LETTER

Hot moments for biodiversity conservation

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Abstract

Biodiversity conservation requires prioritization to be effective. Biodiversity hotspots and conservation planning identify *where* to focus conservation efforts, but it is unclear *when* conservation is most successful. Our goals were to: (a) investigate if hot moments for conservation occur, (b) calculate how important and prevalent they are, and (c) discuss what may catalyze hot moments for conservation. We analyzed the worldwide network of protected areas since inception, analyzing both all countries, and those 35 countries that contained at least 1% of either the total count or the total area protected globally. The evidence for hot moments for conservation was very strong. Among all countries, 44% protected more than half of their protected area in 1 year, and 61% did so in one 5-year period. The 35 countries that contain most of the protected area globally (77%) protected 23% and 49%, respectively, within 1 or 5 years. Hot moments often coincided with societal upheaval such as the collapse of the USSR or the end of colonialism. Conservationists need to account for hot moments for conservation to be most effective.

Introduction

Biodiversity loss is a major challenge for society, because species extinctions can trigger ecological meltdown (Naeem *et al*. 1994) and threaten the functioning of ecosystems upon which human livelihoods depend (Diaz *et al*. 2006). Increasing human population (Cincotta *et al*. 2000), consumption (Brashares *et al*. 2004), and land use change (Radeloff *et al*. 2010), as well as new threats, such as climate change (Thomas *et al*. 2004; Parmesan 2006), emerging diseases (Pounds *et al*. 2006), and increasing bioenergy production (Lotze-Campen *et al*. 2010), all threaten biodiversity (Sala *et al*. 2000; Brook *et al*. 2008; Pereira *et al*. 2010). Given these formidable threats and limited conservation funding, it is crucial that conservation efforts are prioritized in order to be most effective (Margules & Pressey 2000).

Protecting "everything everywhere" is not a helpful goal. Indeed global conservation efforts have increasingly focused on hotspots of biodiversity (Brooks *et al*. 2006), which are defined based on some combination of the richness of species of conservation concern (Reid 1998; Mittermeier *et al*. 2003), irreplaceability (Olson & Dinerstein 1998; Orme *et al*. 2005) and vulnerability (Myers *et al*. 2000), and sometimes, when allocating fixed budget, the cost of conservation (Bode *et al*. 2008; Carwardine *et al*. 2008). Thanks to several recent assessments of hotspots of biodiversity (Brooks *et al*. 2006), we know now *where* conservation efforts should focus (Olson & Dinerstein 1998; Reid 1998; Myers *et al*. 2000;

Mittermeier *et al*. 2003; Orme *et al*. 2005; Soutullo *et al*., 2008). These hotspot assessments identify the general areas where conservation should focus. While past protection efforts have been driven by a range of motivations including aesthetic value, or natural resource management concerns, conservation planning now emphasizes the need to optimize locations for new protected areas based on biodiversity patterns (Margules & Pressey 2000).

When analyzing actual patters of protection though, the general pattern is that countries that are rich, independent, and have high levels of primary education tend to protect more land, rather than those with a high number of vertebrate species or threatened IUCN Red List species (Mcdonald & Boucher 2011). Furthermore, a limitation of conservation prioritization efforts to date is that they do not examine the timing of conservation efforts systematically. Timing has only been considered to solve implementation problems when funds are limited and protected areas have to be designed incrementally (Meir *et al*. 2004), and in the context of dynamic protected areas (Rayfield *et al*. 2008), but whether timing influences conservation success is not clear. Yet, common experience suggests that timing should matter. As governments and institutions change, conservation opportunities may wax and wane; and as societies and economies develop, conservation threats may shift. In other words, there should be hot moments, i.e., brief windows of opportunity, during which conservation efforts are most successful.

The goals of our study were thus to (1) investigate if hot moments for conservation indeed occur, (2) calculate how important and prevalent they are, and (3) discuss what may catalyze hot moments for conservation. We addressed these goals in an analysis of the worldwide network of protected areas, since the beginning of protected area systems in the late 19th century. We show that protected areas in countries across the globe have typically been established during very brief windows of opportunity, i.e., hot moments for conservation.

