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China's endemic vertebrates sheltering under the protective umbrella of the giant panda

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Abstract: *The giant panda attracts disproportionate conservation resources. How well does this emphasis protect other endemic species? Detailed data on geographical ranges are not available for plants or invertebrates, so we restrict our analyses to 3 vertebrate taxa: birds, mammals, and amphibians. There are gaps in their protection, and we recommend practical actions to fill them. We identified patterns of species richness, then identified which species are endemic to China, and then which, like the panda, live in forests. After refining each species' range by its known elevational range and remaining forest habitats as determined from remote sensing, we identified the top 5% richest areas as the centers of endemism. Southern mountains, especially the eastern Hengduan Mountains, were centers for all 3 taxa. Over 96% of the panda habitat overlapped the endemic centers. Thus, investing in almost any panda habitat will benefit many other endemics. Existing panda national nature reserves cover all but one of the endemic species that overlap with the panda's distribution. Of particular interest are 14 mammal, 20 bird, and 82 amphibian species that are inadequately protected. Most of these species the International Union for Conservation of Nature currently deems threatened. But 7 mammal, 3 bird, and 20 amphibian species are currently nonthreatened, yet their geographical ranges are <20,000 km^2 after accounting for elevational restriction and remaining habitats. These species concentrate mainly in Sichuan, Yunnan, Nan Mountains, and Hainan. There is a high concentration in the east Daxiang and Xiaoxiang Mountains of Sichuan, where pandas are absent and where there are no national nature reserves. The others concentrate in Yunnan, Nan Mountains, and Hainan. Here, 10 prefectures might establish new protected areas or upgrade local nature reserves to national status.*

Keywords: endemic species, forest ecosystem, giant pandas, priority setting, protected areas

Los Vertebrados Endémicos de China y su Resguardo bajo la Sombrilla Protectora del Panda Gigante

Resumen: *El panda gigante* (Ailuropoda melanoleuca*) atrae recursos desproporcionados para la conservación. Buscamos determinar qué tanto este énfasis protege a las demás especies endémicas de China. La información detallada para las plantas y los invertebrados no estuvo disponible, así que restringimos nuestros análisis a las aves, mamíferos y anfibios para los cuales había disponibilidad de mapas de distribución en Birdlife International y en la Lista Roja de la UICN. Usamos los datos de extensión de estas fuentes para identificar los patrones de la riqueza de especies. Después identificamos cuáles especies son endémicas de China y cuáles especies, como el panda, viven en los bosques. Después de refinar la extensión de cada especie de acuerdo a su extensión conocida en el gradiente de elevación y de mantener el bosque como el hábitat determinado para la teledetección, identificamos al 5% de las áreas más ricas como centros de endemismo. Las montañas del sur, especialmente las montañas Hengduan del este, fueron centros para los tres taxones. Más del 96% del hábitat del panda se traslapó con los centros de endemismo. Así, invertir en casi cualquier hábitat del panda beneficia a muchas otras especies endémicas. Las reservas naturales nacionales en las que se protege al panda cubren a todas salvo a una de las especies endémicas que se traslapa con la distribución del panda. Para China en su totalidad, son de particular interés 14 especies de mamíferos, 20 de aves y 82 de anfibios que no están protegidas adecuadamente. La Unión Internacional para la Conservación de la Naturaleza enlista a la mayoría de estas especies como amenazadas, pero 7 especies de mamíferos, 3 de aves y 20 de anfibios están actualmente como no amenazadas, aunque sus extensiones geográficas sean < 20, 000*

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km² después de considerar la restricción de la elevación y el hábitat permaneciente. Estas especies estuvieron concentradas principalmente en cuatro áreas: Sichuan, Yunnan, las montañas Nan y Hainan. En Sichuan hubo una concentración alta en el este de las montañas Daxiang y Xiaoxiang, en donde los pandas están ausentes y no hay reservas naturales nacionales. En las cuatro áreas mencionadas, si 10 de las prefecturas establecieran áreas protegidas nuevas o actualizaran las reservas naturales locales a la condición nacional, estarían protegidas más especies endémicas.

Palabras Clave: áreas protegidas, ecosistema de bosque, especies endémicas, establecimiento de prioridades

Introduction

China is exceptionally diverse. It holds many types of ecosystem (Liu et al. 2003) and harbors 15% of the world's vertebrate species and 12% of all plant species (Kram et al. 2012). Although China is confronting serious environmental problems during its rapid social and economic development (Wu et al. 2014), it has emphasized conservation of biodiversity in recent years (Wang et al. 2007; Wandesforde-Smith et al. 2014; Xie et al. 2014). Importantly, the total protected area has expanded 35-fold since 1980 (Liu et al. 2003; Liu & Diamond 2005; Xu & Melick 2007; MEP 2013; Xie et al. 2014). We ask: how well has China allocated these areas to protect its diversity?

A simple part of the answer is that like other nations, it has protected high elevation and sparsely vegetated lands disproportionately (Xie et al. 2004; Jenkins & Joppa 2009). Unlike other nations, China has the global icon of endangered species, the giant panda, to which China and international organizations devote exceptional resources. How well does this emphasis protect other vertebrate species?

