Evidence-Based Guidelines for Prioritizing Investments to Meet International Conservation Objectives

Caitlin D. Kuempel,[1,*] Alienor L.M. Chauvenet,[2] Hugh P. Possingham,[3,4] and Vanessa M. Adams[5]
[1]National Center for Ecological Analysis and Synthesis, University of California, Santa Barbara, 735 State Street, Suite 300, Santa Barbara, CA 93101, USA
[2]Environmental Futures Research Institute, School of Environment and Science, Griffith University, Gold Coast, QLD, Australia
[3]The Nature Conservancy, Arlington, VA 22203, USA
[4]School of Biological Sciences, University of Queensland, Brisbane, QLD 4070, Australia
[5]School of Technology, Environments and Design, University of Tasmania, Hobart, TAS 7001, Australia
*Correspondence: kuempel@nceas.ucsb.edu
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Biodiversity is in rapid decline, largely driven by habitat loss and degradation. Protected area establishment and management are widely used to maintain habitats and species in perpetuity. Protected area extent has increased rapidly in recent years with area-based targets set within international conservation agreements such as the Convention on Biological Diversity's Aichi Target 11. Researchers have proposed new targets to guide conservation actions post-2020, but most do not provide concrete recommendations to practitioners on how to navigate the inevitable and complex decisions between conservation actions to achieve these goals. We propose a decision-theoretical framework to better achieve components of Aichi Target 11 (expand protected areas, improve representation of conservation features, and manage protected areas better). We provide summaries of current system states within our framework and recent evidence-based guidelines on allocating resources between states. These guidelines will enable the next generation of conservation investments to achieve better conservation outcomes.

Biodiversity is in rapid decline, threatening many of the ecosystem services, natural resources, and societal benefits on which humans rely.[1] Habitat loss remains the largest threat to biodiversity globally.[2,3] Protection and management of intact and degraded habitats remain primary tools for conservation, as demonstrated by the rapid expansion of protected areas throughout the world.[4,5] International conservation targets have been set to protect 17% of the land and 10% of the sea in representative, equitably managed, and well-connected protected area systems by 2020 (CBD Aichi Target 11), with hopes that post-2020 targets will catalyze conservation action and be improved to achieve better conservation outcomes.[6]

The rapid expansion of protected area networks over the past decade reflects some level of investment in conservation action and commitment to achieving, at least, the areal extent objective of Aichi Target 11. However, it is clear that we are still losing biodiversity faster than the background rate,[7] and many species and habitats within protected areas continue to decline.[8–10] The impact of different broad conservation strategies has been investigated at the program level, but direct comparison of relative impacts of different broad conservation strategies is rarely considered.

Instead, conservationists have often relied on accepted positions such as "protect first restore later," without strong evidence that these positions reflect the best return on investment across conservation options.[11,12] This non-strategic approach to conservation at a high level is particularly troubling because there is currently not enough available data to set meaningful adequacy objectives for most habitats and species, making it critical to determine the most cost-efficient allocation of available resources between conservation actions. If we do not know what is "sufficient" for conservation, we need to ensure conservation investments are "efficient" and deliver the greatest returns on investment.[13]

Even though many conservation actions may not necessarily be mutually exclusive, investing a dollar in one action does preclude that dollar from being invested in another action. Therefore, it is necessary to explicitly recognize these trade-offs and determine the relative costs and benefits of investing in one action over another. In attempts to achieve Aichi Target 11 over the past decade, funders and decisions makers have had to choose how limited conservation funds are invested between the multiple objectives of protecting areas of value, protecting a representative sample of biodiversity, and managing existing conservation areas. However, it is often unclear how and why certain actions and locations are chosen over others and, despite significant research in these areas over the past decade, it is still unclear how to prioritize actions across these objectives.

Most guidelines and newly proposed conservation objectives do not provide concrete recommendations to practitioners and managers on how to navigate the inevitable, and often complex, decisions between conservation actions. We desperately need a unified theory of conservation that directly compares the available conservation actions in a single framework and provides clear guidance to conservationists on the best action (e.g., Figure 1). Here, we propose a systems model framework comprised of six system states and pathways between these states that represent the components of Aichi Target 11. We

