource industries, our analysis suggests that governments will preference rhetorical adoption over

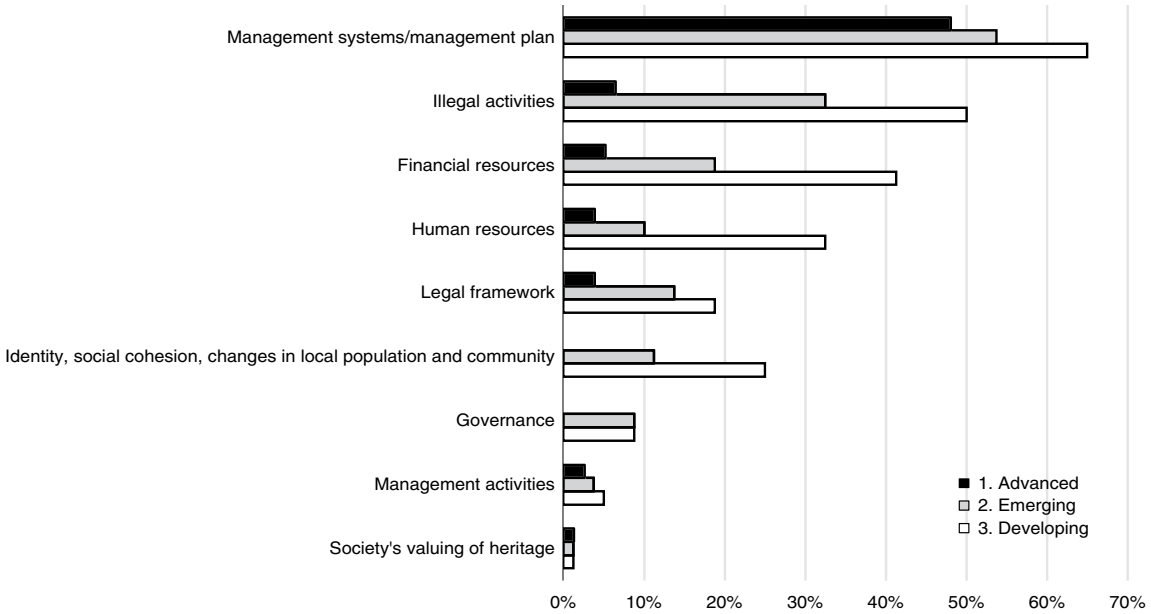

Fig. 4 | Governance threats discounted in social and institutional threat reporting by UNESCO 1972–2018. Only 6% of 238 natural WH sites have ever had governance declared as a threat by UNESCO, with a strong bias towards developing economies (seven sites) and emerging economies (seven sites), rather than developed economies (zero sites). Most reporting is focused on local 'management' threats rather than governance threats at other scales (WH reporting across economy types for relevant social and institutional threats)[6].

compliance or negotiation, irrespective of their country's overall level of economic development.

Regulatory capture

Why does high natural resource dependency cause governments to favour rhetorical adoption over straightforward negotiation or compliance? In sites characterized by rhetorical adoption, we find that the influence of natural resource industries extends far beyond their local environmental footprint. Key stakeholder respondents confirmed that coalitions of industry actors, some of whom are more powerful than individual nation-states, are capable of having a substantial political impact on a government's stance on WH and have become a prime motivator in both seeking WH status and keeping threatened sites off the WH in Danger list (interviews WH01, WH07, WH10, WH14).

Industry coalitions often lobby governments, UNESCO and WH Committee member countries, claiming that a WH in Danger listing diminishes a nation's international reputation and restricts foreign investment, national productivity, local employment and industrial license to operate. For example, powerful coalitions of industry actors have sought to challenge the WH system and undermine reports by scientists, nongovernmental organizations (NGOs) and the media. These efforts have heightened a government's sense of political threat by linking WH in Danger listings to national economic performance and to the individual reputations of politicians and senior bureaucrats (Interview WH14).

Governments have responded to these pressures by prioritizing management of reputational threats over management of environmental threats (for example, through partial compliance and diplomatic pressure on countries that are members of the WH Committee) (Interview WH14). Because such responses may reflect regulatory capture of governments by powerful industry interests[44,45], interviewees confirmed that politicians and bureaucrats often work to conceal these dynamics, rendering the governance outcome both unpredictable and uncontrollable. At the same time, UNESCO is acutely aware of these dynamics and concerned about threats to its own reputation (Interview WH01). In these circumstances, interviewees stated that the usefulness of the List of WH in Danger as a policy tool is diminishing, because "the energy of the Convention and of the responsible governments is spent in a way that does not improve the protection of WH areas" (Interview WH01).