Methods

We conducted our analysis for two sets of countries. First, we conducted analysis for all countries globally for which the WPDA provides data. However, small countries with only few protected areas could potentially inflate estimates of hot moments. This is why we conducted a second level of analysis in which we focused on those countries that contain at least 1% of either the global area or count of protected areas (i.e., at least 68,521 km^2 protected, or 294 protected areas). These two criteria resulted in a set of 35 countries (~a sixth of the global total), represented six regions (Western Europe, North America and Australasia, former Soviet Bloc, South America, Southeast Asia, and Africa, see section Methods later), and comprised 77% of the area that is protected globally and 87% of the count of protected areas. However, we stress that our 35 selected countries do not just constitute a sample in a statistical sense; they are the primary stewards of the global conservation estate.

We used the 2009 version of the UNEP-WCMC World Database on Protected Areas (WDPA) to analyze protected areas globally. The database includes 37,637 protected areas, including marine protected areas, for 167 countries for which both IUCN categories (I to VI) and which the year of establishment (from 1872 until 2009) is provided (out of a total of 100,636 protected areas in the WDPA). The WPDA follows the IUCN definition of protected areas as *"A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values"* (Dudley 2008). Generally, this includes only protected areas that are legally established, not those that have been only proposed, but we caution that the level of protection can vary greatly among countries and regions. From the database, we calculated for each year the total area and the number of protected areas by IUCN category globally, and by country. Protected areas for which no year of establishment was provided in the WDPA were excluded from the analysis; we did not impute missing dates based on the distribution of existing dates as in McDonald and Boucher (Mcdonald & Boucher 2011). We also did not include areas without information as to their IUCN status, because such areas may not be protected areas (Soutullo 2010). Area estimates were based on the information provided in the database itself. When no official estimate was available, we calculated the area based on the Geographical Information System (GIS) data that is part of the WDPA.

We conducted our analysis for four subsets of protected areas, first, strict nature reserves, wilderness areas and national parks (i.e., IUCN categories I–II), second all protected areas that are primarily managed for conservation (i.e., categories I–IV), third natural monuments and habitat/species management areas (i.e., categories I–VI), and fourth protected landscapes and protected areas that allow sustainable use of natural resources (i.e., categories V–VI). In the manuscript, we present results for IUCN categories I–IV only; results for the other IUCN subsets are presented in Tables S1 and S2 in the supporting information.

The selected countries were grouped into six regions: Western Europe included France, Germany, Greenland, Italy, Norway, and Sweden; North America and Australasia included Australia, Canada, and the U.S., the former Soviet Bloc included Bulgaria, Latvia, Mongolia,