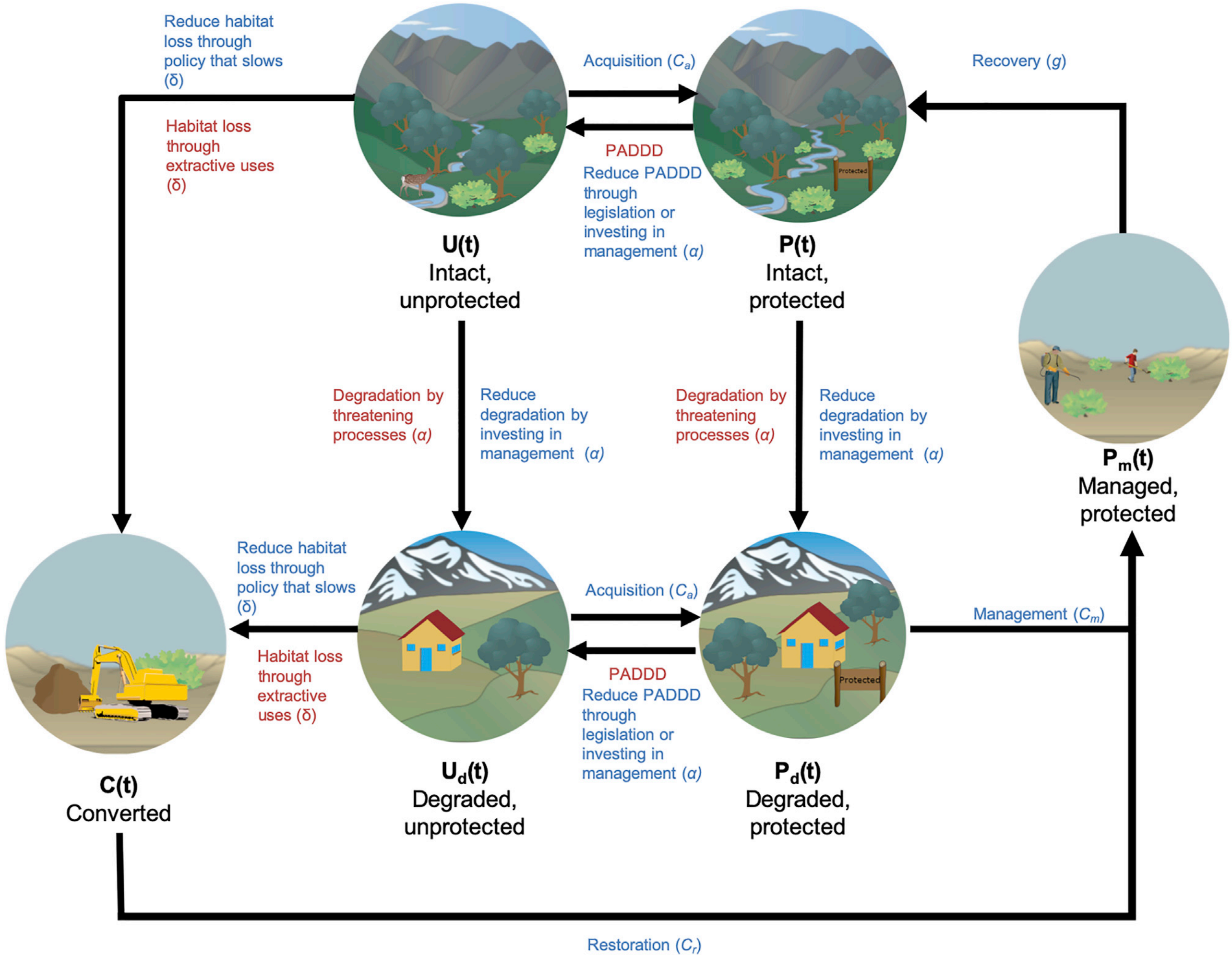

Figure 1. Conceptual Diagram of Potential System States and the Possible Pathways between States

The potential system states include converted habitat for multiple use (C), unprotected intact habitat (U), unprotected degraded habitat (U_d), protected intact habitat (P), protected degraded habitat (P_d), and protected managed habitat (P_m), which lie on a gradient with significant variability between states. Possible pathways include conversion (δ), degradation (α), acquisition (C_a), management (C_m), protected area downgrading, downsizing, and degazettement (PADDD) and recovery (g). Processes and actions increasing these pathways (i.e., improving the system state) are shown in red and processes and actions decreasing pathways are shown in blue.

review the current status of each system state and synthesize recent evidence-based guidelines on how to allocate resources to shift between states and achieve Aichi Target 11 objectives (protect, manage, and represent) in the future. Ultimately, we aim to help guide the next generation of conservation investments to achieve better outcomes for habitats and species. These recommendations are important to consider as decision makers begin to develop post-2020 targets.[6]

A Generalized Model of Conservation

To better elucidate when and where to implement different conservation actions, a generalized model of the system within which decisions are made is critical. There are six broad land and sea uses that describe the types of systems that conservation acts in for every ecosystem type: converted habitat for multiple use (C), unprotected intact habitat (U), unprotected degraded habitat (U_d), protected intact habitat (P), protected degraded habitat (P_d), and protected managed habitat (P_m) (Figure 1). Importantly, these system states are not binary but lie at the ends of a spectrum with significant variability between broad classifications.