Challenges for WH

The WH case shows that interventions that have proved to be effective in the past (such as local science-based improvements in management capacity and resources) are less adequate in advanced and emerging economies characterized by a high dependence on natural resources. In many instances, threats to political systems, such as reputational risk, mediate how governments respond to local socio-environmental threat. Indeed, managing political threats now forms the pervasive logic of many governments, including in the advanced democracies. This phenomenon parallels a global trend whereby managing reputational threat is now the dominant concern of many large organizations[46]. In these cases, conventional interventions are failing to address the degradation of the world's protected ecosystems. The WH system is in many senses locked in a governance trap, in which the ability to arrest degradation is constrained both by a misdiagnosis of the nature of the problem and by the unpredictable and uncertain behaviour of the actors responsible for its solution[33].

Harnessing governance threats to improve environmental governance

Ecosystems are in decline. International science-based interventions, such as protected area designation and monitoring, are typically promoted as the principal solution. Our analysis illuminates the underestimation of the threats and documents how the traditional powers of the nation-state and science-based solutions continue to struggle to address environmental degradation. In the case of WH, hidden governance threats explain why some governments favour rhetorical adoption, passive resistance or appropriation over compliance or negotiation.

While WH is an important but very small part of global environmental effort, the evidence we present here has wider application, for