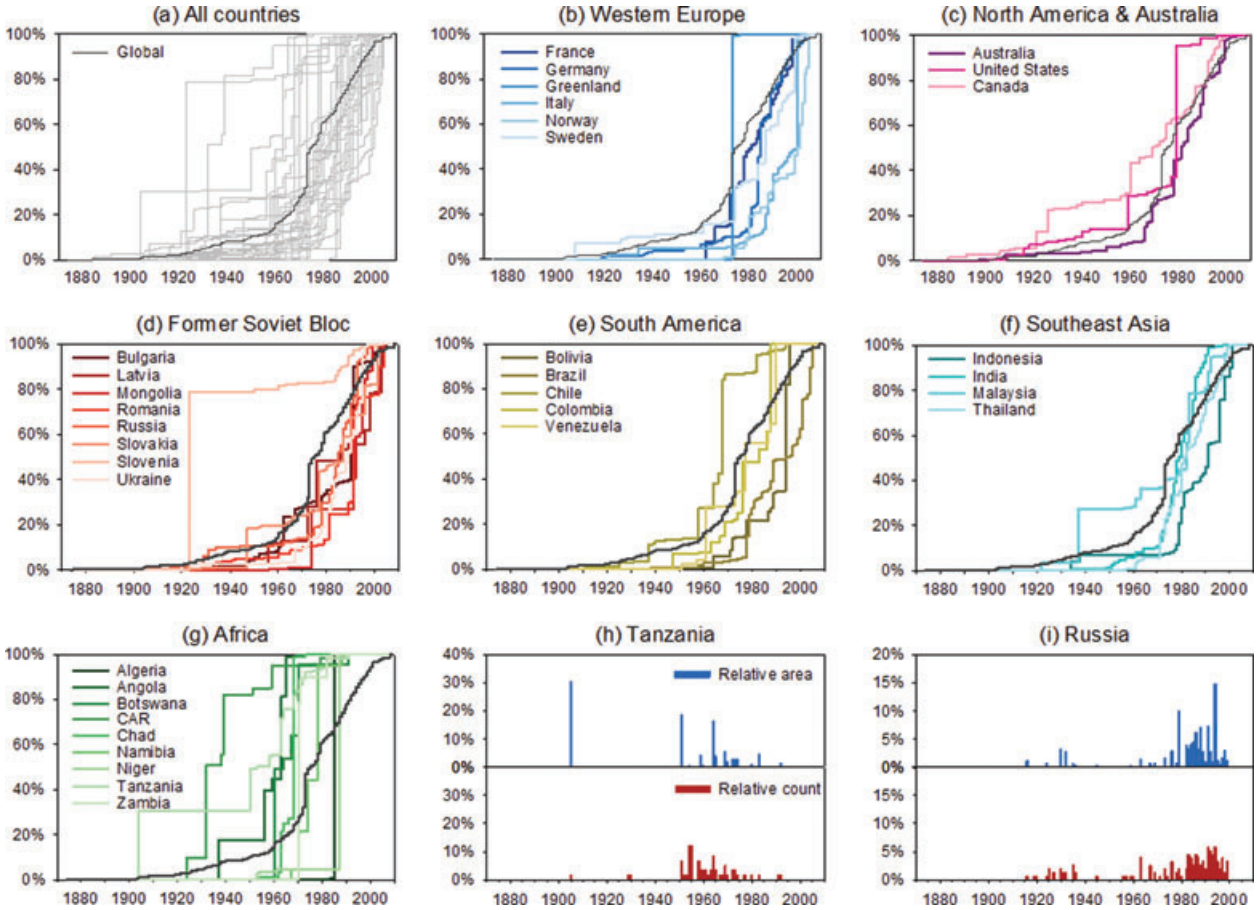

Figure 1 Cumulative growth curves of the total area that is protected areas (a) globally (see supplement for a full version with country legend), (b–g) in different regions; and the percentage of all protected area and the count of protected areas set aside in a given year in (h) Tanzania, and (i) Russia.

Slovakia, Slovenia, Romania, Russia; and Ukraine; South America included Bolivia, Brazil, Chile, Colombia, and Venezuela; Africa included Algeria, Angola, Botswana, Central African Republic, Chad, Namibia, Niger, Tanzania, and Zambia; and Southeast Asia included India, Indonesia, Malaysia, and Thailand.

To identify hot moments, we summarized both the relative area and the relative count of protected areas in a given country for single years, and for windows of three and five consecutive years, and totaled the number of countries that set aside either more than 50% or more than 33% of their total protected area within those time periods. The advantage of these summary statistics is that they are straightforward to interpret, but the disadvantage is that they would miss countries that experienced several hot moments in years that were not consecutive.

The Gini coefficient (Gini 1912) represents a more general measure of differences in values (in our case the area protected and the count of new protected areas in a given year). Gini's coefficient G is a measure of statistical dispersion which compares the Lorenz curve of a ranked empirical distribution with a line of perfect equality. Gini's coefficient ranges from 0 (perfect equality, i.e., the same amount is protected in each year) to 1 (perfect inequality, everything is protected in 1 year), and is calculated as follows:

$$G = 1 - \left(\frac{2}{T} * \sigma + 1\right)/n$$

where T is equal to the total number of protected areas or acres protected, σ the sum of the cumulative protected areas or acres protected, sorted from smallest to largest amount protected each year excluding the last year of our study, and n the number of years in our study.

Results

Considered as a whole, the global cumulative growth curve of the area that has been protected over time was fairly smooth, but not linear (Fig. 1a, Supporting

Table 1 The number of countries that protected either more than half, or more than a third, of the either the total area or the total number that they are protecting today within either a single year, a 3-year window, or a 5-year window (out of a total of 167 countries for which the WPAD provides data)

		Total area protected		Count of protected areas	
		Count of countries	Percent of countries	Count of countries	Percent of countries
More than half protected in a:	Single year	74	44.3%	41	24.6%
	3-year window	88	52.7%	58	34.7%
	5-year window	101	60.5%	75	44.9%
More than a third protected in a:	Single year	109	65.3%	83	49.7%
	3-year window	124	74.3%	111	66.5%
	5-year window	139	83.2%	130	77.8%

Information, Fig. S1). It took 75 years for the first 10% of the area to be set aside, and 100 years for 50% to be protected. However, other than a jump in the mid-1970s, growth was never abrupt. This smooth pattern for global protection efforts was in stark contrast to growth curves for individual countries, which had distinct step-like shapes indicating that protection occurred during short time periods (Figure 1b–g).