Strategically allocating funds, closing gaps in key spatial conservation objectives (e.g., representation, management), and ultimately maintaining biodiversity in perpetuity requires knowledge about the benefits of conservation, such as the location and state of habitats and species (e.g., species richness, Figure 2A,[14] or associated measures such as species accumulation within reserves, avoided extinction debt or species biomass), and each of the possible system states (Figures 2B–2E), which will drive the allocation of conservation funds.[11,15,16] Given the relative contributions of different system states to biodiversity outcomes, conservation practitioners will need to implement actions to shift between system states and to maximize biodiversity outcomes or minimize losses (Figure 1).

We synthesize the knowledge of the relative state of the world for each of the system states and actions in this generalized

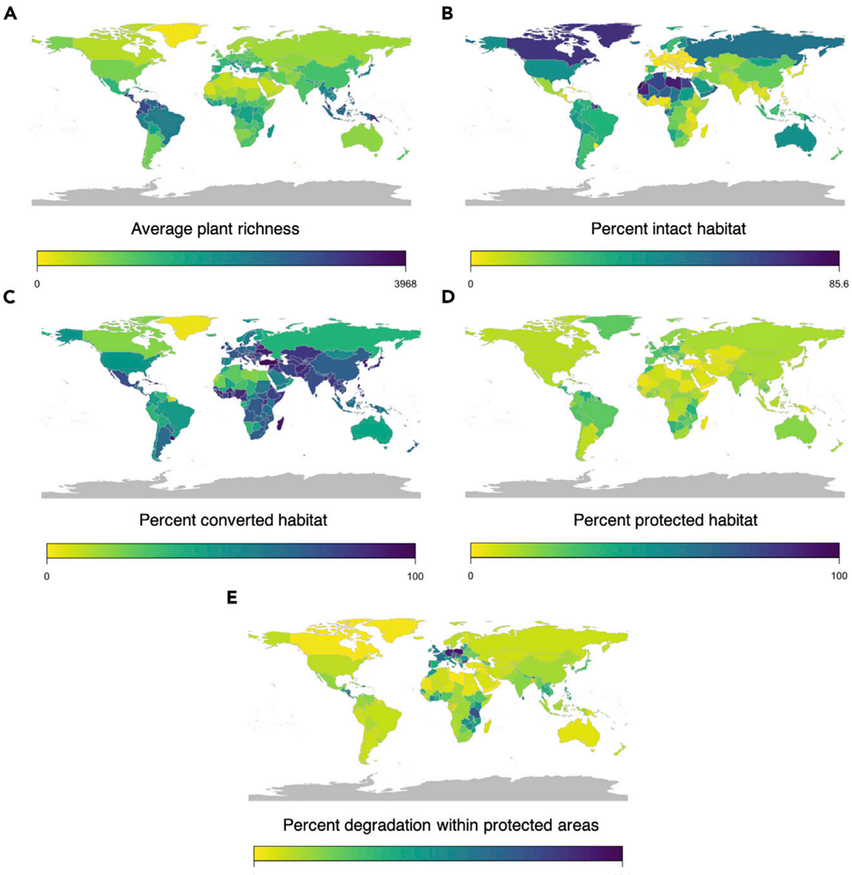

Figure 2. Current Status of System States Globally

(A) Average vascular plant species richness, (B) the percentage of intact habitat in each country globally (human footprint [HFP], <4), (C) the percentage of converted habitat in each country globally (HFP, ≥4), (D) the percentage of terrestrial area protected in each country globally, and (E) the percentage of degraded area within protected areas in each country.

model. To do this, we use the human footprint dataset[17] to quantify the current state of habitats as degraded (human footprint [HFP] ≥4) or intact (HFP <4) and the World Database on Protected Areas (WDPA)[18] to classify habitats as protected. In addition, we discuss conservation implications in terms of achieving Aichi Target 11.