By 2010, China had dedicated 18% of its land to conservation in >8000 protected areas (Xie et al. 2014). These include nature reserves, forest parks, scenic areas, and national parks. They vary in the level of legal protection and effectiveness. Thus, they differ in their capability to protect effectively their species (Singh 1999; Xie et al. 2014). Nature reserves are the most important as well as the best protected class (Xu & Melick 2007). By 2013, China had established 2669 nature reserves covering 1,497,900 km^2 (this excludes Taiwan, Macau, and Hong Kong). Of this, the Ministry of Environmental Protection (MEP) estimated that in 2013 1,433,800 km^2 was terrestrial, some 14.9% of the land area. The remainder was marine. This is substantial progress toward the Convention on Biological Diversity's Aichi Target 11, which seeks to protect 17% of a country's area (CBD 2011). What should China protect next to meet that target?

Some 69% of this total is in the 4 western and northern, arid or high (or both), and sparsely populated regions of Tibet (413,689 km^2), Xinjiang (214,944 km^2), Qinghai (218,222 km^2), and Inner Mongolia (136,890 km^2). The majority of the reserves are 10–100 km^2 (40%) and 100–1000 km^2 (34%). The largest size category (>10,000 km^2) contains only 19 nature reserves, but covers 58% of the total reserve area (MEP 2013). Nature reserves are small in central and eastern China, where human activities dominate (Wu et al. 2014).

There are 2 administrative levels: national and local. The latter includes provincial nature reserves, municipal nature reserves, and county nature reserves. National nature reserves cover 62.5% of the protected areas and 9.8% of the total land area (MEP 2013). Moreover, although only 52.2% of the local nature reserves have established managements, all national nature reserves have established corresponding entities (MEP 2013). Compared with local nature reserves, national-level reserves usually receive more financial resources (Li et al. 2013).

In addition to this uneven geographic coverage, there is an uneven coverage for species conservation. From 2007 to 2014, the number of nature reserves targeted mainly at giant pandas doubled from 34 to 67 (State Forestry Administration 2015). They now cover 33,600 km^2—some 7.5% of the 450,055 km^2 of protected areas that lie outside the 4 less populous provinces listed above.

Charismatic and threatened species, especially giant pandas, have drawn disproportionately from other conservation resources (Lu et al. 2000). Around 48 pandas are loaned to other countries with an annual fee about $1 million per pair to support their conservation in China. In addition to these fees from zoos, in 1993, the Chinese government created the National Panda Program with US$5 million support and announced a new Wildlife Conservation and Nature Reserve Development Program (WWF 2004). It listed the panda first among 15 targeted flagship species in 2002. This plan aims to improve the infrastructure, management, education, research, and monitoring capacity of the existing 34 panda nature reserves, and to establish 28 more panda reserves, a monitoring station for each of the 55 counties with panda distribution, breeding, and reintroduction centers, and encourage research. The main budget includes US$5 million per new nature reserve and breeding center from 2001 to 2010 and US$7.5 million from 2011 to 2030 (National Development and Reform Commission 2007). A national panda survey takes place every decade lasting 3–4 years. It covers >43,600 km^2 and with DNA analysis in the survey starting in 2011 (State Forestry Administration 2015). In addition, large, international nongovernmental organizations have been actively involved in panda conservation since the early 1980s.

Does emphasizing a single species jeopardize China's vast array of biodiversity (Kram et al. 2012)? Might the focus on the panda harm less attractive species that are underrepresented in the conservation agenda, such as small mammals (Ceballos & Brown 1995; Entwistle & Stephenson 2000)? Giant pandas are widely recognized as flagship species with their possibility to protect broader biodiversity (Lu et al. 2000). Yet, there is no study that quantifies the effectiveness of how much of the range of other species—especially other forest species—it can protect.

To assess effectiveness, we map the distributions of amphibians, birds, and mammals to ask several questions. First, what are the patterns of species diversity and endemism in China? As in previous studies (Harris & Pimm 2008; Schnell et al. 2013; Ocampo-Penuela & Pimm 2014), we start with published range maps and then see how data on elevation preferences and remaining vegetation cover modify these distributions. Second, we consider the species that International Union for Conservation of Nature (IUCN) defines to be threatened. As in previous studies, we assess whether other species might be added to this list in light of our updated predictions of their remaining ranges.

Third, we ask how well the giant panda protects China's other vulnerable species. Finally, we ask how well the existing national nature reserves cover these crucial regions of endemism and how one might make improvements.

Methods

Study Area and Species

We compiled the species lists for terrestrial mammals and amphibians from the IUCN (2014) and for terrestrial birds from BirdLife International (2014) for China. We include Hong Kong, Macao, Hainan, and Taiwan. Some 608 mammal, 1342 birds, and 394 amphibian species have part or all of their ranges in China.

To define which species are endemic to China, we created a 100 km buffer around its political boundary. If a species' range entirely falls in this area and has more than 80% of its range in China, then we defined it as endemic. This includes species that are mostly within China, but range outside, although it excludes species with very small ranges that fall mostly within the 100 km buffer. For birds, we only considered their resident or breeding ranges. So defined, our study includes 132 mammal species, 117 birds species, and 250 amphibian species.

Among these species, the IUCN Red List (IUCN 2014*a*) classified 65 mammal, 78 bird, and 96 amphibian species as threatened species— that is, vulnerable, endangered, or critically endangered. In addition, IUCN identifies 23 mammals and 62 amphibians as data deficient.

We produced richness maps for each taxon to identify patterns of biodiversity by summing up all the available range maps. Because *Oreolalax weigoldi* lacks spatial distribution data, we mapped only 249 amphibian species.