The same step-like pattern held for the count of protected areas: globally a smooth cumulative curve, but largely step-like for individual countries (Supporting Information, Fig. S2). In other words, many countries conserve many protected areas in short periods, and the step-like functions for the cumulative area curves of the different countries (Fig. 1) were not an artifact of a few very large protected areas.

Accordingly, the empirical evidence of hot moments for conservation was overwhelming. Of the 167 countries for which the which the WDPA provides data, 44.3% set aside more than half of the area they protect today in a single year, and 60.5% protected more than half of the area in one 5-year window (Table 1), and these 5-year results are particularly important because they are less prone to potential inaccuracies in the reported year of protection in the WPDA. Patterns for the count of protected areas were similar, but not quite as strong. Among the different IUCN categories, i.e., different level of protection, the prevalence for hot moments was also very similar (Tables S1 and S2). However, the full set of all countries includes some that set only a few protected areas aside ever and that could potentially inflate estimates of hot moments.

The evidence for hot moments for conservation was also very strong though in the 35 countries that are the primary steward of the global conservation estate. About a quarter of all the countries analyzed (8 of 35) set aside more than half the area they protect today within a single year (17 set aside more than a third of their protected area, Fig. 2). Even more striking, 17 of the 35 countries

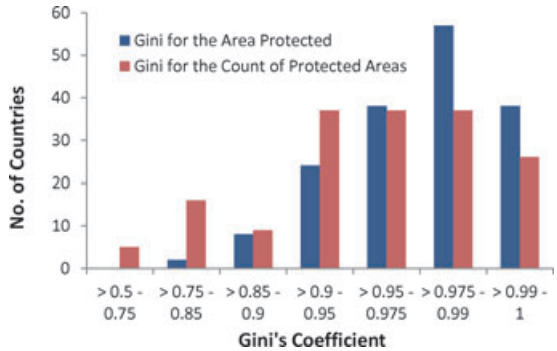

Figure 2 Frequency distribution of Gini's coefficients for the 167 countries for which the WPDA provides data. A Gini coefficient of 1 indicates that the entire protected area of a country was set aside in a single year; a Gini coefficient of 0 indicates that an equal proportion was set aside in each year.

set aside more than half of their protected area in one 5-year period (and 25 countries protected more than a third in 5 years). Similarly, when considering the count of protected areas, almost half of the countries (17 of 35) set aside more than a third of the individual protected areas in a 5-year period. This confirms that hot moments for conservation are not just driven by a few exceptionally large protected areas, but by setting aside large numbers of protected areas when political conditions allow.

Even in countries which did not exhibit a single hot moment, timing may matter for conservation. To quantify this, we calculated the Gini coefficient of conservation effort for each country, which measures the degree of dispersion of conservation effort over time (see Supporting Information). If the area protected each year was constant, then the Gini coefficient is 0; if the entire area is protected in a single year, then the Gini coefficient is 1. Again, the evidence that protected areas are only established in few years during a countries' history was overwhelming for both the full dataset (Fig. 2), and the 35 countries with the most protected areas (Fig. 3). Among all 167 countries, 57% had a Gini's coefficient larger than