Current Status of System States Globally

Different system states present variable benefits to biodiversity, spanning a gradient of high benefit associated with intact habitat (both protected and unprotected) through to low or negligible benefit for fully converted habitat. Intact areas (U and P) are becoming increasingly scarce across the globe (Figure 2B). We estimate that there is currently ~40.1% of global terrestrial area that is intact (HFP <4) or ~34.6% if protected areas are not included. Other studies have estimated the remaining extent of "wilderness" areas—defined as "biologically and ecologically largely intact land or seascapes that are mostly free of human disturbance"—revealing that only 23.2% of land has no mapped human pressure[19] and 13.2% of the sea[20] is within the bottom 10% of pressure across both single and cumulative measures. Wilderness and intact areas may hold critical biodiversity value as they support unique species compositions and higher biomass than impacted areas, can exhibit high endemism, contain rare functional traits, and buffer against changing conditions from human use and climate change.[21–23]

Habitat conversion (δ) and degradation (α) vary within countries, with 142 (72%) countries having more degraded than intact terrestrial habitat (Figure 3). We calculate that 49.6% of terrestrial landscapes have been converted between 1993 and 2009 to allow for extractive uses, such as urbanization and/or food production; this figure includes ~4.6% of conversion inside protected areas (P_d), which may signify shortfalls in protected area management effectiveness (Figure 2E). Converted habitat has become so pervasive that it now threatens our ability to meet current protection objectives. While some degraded land is too converted to ever return to its original state, other areas may still contain biodiversity value or can be restored and managed (P_m). For example, it is estimated that nearly 1.9 million km^2 of land spanning 190 ecoregions needs restoration in order to protect suitable habitat within 17% of terrestrial ecoregions.[24]

Today, 14.9% of land and 16.8% of national waters are within protected areas,[5] signifying progress in meeting area-based conservation objectives. We estimate that countries have protected an average of 25.3% (median, 15.5%) of their terrestrial area globally (Figure 2D). However, the state and conservation value of protected areas is highly variable (ranging from intact to converted, U_d to $P_{d,}$ with varying levels of threat management from effective to ineffective and non-existent, P_m), and many conservation scientists believe that prioritizing area-based objectives has led to an inefficient and ineffective global protected area system, even potentially leading to perverse outcomes.[25–27]

It is widely recognized in the scientific community that conservation outcomes achieved through protected area establishment rely not only on the extent of area protected but also on the level of representation, connectivity, and effective management within a protected area. Representation ensures that a sample of each biodiversity feature is included within a protected area system, effective management requires adequate funding and resourcing to enable sufficient enforcement and control of threats within a protected area's borders, and connectivity refers to the spatial arrangement of protected areas across land and seascapes to allow for the movement of species across habitat patches. However, these objectives are not accompanied by clear definitions, quantifiable objectives, or specific guidance on implementation within the current biodiversity framework and thus have often not been prioritized in conservation efforts.[25,28]

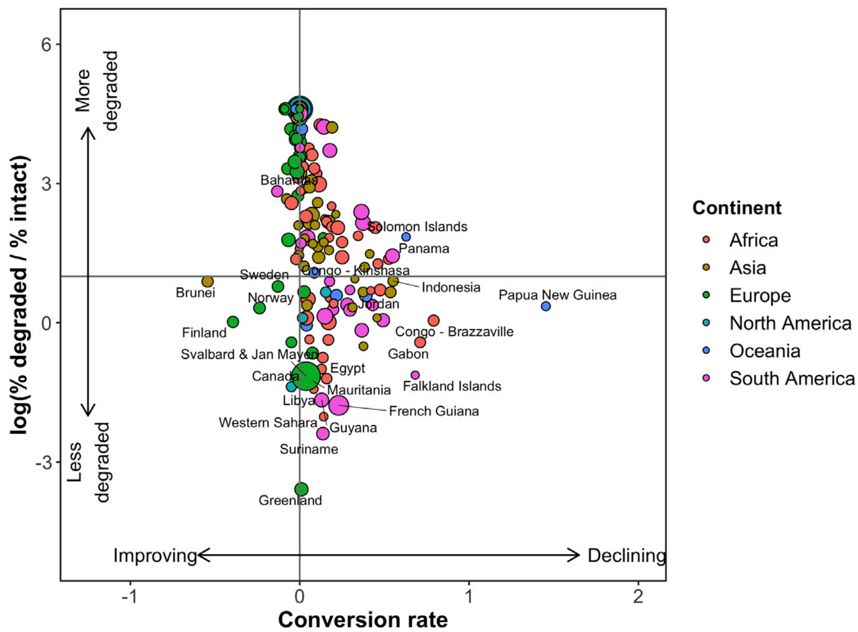

Figure 3. Patterns of Habitat Degradation and Conversion Rates (Pathways between System States) in Countries Globally

Countries in the top half of the plot have more degraded than intact area. Countries in the top left quadrant have a declining conversion rate (habitat state is improving), whereas the top right have a positive conversion rate (habitat state is declining). Countries in the bottom half of the plot have more intact than degraded habitat area, with the bottom left and bottom right quadrants exhibiting improving and declining habitat states, respectively. Point size indicates the percentage of area protected in each country.