Patterns of Biodiversity in China

Although the IUCN range maps provide useful initial guidance, they encompass areas that are not suitable habitats for species. Thus, we refined the range maps first by elevational range and then by suitable vegetation type for each species. We excluded species that are data deficient from this step onward because the data are inadequate to identify their habitats.

We collected elevational data from BirdLife International and the IUCN Red List. To supplement the missing information from these sources, we also searched for individual studies. We used elevational data from the 90 m resolution Digital Elevation Model from the NASA Shuttle Radar Topographic Mission.

We extracted information about preferred habitats for each bird species from BirdLife International, which lists the principal habitats under a class they call level 1. We extracted corresponding vegetation types from the global land cover map GlobCover Version 2.3 2009 with 300 m resolution from the European Space Agency. Then we produced a species-specific habitat map for further trimming. We compiled similar information for mammals and amphibians from IUCN Red Lists. Matching habitat descriptions to land cover classifications need not be easy for they are independent sources with potentially different definitions.

Excluding data deficient species, data on endemic species suggest that about half (53 mammals, 49% of total; 73 birds [62%] and 121 amphibians [64%]) are principally forest species. Often their habitat descriptions include shrublands as well. Inspection of where shrublands are shows that they are usually in the transitions from forest to other habitats in mountainous areas or areas with historical human disturbance like logging (Fig. 1). Species that use both forests and shrublands mainly depend on forests: the highest percentage of shrublands in a species' range is 35% among our target species. We define forest species as those that exclusively use forest or use both forest and shrubland as suitable habitats.

Species that use other habitats are not so readily matched to maps of other land use cover classifications. For these, we cannot confidently trim their ranges by remaining habitat.

Range Map

After refining each species' range by elevation and habitat, we summed the ranges to produce a richness map for each taxon. To compare the key areas across different taxa without the influence from differences in the

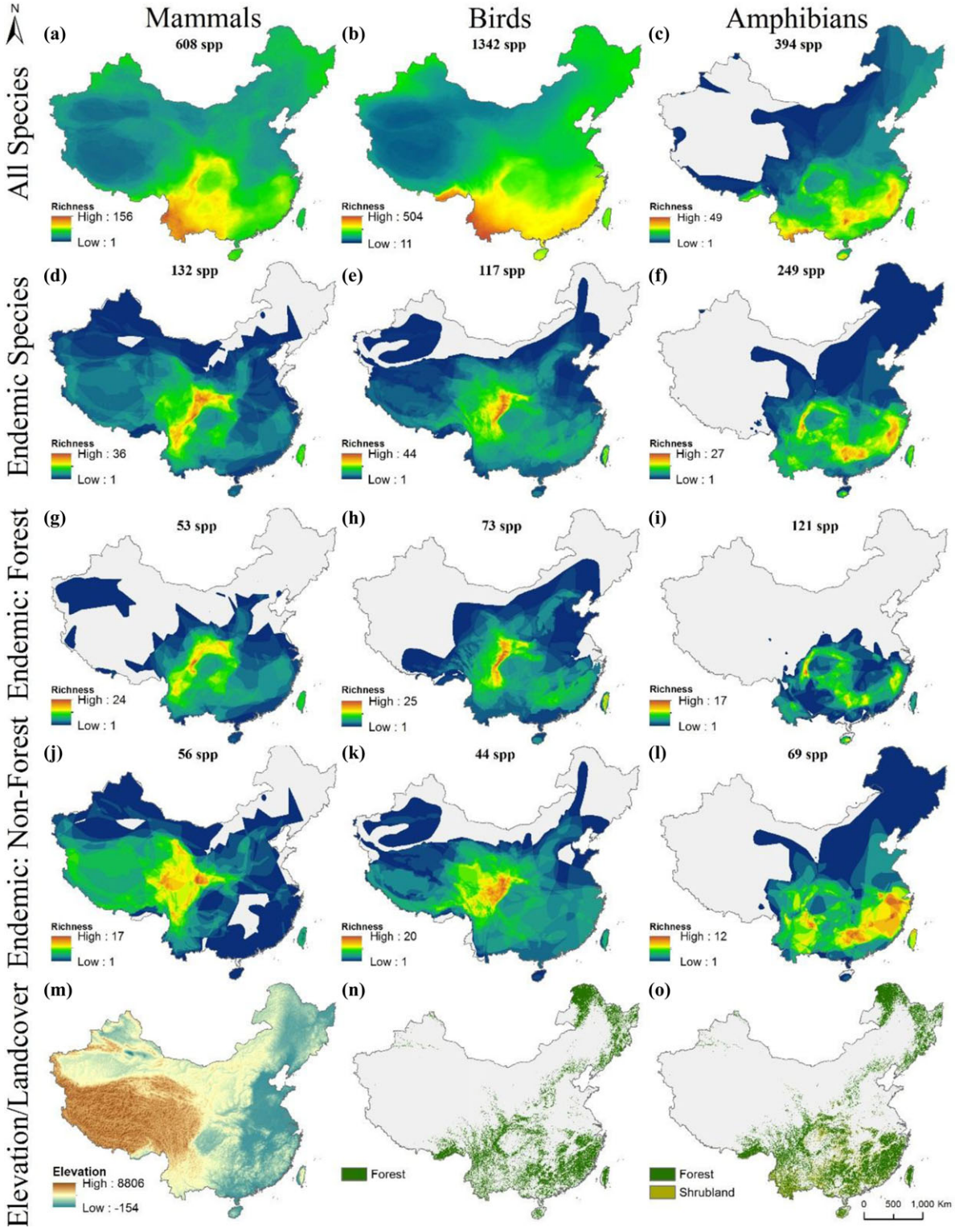

Figure 1. Species richness maps for China. (a-c) show all the species that occur in China for mammals, birds, and amphibians. The second row (d-f) shows the endemic species (see text for definition). The third row (g-i) shows the distribution of endemic forest species, and the fourth row (j-l) shows the nonforest species. (m) shows the elevational range of China, (n) is the distribution of forests, and (o) shows the distribution of both forests and shrublands. The land cover types are from ESA 300 m land cover map.

number of species, we identified the center of endemism by selecting the top 5% richest land areas of forest and shrubland for each taxon (Jenkins et al. 2013). Thus, by simply summing up 3 centers, we were able to rank the importance of different regions according to the extent of overlap for 3 taxa.