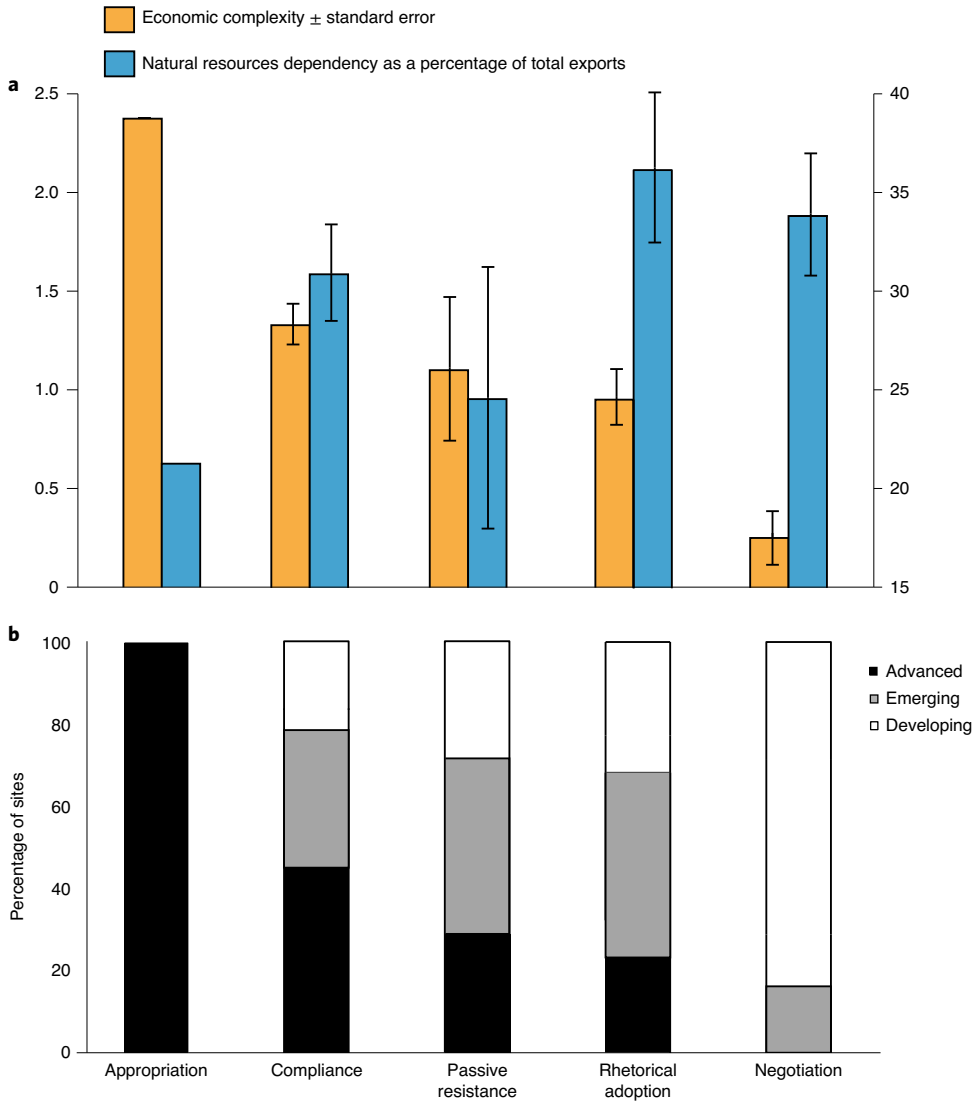

Fig. 5 | National responses according to economic complexity and natural resource dependency. a, National responses according to Massachusetts Institute of Technology (MIT) economic complexity (left, average ± standard error) and World Bank natural resources dependency (right, international tourism receipts, agricultural raw material exports, fuel exports, and ores and metal exports, as a percentage of total exports)[38–43,58]. **b**, National responses according to economy type; International Monetary Fund (IMF) economic development categories[57].

example, to the Ramsar Convention on Wetlands, the Convention on Biological Diversity, the United Nations Framework Convention on Climate Change and many other environmental governance initiatives. We provide robust evidence of governance threats that can critically empower scientists, NGOs and policymakers to challenge the industrial lobbying and regulatory capture currently undermining environmental governance around the globe (Fig. 3). Indeed, a number of emergent developments in the WH system demonstrate that it is possible to harness such governance threats through developing countervailing power and new leverage points for action[7–11,33]. For example, a nascent international network known as WH Watch has mobilized to form a competing coalition and to push for similar standing to the formal advisory bodies. New availability of remotely sensed data, online reporting and citizen science are increasing levels of transparency and accountability, revealing partial compliance, protected area dismantling and conflicts of interest. PADDDtracker.org, for example, is an online, crowd-sourced mapping tool for measuring and disseminating data on protected areas that are being downgraded, downsized and degazetted[47]. In 2019, the World Wide Fund for Nature released a report recommending a strategic reframing of the WH Convention and tactical changes to its structures and processes. And in February 2020, a consortium of 76 organizations and individuals petitioned UNESCO to address national climate action in WH decision making.

However, long-held assumptions and knowledge gaps remain in environmental governance. Prevailing beliefs that poor governance only happens in less technologically advanced economies, for example, are not well founded. The demonstrable influence of industry elites in blocking environmental governance mechanisms is prevalent in all regions and systems. Furthermore, current incentives tend to focus on environmental ministries, local resource managers, scientists and environmental groups, who are often the least powerful within their own systems. Additional research is required to understand how intervention strategies can be designed to incentivize cooperation among more powerful actors, such as politicians, senior bureaucrats and business elites[48]. Such work must extend beyond the traditional and disciplinary boundaries of local protected area management.

In this regard, recent findings on international peacekeeping intervention in resistant states[21,49,50] could be usefully extended

to efforts to improve environmental governance. It is possible, for example, to redirect the national balance of power away from industry lobbyists by supporting broader good governance and compliance. Strategic reframing[33,51] can be used to highlight mutual interests to a broad polity, such as economic resilience and resource security. Reframing can also be used to exploit key fractures, such as internal corruption, and to focus responsibility, for example, by highlighting how resource dependency increases risk of economic and political capture at regional and national levels (Fig. 3). Further study of the role of transparency mechanisms, government audits, inquiries and commissions, independent certification and deliberative experiments will also enable better identification of other forms of intervention[12,15,17].

As human pressures on the environment accelerate, it is critical to strengthen, not weaken, governance across the entire environmental estate. The Australian government's 2019 rhetoric on segregating climate change from WH intervention, for example, could embolden other countries to embrace a similarly counterproductive narrative. Given the global investment in environmental governance over the past 50 years, it is essential to accelerate research and support evidence-based strategies to address hidden threats to governance and to safeguard all ecosystems.

Methods

We investigated the assumption that the standard mix of WH interventions (namely, WH in Danger certification, financial assistance, co-developed management plans and ongoing threat monitoring) will effectively arrest ecosystem degradation. We approached the problem of ecosystem intervention by focusing on how political-economic dynamics shape and are shaped by longitudinal relations between national governments and UNESCO across multiple scales and contexts.