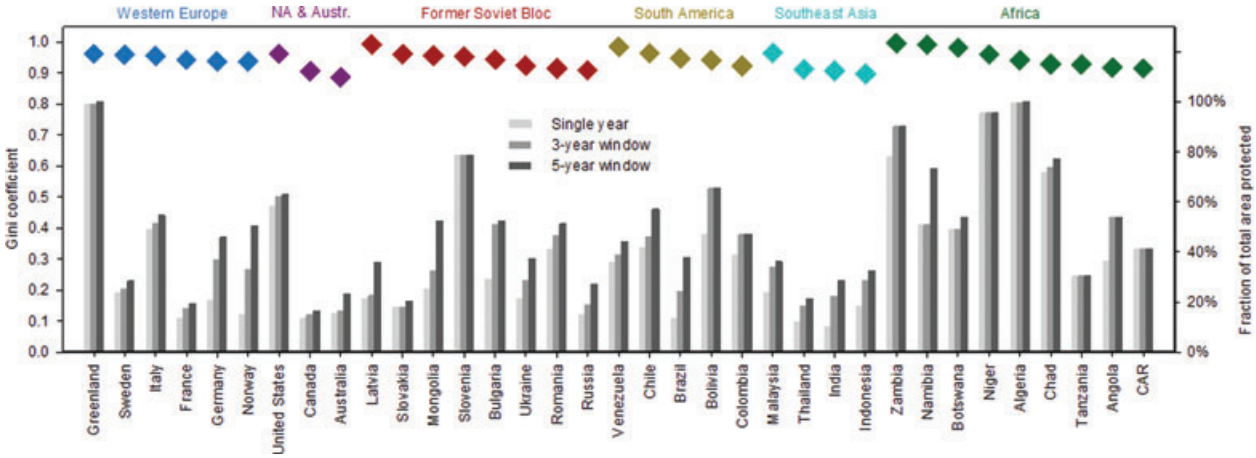

Figure 3 Strength of hot moments in each of the 35 selected countries, i.e., the percentage of the total area that is protected that was set aside in either a single year, a 3-year window, or a 5-year window in the grey histograms, and Gini coefficients for each country at the top in the colored symbols.

0.975 based on the area protected in each year, and 60% had a Gini's coefficient larger than 0.95 based on the number of protected areas in each year. Similarly, the smallest Gini coefficient among the 35 selected countries was 0.88 (for Australia), and the mean for the 35 countries that we studied was 0.94.

Discussion

We found strong evidence that hot moments for conservation, which we defined as brief periods during which a large proportion of a country's protected areas were established, indeed occurred. Such hot moments were pronounced, and common among countries. Conservation planning has made great strides in identifying spatial conservation priorities, for example, by delineating ecoregions, mapping conservation hotspots, and identifying important bird areas. Our findings highlight that future efforts to establish protected area need to focus not only on such hotspots for conservation, to help identify *where* conservation efforts should focus, but also on hot moments for conservation, to help identify *when* to focus conservation efforts.

What may have caused these hot moments for conservation? Our results suggested that national factors are likely more important than global factors, since national growth curves of both the area and the number of all protected areas showed strong evidence for hot moments, but the respective global growth curves did not. Indeed, within some of the regions that we studied, countries did show interesting similarities (Fig. 1b–g).

African countries generally had distinct hot moments, and these hot moments occurred mostly in the mid-1950s to mid-1970s (Fig. 1g). All African countries in our analysis exceeded global averages of the relative area of the country that is protected. Tanzania's protection patterns are very typical for African countries (Fig. 1h). Tanzania's largest protected area (the Selous Game Reserve) was set aside in 1905, but the majority of Tanzania's protected area (a full 30% of the country) was set aside at the end of the colonial period in 1961 when both the outgoing and the incoming governments created numerous and large protected areas.

Very different patterns occurred in the countries of the former Soviet Bloc (Fig. 1d). In general, they lagged behind the global trend, but exhibited distinct hot moments in the late 1980s and early 1990s. In Russia, for example (Fig. 1i), the main peak in the establishment of protected areas occurred from the mid-1980s to the mid-1990s, coinciding with the 1991 collapse of the Soviet Union. This hot moment occurred while Russia's GDP was cut roughly in half, strikingly different from the global pattern where countries with higher GDP have generally more protected areas (Mcdonald & Boucher 2011).

However, not just instances of regime collapse spurred hot moments—they were catalyzed by changes in administrations as well. In the United States, 58% of the area that is protected today was set aside in a single year. President Carter's loss of the election to Ronald Reagan in November of 1980, prompted Carter to sign the "Alaska National Interest Lands Conservation Act" protecting 321,900 km^2. Since then, the United States' government has established few terrestrial protected areas.

In general, hot moments for conservation often coincided with governmental changes, and we suggest

that identifying potential causal relationships underlying these coincidences would be a fruitful area for future research. Both outgoing and incoming governments can be inclined to set aside land, either to leave a legacy, or to signal a new era. Obviously though, not all times of governmental change constitute hot moments. In addition to a window of opportunity, hot moments also need conservation advocates. A striking example was the creation of a full half of Germany's 14 National Parks during the very last meeting of the East German cabinet in September of 1990, less than 3 weeks before the dissolution of East Germany and its reunification with Western Germany. A small group of conservationists led by M. Succow created protected area plans and assured their enactment. Without their efforts a critical hot moment in German conservation would have been missed.

We also tested if major global conservation summits (i.e., the 1971 RAMSAR convention, the 1972 World Heritage Convention the 3rd World Congress on National Parks in Bali in 1982, the 4th World Congress on National Parks and Protected Areas in 1992, the 5th World Parks Congress in Durban in 2003, and the 2002 World Summit on Sustainable Development) coincided with hot moments either globally or in specific countries. We found little evidence that they did coincide (results not shown), but that may not be surprising given that there are likely time lags, and that establishment of protected areas was not necessarily a goal of these summits. Thus we do not suggest that the lack of clear coincidence indicates that conservation summits did not trigger protection (e.g., in Madagascar (Norris 2006)).