Nature Reserve and Gap Analysis

Peking University's Center for Nature and Society compiled the spatial boundary data for national nature reserves. Information about some national nature reserves is incomplete either because the spatial data were not available at that time or because a nature reserve was upgraded afterward. We supplemented these data by digitalizing maps from the website of MEP. There were 395 terrestrial national nature reserves established before 2014. From this section on, we only consider mainland China and Hainan. We exclude Hong Kong, Macao, and Taiwan and their endemics because they have different protected area systems. For species occurring on both the mainland and these islands, we only analyzed the range on the mainland.

In a conservation context, J. M. Scott developed and pioneered implementation of gap analysis in the late 1970s as a consequence of seeing the incomplete coverage of concentrations of threatened Hawaiian birds by the existent network of protected areas (Scott et al. 1987; Scott et al. 1993). It is widely used as a method to identify gaps of protected area network in representing or supporting the survival of target species or ecosystems (Margules & Pressey 2000).

There is a large body of literature on what should be the minimum level of protection. We adopted criteria from Watson et al. (2011). If a species' geographic range was $<10{,}000$ km^2, then the target of coverage was set to be the smaller of 1000 km^2 or 100% of the range. If the range was $>10{,}000$ km^2, the target was at least 10% of the range. If a species had less area protected than the target, then for simplicity, we called such inadequately protected species a gap species.

We also evaluated the coverage of current national protected areas in conserving the endemism centers. We calculated the percentages of 1-, 2-, and 3-taxa centers that fell within the national protection network.

Role of the Giant Panda

We overlapped the giant panda distribution and the endemic centers. Then, we calculated the area of giant pandas' range that falls in each category, 1-taxa, 2-taxa, and 3-taxa center, respectively. We also calculated how the giant panda national nature reserves cover the endemic species that overlap with giant panda distribution.

Identifying Priorities for Future Conservation

For all the endemic species, we focused on threatened species and nonthreatened species with their remaining ranges $<20{,}000$ km^2. We called these endemic species of concern. (Parenthetically, the range size of 20,000 km^2 is the threshold to consider the species as threatened by IUCN. This applies to the range size before being refined by elevational limits and remaining habitats. Nonetheless, we retain this threshold to flag potential threatened status.)

As many species lack information or adequate studies of their life history or population size, range size becomes a key factor in identifying their vulnerability (Harris & Pimm 2008). We define gap species of concern as those that are both gap species and endemic species of concern. To direct future conservation efforts more effectively, we mapped the distribution of all the gap species of concern and summed up their remaining ranges. This process produced a map to reveal the high concentration of gap species, where future conservation priorities should be.

We applied one-way ANOVA to test the statistical differences between groups. Post hoc test, Turkey-Kramer HSD was implemented in conjunction with ANOVA for the following 3-way comparison. We used Pearson's χ^2 to compare the composition difference between 2 samples.

Results

The greatest numbers of bird, mammal, and amphibian species are in the tropical province of Yunnan, along the border with Myanmar, Laos, and Vietnam (Figs. 1a & 1c). Although all 3 taxa share general trends, they differ in details. Mammal richness reaches farther north to the Qinling (Fig. 1a, Supplemental Fig. 1 is a map with the places names used in the text). Although birds are similar to mammals, high numbers extend more to the east, along the southern coastal lowlands (Fig. 1b). Amphibian richness differs from the other taxa and is highest in southeast China (Fig. 1c).

The highest endemism distributes along the easternmost edge of the Tibetan Plateau (Figs. 1d-f). This area is perpendicular to the main Himalayan chain and mainly constitutes the eastern Hengduan Mountains (which includes the Min Mountains, Qionglai Mountains, Daxue Mountains, and Gaoligong mountains). Total richness and endemism differ because the former include species that occur in adjacent countries, whereas the latter do not (Orme et al. 2005). Endemic mammals concentrate south to the Gaoligong Mountains and north to the Qinling and the Daba Mountains (Fig. 1d). Endemic birds concentrate in the central Hengduan Mountains (Min, Qionglai, and Daxue Mountains) and Qinling (Fig. 1e). Because most of the amphibians that occur in China are endemic species, the pattern of total richness matches that of the endemism. Except for the southern tip of Yunnan Province, amphibians still show a high concentration in southeast China with 2 distinctive areas (Fig. 1f). One is the Wuyi Mountains in Fujian and Jiangxi Province.

Table 1. Summaries of the numbers of species in each category and overlap of areas.