Rates of Change between System States

Habitat conversion and degradation can be driven by many processes, which are nearly always in relation to human use. Agriculture, for example, now occupies 40% of terrestrial landscapes[29] and fishing now occurs in ~4% of our oceans.[30] We estimate that 112 (57%) countries have conversion rates greater than zero (calculated as the rate of increase of converted area, HFP $\geq$4, between 1993 and 2009), signifying a decline in habitat state (intact unprotected/protected to degraded unprotected/protected), whereas 85 (43%) have negative conversion rates, indicating a possible improvement in habitat quality relative to its state in 1993 (Figure 3). While protection and conversion should not necessarily be viewed as two opposing actions (i.e., protection does not ensure habitat degradation will stop or be reversed), previous research has used these rates in efforts to prioritize areas for protection. For example, Watson et al.[31] found that protection has outpaced habitat conversion on land, but over 50% of terrestrial ecoregions still have high rates of conversion relative to protection and should potentially be prioritized to safeguard habitats and species. It remains difficult to measure and quantify conversion within the world's ocean, but research has estimated that ~5% of the ocean is heavily affected by human use,[32] and that 59% of the ocean has experienced significantly increasing cumulative impact.[33]

Even areas that are designated as "protected" are not free from the threat of habitat conversion, with an estimated one-third of global protected lands under intense human pressure[10] (Figure 2E). Similarly, protected area downgrading, downsizing, and degazettement events (PADDD) are becoming increasingly common and are largely associated with industrial-scale resource extraction and development within protected sites.[34] Records of PADDD are now documented across 73 countries and often represent shortfalls in the legal protection status of these areas.[35]

Guidelines for Achieving Aichi Target 11 Objectives

Scientists have gone to significant effort to assess conservation progress toward achieving protection, representation, and management goals within Aichi Target 11. In doing so, existing and potential trade-offs and synergies between these objectives, as well as scenarios on how best to meet these objectives in the future have been described and, in some cases, quantified. However, the literature to date is largely focused on protection, with little evidence of progress toward, or required future efforts for, meeting management and representation objectives. Here, we summarize evidence-based guidelines for meeting management and representation objectives within Aichi Target 11. It is important to note that these models are simplifications of very complex systems but are useful in measuring specific trade-offs of actions and identifying general rules.

Ensuring Effective Management

Globally, protected areas are under resourced, which prevents effective management. For example, 60% of protected areas in a global assessment of management effectiveness scores reported the lowest scores on adequate resourcing,[36] and a recent analysis found that representation of amphibians, birds, and mammals are >5 times lower when only effectively resourced protected areas are considered.[37] While protected areas can allow for a range of human uses—from strictly no-take to extractive or multiple-use zones—we estimate that habitat degradation within protected areas ranges from 0% to ~75% (mean, 9.2%; median, 5.25%) globally, which may reveal signs of management ineffectiveness. It is difficult to attribute this degradation directly to management shortfalls without knowing the baseline state before gazettement. However, recent research has shown that protected areas have not reduced anthropogenic pressures compared with similar unprotected sites[9] and that as much as one-third of global protected lands may be under intense human pressure.[10]

Effective management has been shown to increase biodiversity benefits that protected areas achieve.[38–40] Marine protected areas with adequate staff capacity have been shown to have nearly three times greater ecological effects than those with inadequate capacity.[41] Current measures of management effectiveness (e.g., Protected Area Management Effectiveness [PAME] evaluations) do not always correlate with conservation outcomes.[42] However, with inadequate conservation resources, it is no surprise that threats to species within protected areas continue to persist, and in some cases, increase.[9,10] Some types of threats—for example, intensive extraction uses such as deforestation or overgrazing—can be counteracted by declaring and effectively enforcing a protected area; other threats, such as changes in fire frequency, disease outbreaks, and invasions of weeds and feral species, require active management.[43] Our model definition of degraded includes the presence of either or both of these types of threats. However, we note that the type of management action required to address extraction is typically enforcement, whereas management of other threats such as weeds and fire require active on-ground management activities. The system model can be parameterized to address these individually or collectively.[16,44] Alternatively, management that is required in perpetuity (such as enforcement) can be included in the model as a component of acquisition costs and assumed to be effective.[16]

Given the lack of resourcing for effective management of protected areas, studies that aim to maximize species abundance and/or retention have found that management is the better first investment (over further expansion of protected areas) in many contexts. Within terrestrial protected areas, for example, Adams et al.[16] found that the relative priority of expansion and management is determined by observable factors: the relative costs of the two actions and rates of degradation in protected and unprotected areas. Further, Runting et al.[45] found greater biodiversity outcomes from improved management compared to shifting to a landscape-sparing strategy. Similar results were found by Kuempel et al.[44] in the marine context where optimal budget allocations were split across enforcement or expansion, but the long-term allocations favored enforcement, and by McGowan et al.,[46] who found that small management budgets favor marine protected area establishment, whereas larger budgets favor fisheries management strategies. Even restoration, one of the most extreme forms of management, has been found to produce greater outcomes when carried out alongside or even in place of protected area expansion,[47] which is in contrast to tradition orthodoxies.