Hot moments for conservation can occur not only in the context of protected area establishment, and we recognize that important questions remain regarding the effectiveness of at least some of the existing protected areas (Liu *et al*. 2001; DeFries *et al*. 2005; Joppa *et al*. 2008). We focused on protected areas because they are a cornerstone for conservation, and because their establishment and extent is comprehensively and iteratively documented. However it is likely that there are also hot moments for the passage of conservation laws and regulations, such as the number of species listed under the Endangered Species Act in the United States, and status upgrades and expansions of protected areas could be other interesting indicators of hot moments.

Furthermore, there are likely not only hot moments for conservation, but also ice ages, i.e., long periods with no new protected areas, and chilling moments, when areas are removed from protection (e.g., in Russia during the Khrushchev administration), epidemics or extreme environmental events cause steep declines in biodiversity (Pounds *et al*. 2006), or civil strife weakens institutional protection of biodiversity (Hanson *et al*. 2009). For example, the collapse of the Soviet Bloc resulted not only in new protected areas, but also in widespread new illegal logging (Vandergert & Newell 2003; Kuemmerle *et al*. 2009) and poaching that now endangers species such as Saiga antelope (Milner-Gulland *et al*. 2003).

For conservation groups and agencies, our results highlight the need to consider the timing of their conservation actions. There are pronounced hot moments for conservation – but also decades-long periods of few conservation gains, during which efforts may be of little consequence. How can conservation organization best prepare for hot moments? In our opinion, it will be futile to try to predict events such as the collapse of socialism, changes in governments, or the uprisings in the Arab world in 2011. However, systematic monitoring of the political climate in each country, focusing on the opportunity for conservation efforts to succeed, could ensure that hot moments are not missed. Such a monitoring may include an annual survey of conservation practitioners in each country, asking them to rate how favorable the current political climate is for conservation, if there are changes in governance that offer windows of opportunity, or if there are changes in public opinion that would favor conservation action. A rapid change in these indicators over time would indicate a potential hot moments, and an additional benefit of such monitoring would be that conservation practitioners would think deliberately about the political climate within which conservation actions occur.

When a country is experiencing a hot moment, the key will be to support in-country conservationists. We suggest that 'foreign interventions' by international conservation organizations are less likely to succeed if they lack local expertise and credibility. However, international conservation organizations have resources that in-country conservations may lack, and technical assistance (e.g., in conservation planning), training, and potentially financial support can all be helpful. It is unclear if pre-existing plans, such as a Biodiversity Action Plan, make it easier to capitalize on a hot moment. Better information is of course always valuable, but one reason why times of social unrest can result in hot moments is that societies are looking for change and something new. Dusting off old plans in such times may not have much success. It appears to us that one key factor is though dedicated, tenacious, in-country conservationists, who are ready to act when a hot moment arises. Building capacity and training conservation leaders may ultimately be the best long-term investment.

For conservation science, the challenge is to delve deeper into the patterns and drivers of past hot moments

for conservation so that it is possible to make more explicit recommendations how to be prepared for future hot moments. To date, the history of conservation successes is not well documented. Fortunately, key actors behind many hot moments are still alive, and can be interviewed, and protected area establishment requires governmental decrees, which are typically archived. It will be fascinating to delve into the history of past hot moments, and the lessons that can provide suggestions how to prepare for future hot moments. Ultimately, such insights would allow to supplement hotspot assessments and conservation planning with an awareness of the existence of hot moments for conservation, and to prioritize conservation actions in the context of the political climate for conservation in order to increase the effectiveness of conservation efforts, and to stretch limited conservation funds further.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure S1. Cumulative growth curves of the area of all protected areas globally and in each of the selected countries.

Figure S2. Cumulative growth curves of the count of all protected areas globally and in each of the selected countries.

Table S1: The effect of the IUCN categories used in the analysis on the number of countries that protect either more than half, or more than a third, of the total area they are protecting today within either a single year, a 3-year window, or a 5-year window (the number of countries reflects who many set aside protected areas in different IUCN categories).

Table S2: The effect of the IUCN categories used in the analysis on the number of countries that protect either more than half, or more than a third, of the count of protected area they are protecting today within either a single year, a 3-year window, or a 5-year window (the number of countries reflects who many set aside protected areas in different IUCN categories).

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