No. of species		*Mammal*	*Bird*	*Amphibian*
All species occur in China		608	1342	394
Endemic species		132 (22%)	117 (9%)	249 (65%)
Endemic forest species		53	73	121
Species for gap analysis		45	53	112
Occur on mainland		43	50	101
Overlap with giant panda distribution		30	35	31
Small-range species	gap species	11	13	72
$<$10,000 km^2	0% coverage	2	1	20
	Total	13	14	73
Large-range species	gap species	18	23	33
$>$10.000 km^2	0% coverage	0	0	0
	Total	32	39	39
Gap species of concern		14	20	82
Coverage from panda NNR				
Overlap with panda NNR		31	34	32
Average coverage		7%	6%	11%
Single species priority areas		8%	9%	1%
Any 2 taxa		13%		
All 3 taxa		10%		

The other is the Nan Mountains along the boundaries of Guangdong, Guangxi, and Hunan Province.

The highest concentrations of forest endemics for all 3 taxa are in the forest biomes of central and southeast China, especially its montane areas (Figs. 1d-f). The patterns of total endemism are mainly driven by forest endemic species (Figs. 1g-h). Nonforest mammals and birds have a clear high concentration on the eastern Tibetan Plateau where the most important 3 rivers of Asia (Yangtze River, Yellow River, and Mekong River) originate.

Refining the IUCN Ranges by Elevational Range and Available Habitat

As one trims the published ranges by elevational limits and available habitats, range sizes shrink (Harris & Pimm 2008; Schnell et al. 2013; Ocampo-Penuela & Pimm 2014). Moreover, they sometimes shrink substantially, especially for species in mountainous regions and where habitat destruction is extensive. Furthermore, some species that IUCN designates as nonthreatened sometimes show refined ranges smaller than those it deems as threatened. Appendix 4 in the Supporting Information lists each forest species, its original range, the range trimmed by elevation, and then by habitat, how much of it is protected, and how much of it is protected by reserves established for pandas.

Centers for Endemic Forest Species in China

Figures 2(a) and (c) show the patterns of forest endemism in China. After trimmed by elevational range and remaining vegetation type, the species' range and the distribution of endemism are obviously highly fragmented. We set the top 5% forest and shrubland area with the highest richness as the endemic center for each taxon (Figs. 2d–f). In addition to the arch of the area formed by the Hengduan, Qinling, and Daba mountains, Yunnan and Taiwan are important areas for endemic mammals (Fig. 2d). Similar to mammals overall, the differences between birds and mammals are that instead of Yunnan, the Nan mountains in southeast China and Taiwan are rich in endemic birds (Fig. 2e). Amphibian richness is high in the arch, but absent from Qinling (Fig. 2f). The Nan Mountains, the Wuyi Mountains in Southeast China, and Hainan are centers of endemism. The eastern edge of Himalaya in central China, mountainous areas in the southeast, and Taiwan are crucial regions for endemics of all 3 taxa (Fig. 2h).

The giant panda range overlaps with 70% of the forest bird species, 70% of forest mammals, and 31% of forest amphibians that are endemic to mainland China (Table 1). Ninety-six percent of its range falls in the endemic centers (Fig. 2). Some 13% of its range falls in the center for 3 taxa, 58% falls in the center for 2 taxa, and 25% falls in 3-taxon center. Thus, by directing conservation efforts into panda habitats could protect 28.6% of the 3-taxa center and 17.1% of the two taxa center.

Gap Analysis for National Nature Reserves

Figure 2(g) shows the distribution of 395 national nature reserves established up to 2014. The concentrations of endemic species lie elsewhere, however. Overall, national nature reserves cover 6.9% of the area that are important for 1 taxon, 19.2% for 2, and 13.0% for 3 on mainland and Hainan. Amphibians have a higher percent-