Many habitats and species are still highly underrepresented within the protected area network and require further protection, making it clear that investing in both protected area expansion and management effectiveness are necessary to safeguard the full range of biodiversity in perpetuity. However, determining where to invest in management first is a critical question given limited conservation resources. This topic has received relatively less attention, but a study by Geldmann et al.[39] suggests that investing funding and resources in protected areas under greater threat can have a greater conservation impact. It has also been shown that investing in management can help counteract PADDD events. For example, initial research has shown that PADDD events are more likely to occur in ineffective protected areas that have experienced higher incidents of degradation or fragmentation.[34,48,49] Therefore, investing in management effectiveness can aid in strengthening legal frameworks and safeguarding protected areas from PADDD. Conversely, strategic PADDD events, or concentration of management efforts within smaller areas, have been proposed as a way to increase management effectiveness with limited resources.[44,50]

Achieving Representation

The current protected area system has been shown to perform poorly across most representation measures. For example, representation of habitats and species has been shown to be inadequate and unequally distributed. Klein et al.[51] found that >97% of marine species have <10% of their ranges within protected areas, and Butchart et al.[52] quantified that just 41% and 32% of terrestrial and marine ecoregions, respectively, have met target levels of protection. Further, studies have shown a strong bias in protection toward areas that are not valuable for human use and that are far from the threatening process that protected areas are intended to abate.[53–56] Metrics that evaluate the evenness of protection across habitats have revealed further bias, with 73% of countries inequitably protecting ecoregions within their borders,[57] and protection equality values (a measure of the evenness of habitat representation) ranging from 0 (perfect inequality) to nearly 1 (perfect equality) across countries globally (mean, 0.6; Q1, 0.41; median, 0.61; Q3, 0.8; protection equality calculated as in Chauvenet et al.[58]).

There is often an unnecessary trade-off between area expansion and the representation of habitats and species inside protected areas, because, historically, protected areas have been established in the same unproductive and/or inaccessible locations where there would be no conflict between development and conservation,[55,56] leading to expansion of protected area extent without achieving representation goals.[4,52] However, strategic protected area growth can reach global area-based objectives while simultaneously increasing representation of habitats and species.

Studies exploring better ways to achieve representation have mainly focused on strategically targeting underrepresented biodiversity features. For example, Jantke et al.[27] found that inefficiencies of marine protected areas in representing ecoregions now require a total of 16.3% of national waters to be protected to meet current representation objectives, as opposed to just 10.3% if representation was prioritized from the inception of the first global target in 1982. Similarly, Venter et al.[26] found that >30 times more species could be protected for the same amount of area if protected area growth had targeted underrepresented threatened vertebrates from 2004 to 2014. It is clear that most countries do not seem to be strategically establishing protected areas to improve representation, and in fact, many achieve similar representation scores than if protected areas had been placed randomly.[59] However, prioritizing underrepresented habitats and species in future protected area establishment efforts has the potential to produce large gains in representation, while increasing the extent of protected areas globally, and would likely only be marginally more expensive.[60]

Representation is affected by both gains and losses in protected area extent. Protected area downsizing and degazettement, which together with downgrading are referred to as PADDD, result in a loss of protected area and thus may potentially influence representation of habitats and species. The potential impacts of PADDD on representation have yet to be quantified, but protected area downsizing and/or degazettement of underperforming or poorly sited protected areas, or compensating for PADDD events by increasing the extent or legal protection category of another existing protected area, has been proposed as a mechanism to increase the overall biodiversity value, coverage, and habitat representation within protected areas if done strategically.[48,50] For example, by replacing the bottom 1% of least cost-effective protected areas in Australia, Fuller et al.[50] found that representation of habitat types could be tripled. However, such approaches must be done carefully, because if replacement or compensation efforts result in protection of less important areas, it could weaken already inefficient protected area systems.[61]

It is important to note that meeting habitat extent and range-based representation objectives do not necessarily ensure a species or habitats persistence,[60,62] and as discussed above, the levels of protection necessary to abate biodiversity loss are unknown and difficult to quantify.