WH in Danger listing is not a top-down and static process; rather, it is a relational and fluid exercise, occurring over many years[52]. Formal deliberations occur at annual WH meetings; they are based on information received from national governments, the International Union for the Conservation of Nature, UNESCO's own reactive monitoring missions and NGO petitions[53]. While we acknowledge heterogeneities and competing interests within and among such actors[54,55], we focused on the relationships between UNESCO and the 102 national governments ultimately responsible for implementing ecosystem protection under the WH Convention. We combined WH in Danger certification patterns, site threat records and rates of UNESCO deliberation on threats to 238 individual sites between 1972 and 2019 to develop a more advanced classification of site certification than UNESCO's own system. We then undertook extensive quantitative and qualitative process tracing through document analysis ($n=3,099$) and country-level analysis ($n=102$) to understand how longitudinal relations between national governments and UNESCO shape ecosystem governance and outcomes. Confidential interviews ($n=32$) enabled verification of system-wide results and the extraction of site-specific examples (see Supplementary Fig. 1).

Global database of WH. We compiled a database of 238 UNESCO WH areas that have been certified for their natural or mixed (natural and cultural) significance, across 102 nation-states and spanning the period 1972–2019[6,56]. The individual sites and the WH system as a whole were studied by analysing quantitative patterns of threat reporting and WH in Danger certification and by undertaking extensive process tracing through document analysis, key informant interviews and country-level analysis. On the basis of the threat and WH in Danger analysis, we developed a global analysis of the unrecognized extent of WH sites in danger. Documentary analysis, stratified key-informant interviews and country-level correlation enabled development of a model of national responses to WH in Danger listings. We then assessed different types of responses to reveal different types of outcomes. This process enabled the preliminary theory and typology of iconic ecosystem governance developed from the literature to be expanded and verified (Supplementary Fig. 1). The study is a mixed-methods study combining in-depth interview data (qualitative) with global site threat data (quantitative), data from UNESCO and governmental records (qualitative and quantitative), and economic and governance data (quantitative). We combined new interview data with new analysis and a combination of existing raw data (quantitative and qualitative) from UNESCO, individual governments, the World Bank, the IMF and the MIT Economic Complexity Index. We achieved validity and reliability through multiple sources of evidence, intercoder checks, process tracing, and comparative analysis.

Ecosystem threat and WH in Danger analysis. Initial analysis was undertaken of the different types of threats reported and the frequency of reporting for individual sites ($n=238$) and across the whole WH system. Threats were both primary ($n=14$) and secondary ($n=65$). The threat intensity (TI) value is a quantitative measure of the frequency of UNESCO WH Committee deliberations on threats reported for individual sites[56]. We averaged the TI to determine sites that UNESCO has never certified as WH in Danger but that have a TI value equal to or higher than the lowest TI value of the WH in Danger sites (Supplementary Fig. 1). This approach revealed an additional 41 sites that have never been certified as WH in Danger but have had an average TI value equal to or higher than this threshold (TI $\geq$23.2 since inscription, $n=41$). We termed this new category 'technically in danger' to distinguish those sites from sites that have either never been in danger or have been both technically and formally in danger at least once (which we termed 'never in danger' and 'WH in Danger') (Fig. 2). We also used the advanced word search function to interrogate the entire dataset to confirm that all other sites with a TI lower than this threshold could be categorized as 'never in danger'. We then triangulated our results with changing patterns of threat reporting and WH in Danger listing over time, as discussed in the following (Figs. 1 and 2).

Quantitative national economic and good governance correlation. We interrogated national economic and good governance variables because national governments are directly responsible for implementing ecosystem protection at the site level under the WH Convention. Quantitative country-level data for the 238 sites (102 countries) were correlated with our new 3 categories of site (never in danger, WH in Danger and technically in danger) (Extended Data Fig. 1). IMF categories were used to class each national economy as advanced, emerging or developing[57] (Extended Data Fig. 1). World Bank data on GDP per capita (purchasing power parity (ppp) current international $) and good governance (including (1) control of corruption, (2) government effectiveness, (3) political stability and absence of violence/terrorism, (4) regulatory quality, (5) rule of law, (6) voice and accountability) were correlated with the three new categories of site[36,37] (Extended Data Fig. 1).