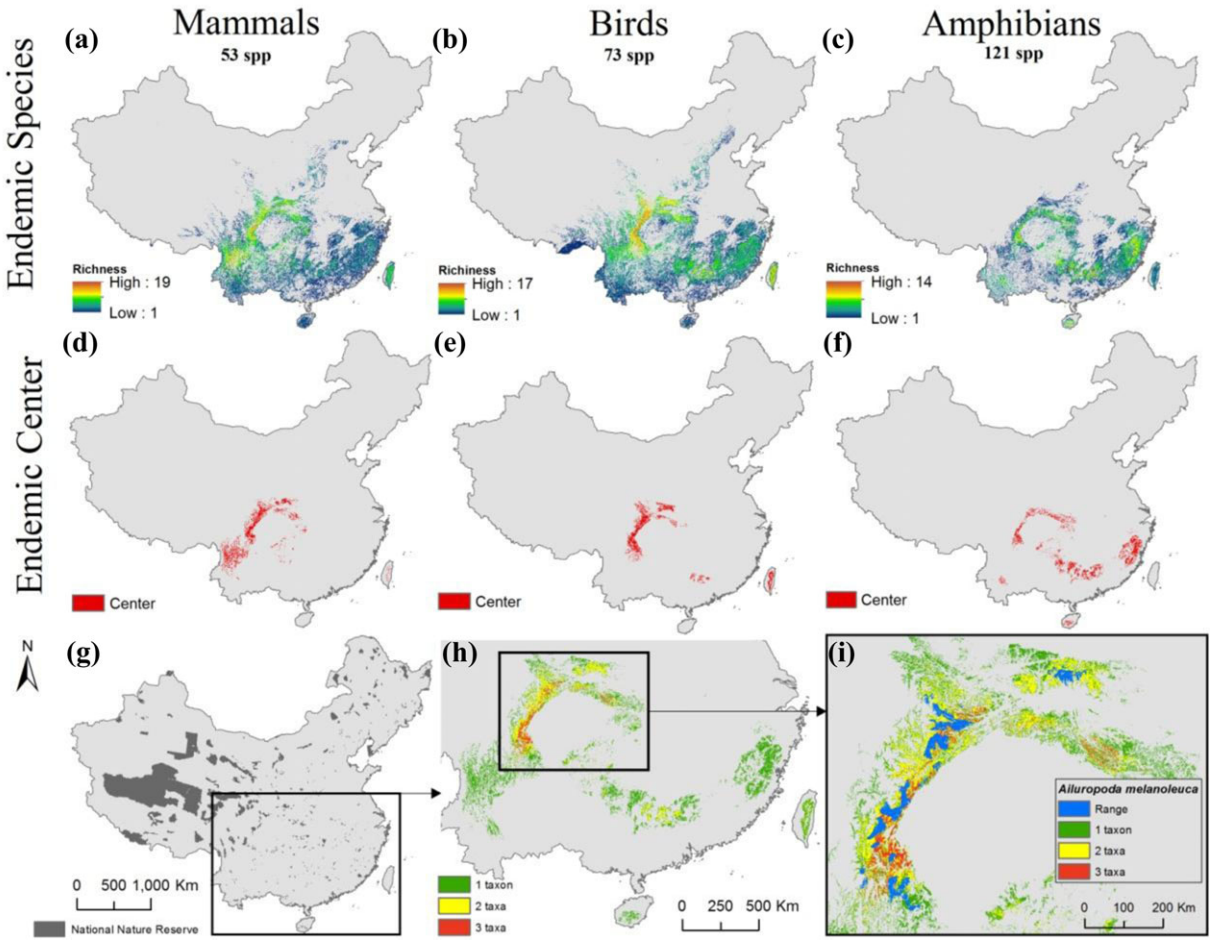

*Figure 2. (a-c) show the numbers of forest endemic species after refined by elevational ranges and suitable habitats. The second row (d-f) shows the endemic centers for each taxon (see text for definition). The third row shows the distribution of national nature reserves (g), overlap of endemism centers for 3 taxa (h), and the relationship between these areas and the giant panda (*Ailuropoda melanoleuca*) distribution (i).*

age of gap species—those without adequate protection—than do birds and mammals (Table 1). Small-range species are less protected in terms of proportion of gap species as well as the number of species without any protection (Table 1). The nature of small ranges makes it easier to miss the coverage of these species in the national nature reserve network. Amphibians receive the least protection compared with birds and mammals: 99% of small-ranged amphibian species, and 85% of large-ranged species are not adequately protected. Mammals are the most effectively protected taxon in terms of percentage of species that reach the target coverage.

The national nature reserve system has significant higher coverage for threatened species than for nonthreatened species (one-way ANOVA, $P < 0.003$). Although nonthreatened endemic species have an average of 8.9% ± 6.2% of the range under protection, threatened species are 6.7% higher (15.6% ± 22.5%). Nonetheless, the threatened species are usually small-ranged species. Compared with 22% of the nonthreatened species that have ranges <10,000 km^2, about 77% of threatened species are small-ranged species. As a result, though the coverage of protected areas is higher for threatened species, it is far from the target coverage. This leads to a higher proportion (91 %) of gap species for threatened species, compared with 73% for nonthreatened species ($\chi^2 = 10.73$, $P < 0.01$).

The gap species of concern include 14 mammal, 20 bird, and 82 amphibian species. Interestingly, where these species concentrate strongly overlaps with the richest area for endemism (Fig. 3). This is similar to the global pattern (Rodrigues et al. 2004). Most of the concerned gap species of mammals are in the area east to Mount Gongga of central Sichuan and southern Hengduan Mountains in northern Yunnan Province (Fig. 3a). Gap species of birds mainly distribute along the edge of Sichuan basin, Hainan, and southeastern provinces. The highest concentration of gap species is primarily in Daxiang Ling and Xiaoxiang Ling (south to Qionglai Mountains), and Nan Mountains along the boundaries of Guangxi, Hunan, and