Beyond 2020

Without careful consideration of conservation investments and budget allocation decisions between actions, biases are bound to arise (or be perpetuated) that will have an impact on the overall conservation outcomes that can be delivered through protected area establishment. We highlight evidence-based research that provides guidance on how to allocate finite resources (e.g., budgets, amount of area) to better achieve Aichi Target 11 objectives within a system model framework. A complete system model of conservation allows for a holistic understanding of the possible options a practitioner may have, as well as a way of ensuring that an optimal set of actions is selected from all possible actions rather than a subset dictated by orthodoxy or convenience. We demonstrate our framework using Aichi Target 11, but the same principles can apply more broadly to all 20 targets of the 2010–2020 strategic plan for biodiversity, and more generally to any decision-making process (Box 1). The critical need of this framework has largely been absent from many post-2020 objective proposals to date. However, the significant research efforts that have unveiled the patterns of protected area establishment and biodiversity decline in relation to current conservation objectives provide the ability to foresee and adapt post-2020 objectives to minimize the potential for perverse outcomes.

The research described here largely tests budget allocation decisions based on two general and differing modeling approaches: maximizing gains (e.g., representation, species retention) or minimizing losses (e.g., reducing extinction debt). Specific objectives aimed at maximizing gains or minimizing losses have been proposed and, due to their reliance on both protection and management, could be used to measure progress toward the goal of safeguarding biodiversity and halting its decline.[61,63] However, previous research has shown that approaches aimed at maximizing gains can overallocate budgets to more secure areas while underallocating budgets to areas or species more likely to be lost.[64–66] Clearly outlining the goal (e.g., maximizing or minimizing) of each objective and recognizing and accounting for potential trade-offs will be essential to ensure the same shortfalls that arose from maximizing and prioritizing area-based objectives are not repeated in future conservation efforts and objectives.

In order to evaluate potential trade-offs, most of the models described here clearly define each action and associated land or seascape state that relate to Aichi Target 11 components and set separate objectives and measures for each objective (Figure 1). This systems analysis approach recognizes the organized relationships between objectives of Aichi Target 11, which are ultimately intended to work together to protect biodiversity and slow its decline. Such an approach can help define the desired state that an objective and/or action is meant to achieve, which is currently lacking.[63] A better understanding of the system states, actions, and potential trade-offs can increase efficiency and flexibility while reducing costs and risks, leading to a greater return on conservation investments. Thus, unnecessary trade-offs, such as representing or protecting habitats and species, can be avoided, and potential synergies within and between objectives can be maximized.

Several other proposed post-2020 protected area objectives have highlighted the importance of documenting the state of both habitats and species[61] and incorporating this information into metrics to evaluate net conservation outcomes.[67] Within our framework, the clear states within Aichi Target 11 suggest that each state should have a separate objective and measure of achievement, often referred to as SMART objectives (specific, measurable, achievable, realistic, and timebound). However, many of these recently proposed post-2020 objectives purposely remove guidance on specific actions needed to reach these objectives and do not necessarily follow the SMART framework. While some argue that this eliminates the problem of "what counts as protected?",[61] allowing for more flexibility in reaching conservation goals, it could also make objectives even more ambiguous in terms of habitat states, conservation actions, and metrics, and create significant and perhaps disadvantageous wiggle room in conservation accounting. Further, devolving specific guidance within targets may simply reinforce the tick box approach, whereas a systems state framework forces meaningful measures of progress against individual actions and objectives.

We generally agree with the need for more outcome-focused objectives that relate to the desired end state that is to be achieved from specific conservation actions. By reframing objectives in terms of desired goals (e.g., increasing or stable trends in biodiversity or other goals such as increasing food security or carbon mitigation [Box 1] within a specified time frame) the conservation actions—protect, manage, represent—can be seen as a means to an end, instead of the end itself (as is currently the case). Outcome-focused objectives still require a unified and broad understanding of the system states, the threats that must be addressed to shift between these states, and the suite of actions that can be taken to achieve the desired trajectory. Without incorporating scientifically based recommendations within such a framework, there is significant risk of the ineffective use of conservation resources (e.g., time, money) and effectively "re-inventing the wheel" of determining conservation actions to achieve outcomes. Further, transferability of successful conservation actions between locations may be more difficult without a systems framework, because comprehensive accounting of conservation actions and investments to reach desired outcomes may be limited or non-existent.