Quantitative and qualitative process tracing. Process tracing was undertaken through a content analysis of all advisory body evaluations ($n=661$), WH decision reports ($n=92$), WH mission reports ($n=210$), WH periodic reports ($n=533$), WH state of conservation reports ($n=1,390$) and state party (government) conservation reports ($n=213$) pertaining to individual sites 1972–2019. The overall case spanned 238 sites. However, the focused analysis was restricted to the use of WH in Danger listing (potential/proposed/actual) for 148 sites inscribed on the WH list for more than 10 years. We excluded 90 sites because they spanned multiple countries ($n=15$), were too recently inscribed (since 2007) ($n=52$) or did not have sufficient reporting to be properly assessed ($n=62$) (Supplementary Fig. 1). We coded the remaining 148 sites according to five types of responses to a proposed or realized WH in Danger listing (Fig. 3 and Supplementary Table 2). Sites that demonstrated regular shared monitoring and reporting and full compliance with shared WH norms were coded as 'compliance'. Those that demonstrated ongoing dialogue and extra technical and financial UNESCO assistance towards co-developed management plans were coded as 'negotiation'. Sites that engaged in voluntary requests for WH in Danger listing and removal were coded as 'appropriation'. Those that opposed and avoided proposed WH in Danger listings through partial compliance and symbolic commitments were coded as 'rhetorical adoption'. Finally, sites that demonstrated low visibility to UNESCO, or indifference by the responsible government despite reported threats above listed WH in Danger levels, were coded as 'passive resistance' (Fig. 3).

To supplement qualitative analysis of the nature of interactions between the WH Committee and individual governments over time, we extracted quantitative and qualitative data on site-level and system-level use of WH in Danger listing (nonuse, proposed, enacted or removed) and financial and technical assistance provided to individual sites over time. These data enabled process tracing and validation of the changing usage of reporting, external assistance and WH in Danger listing 1972–2019 (Supplementary Fig. 1 and Supplementary Table 1). To ensure intercoder reliability, two coders also independently cross-checked a subsample of the data. See Supplementary Tables 1 and 2 for a detailed catalogue of different types of national responses, alongside a subsample of five representative cases.

Quantitative national economic complexity and resource dependency correlation. We interrogated national economic complexity and resource dependency variables because national governments are directly responsible for implementing ecosystem protection under the WH Convention. Quantitative country-level data for the 148 sites (70 countries) were correlated with the 5 categories of national response (compliance, negotiation, appropriation, rhetorical adoption and passive resistance). We used the MIT Economic Complexity Index to measure the diversified capability of a nation's economy[58] (Fig. 5a). Natural resources dependency was calculated as the sum of international tourism receipts, agricultural raw material exports, fuel exports, and ores and metal exports, as a percentage of total exports[38–43] (Fig. 5a).

Stratified and key-informant interviews and external document verification. Confidential interviews ($n=32$) were held with WH experts from the WH

Committee, the advisory bodies, site management authorities, international and national environmental NGOs, national and provincial government agencies, international and national industry bodies and research institutes. Because it was not possible to collect data from all key informants, we stratified the sample to ensure representation of most types of actors. Eight different strata were delineated, involving different combinations of WH actors experienced with environmental, political or economic issues at regional, state, national and international levels. Three people were interviewed across each category. To triangulate further, in-depth interviews were held with eight key informants. Interviews occurred over a 12-month period during 2018 and lasted 60–90 min each. We conducted interviews in person and by Skype. The interview questions were semi-structured and focused on the governance of WH over time, how WH governance differs according to socio-environmental and political threats and the variety of responses to a WH in Danger listing. Interviews were confidential in accordance with James Cook University ethics approval no. H6149. To check saturation and avoid recall bias, we compared the results with each other and with other sources of evidence, such as independent NGO data and individual government sources[10,28–32,52,53].

Data availability

Findings are derived from the following primary and secondary data sources: in-depth, confidential stratified and key-informant interviews ($n = 32$ interviews), threat and certification data for natural WH sites ($n = 238$ sites), documentary analysis ($n = 3{,}099$ documents) and economic and governance data ($n = 102$ countries) (Supplementary Fig. 1). The data that support the findings of this study (excluding confidential interviews) are available from the corresponding author upon request. Interview results are confidential in accordance with James Cook University ethics approval no. H6149. A detailed explanation of methods is available in the Methods.

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Author contributions
T.H.M. conceived the idea and led the study design. W.N.A., K.B., M.C.L. and T.P.H. contributed analytic concepts and ideas. T.H.M., M.H. and C.H. collected, collated and analysed the qualitative and quantitative data. All authors drafted, reviewed and edited the paper.

Competing interests
The authors declare no competing interests.

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