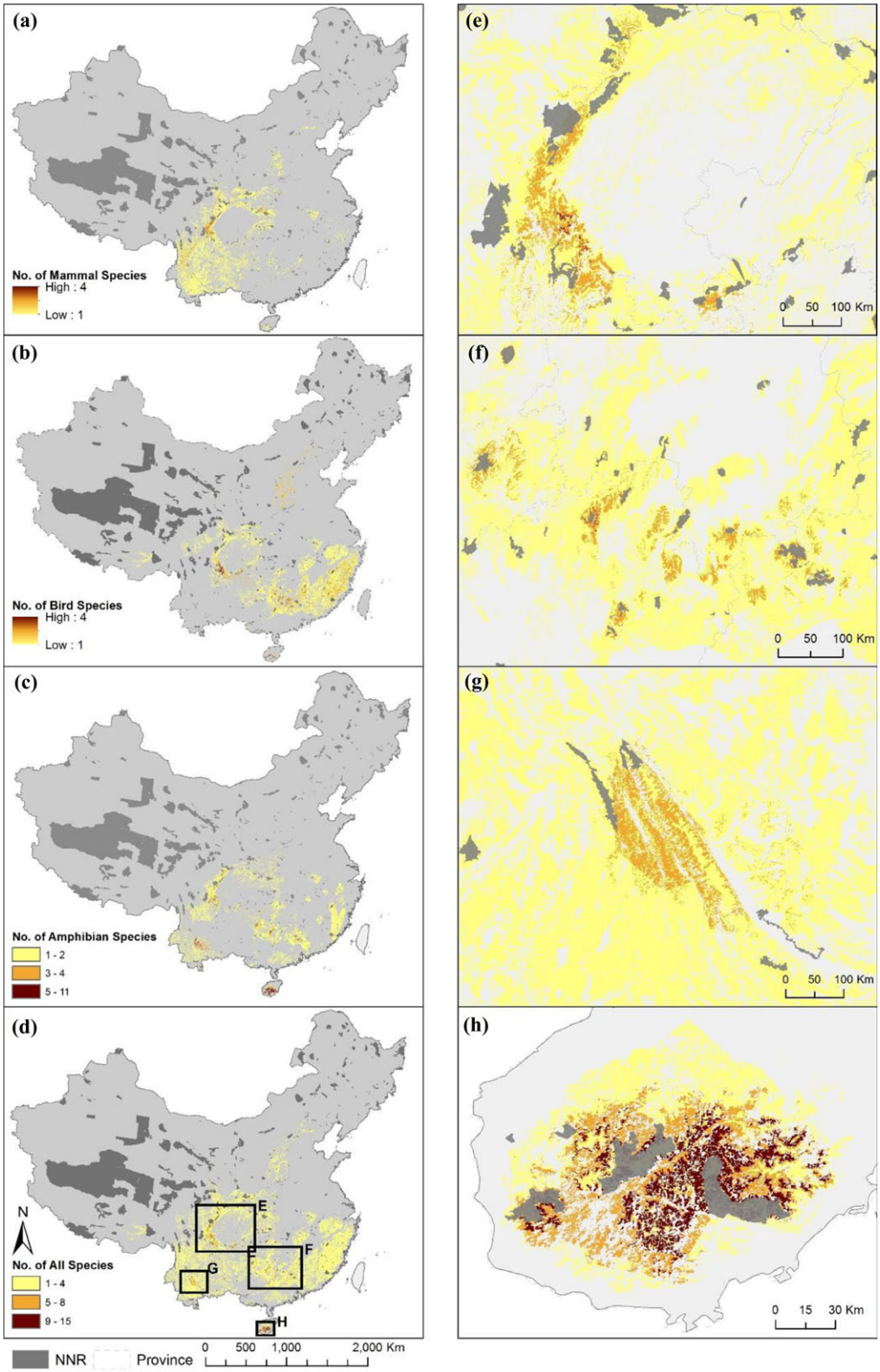

Figure 3. Distribution of endemic species in conservation gaps. These species are either threatened species or non-threatened species with remaining ranges smaller than 20,000km^2. (a-c) show gap mammal species, gap bird species, and gap amphibian species. (d) is for all gap species. Grey polygons show the distribution of national nature reserves in these areas. (e-h) are enlargements of areas of high concentrations of gap species. (e): Sichuan; (f): the Nan Mountains; (g): Yunnan; (h): Hainan.

Guangdong Province (Fig. 3b). Gap amphibian species are mainly in the mountainous area to the west of Sichuan basin, central Yunnan, and southeastern provinces, a pattern similar to that for birds (Fig. 3c). Hainan province shows a high concentration of gap amphibian species. National nature reserves only cover a small portion of these gap species ranges or miss the whole range of some species (Fig. 3d). Local nature reserves cover some of the areas. As many of them lack administrative entities, management, and clear boundaries, it is hard to evaluate whether they provide effective protection.

Coverage by Giant Panda National Nature Reserves

Except for one bird species, *Phylloscopus emeiensis*, the national nature reserves devoted for the giant panda protection include all the endemic forest species that overlap with the panda distribution. They also cover 25% of the *Scutiger ningshanensis*'s range and 1% of the *Cansumys canus*'s range. Neither overlaps with the giant panda distribution. On average, panda reserves protect 7% $\pm$ 7% of these mammals' range, 6% $\pm$ 5% of birds' range, and 11% $\pm$ 19% of the amphibians' range. These are about half of average coverage from all national nature reserves for mammals (14%) and bird (11%), but just slightly lower for amphibians (12%).

Panda reserves cover 8% of endemic center for mammals, 9% for birds, and 1% for amphibians. They also protect 13% of the 2-taxa center and 10% of the 3-taxa center.

Concerned Species for Future Conservation

Some species that IUCN identifies as nonthreatened and least concerned are likely more vulnerable than expected. When ranges are trimmed by elevation limits and available habitats, 4 nonthreatened mammal species (*Cansumys canus*, *Chodsigoa lamula*, *Chodsigoa smithii*, and *Lepus yarkandensis*), 3 bird species (*Certhia tianquanensis*, *Phoenicurus alaschanicus*, and *Phylloscopus emeiensis*), and 10 amphibian species (*Amolops daiyunensis*, *Amolops lifanensis*, *Oreolalax lichuanensis*, *Oreolalax schmidti*, *Oreolalax xiangchengensis*, *Paramesotriton hongkongensis*, *Rhacophorus zhaojuensis*, *Theloderma rhododiscus*, *Xenophrys binchuanensis*, and *Xenophrys omeimontis*) have their remaining ranges falling below 5000 km^2. Only *C. tianquanensis* is under adequate protection from the national nature reserves.