No matter what the post-2020 framework outlines for protected area objectives, budget trade-offs will always exist between conservation actions due to the inherent costs of conserving habitats and species and the limited availability of resources and funding, making it essential to adapt and learn from budget allocation models. While conservation

Box 1. Generalized Models and Other Grand Challenges Facing Humanity

Conserving habitats and species are intrinsically linked to many other grand challenges facing society including food security and carbon mitigation. The same modeling approaches described here for achieving biodiversity conservation and Aichi Target 11 objectives can also be used to explicitly tackle aspects of these challenges. Explicitly stating goals and carefully matching the problem formulation to outlined objectives to achieve these goals can help identify novel and more cost-effective solutions that can ultimately provide multiple benefits and balance trade-offs for humans and nature. We summarize specific examples below.

FOOD SECURITY

The global human population is expected to reach nearly 10 billion by 2050, creating serious concern about our ability to sufficiently feed the growing population. This is particularly true as human development continues to degrade natural habitats, and conservationists call for more of the remaining intact landscapes to be conserved. However, many modeling approaches aimed at increasing biodiversity, often using standing biomass as a proxy, also incorporate minimum harvest levels to ensure the optimal decision considers the need to provide food into the future. For example, McGowan et al.[46] found that investing in no-take marine protected areas can reduce harvest to a point where it no longer becomes optimal, particularly for large budgets. By incorporating minimum harvest levels in this model, important trade-offs between protected area establishment and food security become apparent and can be used to guide the most cost-effective actions for these two potentially competing goals.

CARBON MITIGATION

Deforestation and forest degradation are major sources of greenhouse gas emissions and are the second leading cause of global warming worldwide. REDD+ is a carbon mitigation program that aims to stop deforestation and forest degradation while promoting sustainable forest management and has accrued significant funding commitments to implement and advance programs in nearly 50 countries globally. While REDD+ remains focused on carbon mitigation, many have recognized its potential to simultaneously benefit biodiversity conservation. Venter et al.[68] for example, specifically considered five management and protection strategies within Indonesian forests. They found that where REDD+ programs are present, biodiversity conservation efforts are most cost-effective when they focus on areas that are neglected by REDD+, unveiling important trade-offs in determining the most efficient way to simultaneously pursue biodiversity conservation and carbon mitigation. Importantly, they emphasize that without explicitly considering both biodiversity and carbon mitigation objectives, opportunities for multiple benefits are easily missed.

COASTAL PROTECTION

As sea levels rise and extreme weather events become more prevalent, the value of natural coastal protection becomes increasingly more evident. Coastal marine ecosystems, such as seagrass meadows, coral reefs, and mangrove forests, play a large role in natural wave attenuation and coastal protection. However, these habitats are threatened by actions on land, such as agriculture and urbanization, that cause run-off, sedimentation, and poor water quality. By modeling four potential habitat states (protect habitat on the land, protect habitat in the ocean, restore habitat on the land, and restore habitat in the ocean), Saunders et al.[69] discovered that marine restoration should be prioritized in many cases, especially when marine habitat extent is relatively stable or when marine habitat degradation is high and terrestrial habitats are relatively intact and have low rates of vegetation decline. This explicit modeling approach questioned the conventional wisdom that marine protected area establishment and/or land restoration are the two most cost-effective actions for maintaining coastal ecosystems and solidified the importance of considering how and when land and sea habitat states influence each other.

budgets often have limited fungibility due to donor or spending commitments, understanding how investment decisions affect system pathways and states can help reduce perverse outcomes and direct fungible resources to compensatory actions. Nearly all analyses that have modeled conservation actions based on different budget allocations have concluded that the optimal decision is largely dependent on three factors: the rate of habitat degradation, the relative costs of actions, and time lags between actions.[11,15,16,44,46,70] It is essential that these components are considered when making decisions, however, they are rarely explicitly and transparently included in the conservation decision process (e.g., costs[71]) and are not recognized as important within international conservation objectives.

In order to allocate funds more effectively for biodiversity conservation, more attention must be paid to how finite conservation funds are spent.[72] The majority of conservation scientists would agree, we need more of the world set aside for biodiversity. While the exact percentage needed to safeguard habitats and species into the future is unknown, scientists have provided clear recommendations for ways to improve current and future protected areas and management actions to achieve more for habitats and species. These guidelines, and the factors that have been identified as important in these decisions, need to be explicitly and transparently incorporated into international conservation agreements post-2020 to ensure better conservation outcomes in the future.

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AUTHOR CONTRIBUTIONS

C.D.K., A.L.M.C., H.P.P., and V.M.A. developed the initial idea for the manuscript and the proposed framework. C.D.K. drafted the manuscript, and A.L.M.C., H.P.P., and V.M.A. provided significant feedback to refine the organization, text, and figures. A.L.M.C. performed the analyses to quantify the current system states and pathways.

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