Six more nonthreatened mammal species, 3 bird species, and 12 amphibian species have their remaining range size less than 20,000 km^2. One bird species (*Babax waddelli*), 3 mammal species (*Blarinella quadraticauda*, *Myotis davidii*, and *Niviventer excelsior*), and 10 amphibian species (*Bufo cryptotympanicus*, *Ichthyophis bannanicus*, *Leptobrachium ailaonicum*, *Odorrana lungshengensis*, *Oreolalax popei*, *Paramesotriton caudopunctatus*, *Tylototritontaliangensis*, *Xenophrys glandulosa*, *Xenophrys jingdongensis*, and *Xenophrys mangshanensis*) are inadequately protected by the criteria defined in our article.

Priority Settings for Endemism

Interestingly, where most gap species concentrate are also the areas of the richest endemism (Fig. 3). Setting future priorities to fill in the conservation gaps could also enlarge the protection for endemic species in general. For example, Sichuan has 18.5% area protected (6.0% under national protection), ranking the third in China. (It is just behind Tibet and Qinghai where vast areas have very low human densities.) Because of the high concentration of endemism, many species are unprotected despite the large percentage of current protection.

There are 4 major gap species concentrations: central Sichuan, central Yunnan, Hainan, and Nan Mountains along the borders of Guangxi, Guangdong, Guizhou, and Hunan Province (Figs. 3e–h). For Sichuan, the prefecture cities Ya'an, Leshan, and Meishan have the most gap species, where pandas are mostly absent (Fig. 2i). Some of the areas are protected by provincial nature reserves. These need more resources for their management. Hainan also has a high concentration of gap species especially in the central and western part (Appendix S3 lists specific areas).

Discussion

Patterns of Biodiversity in China

China's endemic species are now largely confined to mountainous areas. These areas suffer less from anthropogenic influences (Korner & Spehn 2002; Tang et al. 2006). Even the road network expansion has been slower there than other areas because of the huge cost (Li et al. 2010). Since the late 1990s, forests have become an important target for protection under the large national level policies such as the National Forest Protection Program. This includes a national logging ban and reforestation projects, and Sloping Land Conversion Program (Xu & Melick 2007). Although the actual effects need to be scrutinized continuously, these efforts have nonetheless reduced large-scale deforestation (Li et al. 2013). Thus, the topographic complexity coupled with national level policy for forests harbors the remaining habitats for endemic forest species.

Our study shows differences in the centers of endemism from a previous study (Lei et al. 2003). This discrepancy is because of the selection of forest endemic species and the use of different data. We point out that another important area for birds, the Nan Mountains, has

not been mentioned (Lei et al. 2003). Although different taxa share common areas for high species richness, there is an obvious difference in their patterns. Amphibians are distinctive compared with birds and mammals. This raises a concern of using single taxon as a surrogate for all taxa (Rodrigues et al. 2004). If the intention is to inform crucial areas for different groups of wildlife, one should take into account the differences and weigh the importance according to richness and threats for each taxon with concern.

The Giant Panda as an Umbrella

The giant panda serves as an umbrella species: 96% of its range overlaps with the centers for at least 1 endemic taxon. This overlap means that directing resources to almost any panda distribution area or restoration of forest to connect habitat fragments could lead to the protection of the richest forests for endemics. We caution that although it shows the important role of giant pandas and the existing panda reserves, one should look beyond them. There is a significant gap in Daxiang Ling and Xiaoxiang Ling in Sichuan, a center for all 3 taxa, but with few pandas.

Future Species of Concern

Many species currently not listed as threatened likely have smaller ranges than previously thought. These small-ranged species should receive immediate scrutiny. IUCN (2012) requires information on population or geographic range to list a species as threatened. Compared with range size, population estimates are usually hard to get (Harris & Pimm 2008). Of course, the conservation community should regularly evaluate species ranges and estimate population sizes. Our methods have limitations, but they shed light on the need for exploration and focus on where assessments need particular care. With the rapid development of land cover products at finer scale with free access and large platforms for sharing species occurrence data regionally and globally, we believe it could promote the conservation work on these understudied species.

Data for Systematic Conservation Planning

Incorporating more information into IUCN range maps can change priority settings. Although the general patterns are consistent, issues may appear when it comes to practical implementation. From the global Aichi target to the national commitment of 20% of land area protected by China (IUCN 2014*b*), conservationists usually set a percentage of land that will be put aside for conservation. The priorities may change, and some key areas will be missing if they do not incorporate necessary information to refine the relatively coarse ranges to inform national strategy.

Protected Areas and Gaps

Compared with charismatic mammals and birds, amphibians are less attractive to the public as well as to previous conservation planners. The taxonomic bias lead to fewer nature reserves specifically designed to protect them. Conservation planning should pay more attention to amphibians and other neglected taxa. Although the national nature reserve network does a better job in covering threatened species, it is still inadequate to support long-term survival considering their small ranges. Besides continuing work on these threatened species, small-range nonthreatened species should be another focus as we have discussed above. The gaps identified in our analysis not only show a lack of coverage in certain areas, but also reveal a problem with the existing national nature reserves. Even though they are in the right place, many reserves are too small to provide sufficient geographic protection for the surrounding endemic rich areas (Fig. 3f). Admittedly, other gaps may be covered with local nature reserves or other forms of protected areas. These local level nature reserves can be the candidates for future national nature reserves. They can also turn into opportunities for the establishment of other forms of protected areas such as national parks (Wang et al. 2012) or private protected areas (Stolton et al. 2014) that China is exploring.

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Supporting Information

Detailed Map of China (Appendix S1), refining ranges of IUCN (Appendix S2), and subregions for future conservation (Appendix S3) and species lists and the estimates of remaining habitat and protection (Appendix S4) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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