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Prioritizing avian conservation areas in China by hotspot scoring, heuristics and optimisation

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Abstract. A quantitative process for the conservation analysis of 179 endangered birds of China is presented. At first, for each bird species its conservation priority status was assessed by calculating its conservation priority index (CPI), using six protection attributes (e.g. extinction risk, taxonomic uniqueness, public appeal). Second, based on the birds' conservation status, prioritisation by alternative approaches was performed. A hotspot score, a heuristic and an optimisation approach were used. The territory of China was divided into 583 grid cells (1° x 1°). The efficiency of the current network of protected areas was tested by comparing it with data obtained from prioritization. Analyses indicated that 28 species should be classified as highest conservation priorities, 13 of them were recommended for inclusion to the national wildlife protection list. The optimisation method for area selection was shown to be superior to the heuristic and hotspot approaches, since it selected more currently unreserved high priority areas whilst keeping the total number of sites low. It is proposed that seven Important Bird Areas (IBA's) should be added to the current protected area network. The suggested avian conservation assessment procedure can identify previously overlooked endangered bird species and candidate priority areas for conservation throughout comparative approaches.

Key words: avian conservation priority, area prioritization, complementarity, hotspots, China, biodiversity

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INTRODUCTION

Realization of the goals in avian conservation depends to a great extent on the continuous works of preserving species distributional areas. This include the procedure of important bird areas (IBA's) identification. Birds' inherent conservation status plays an essential role in constructing a robust and well-built nature reserve network (Dhar et al. 2000, Xie 2003). Therefore, selecting avian priority areas considering species conservation priority characteristics would be an efficient and economical route in the context of implementation of a detailed conservation project (Given & Norton 1993, Griffin 1999, Rodríguez et al. 2004, Greenbaum & Komar 2005). As a matter of fact, focusing on threatened species is an efficacious way in conservation planning. Threatened species might be regarded as a surrogate in reaching regional conservation objectives (Das et al. 2006). However, to date, the integrity between avian conservation assessment and their priority areas have not been investigated. Studies seldom have combined the two procedures into conservation planning. Although some have carried out studies throughout merging the two procedures (Rodríguez et al. 2004, Greenbaum & Komar 2005), the combination of alternative priority areas selection approaches and comparisons of these approaches based on species conservation status have not been investigated.

To address these issues China — one of the megadiversity countries worldwide and with a total number of species making up more than one tenth of the world's total — was selected as a representative area for performing the analysis. There have been also recently a few systematic studies with regard to biological conservation in China, which are incommensurate to its diversified species and its impact on Asian and global biodiversity. Lei et al. (2003) identified conservation hotspots of Chinese endemic birds at generic level with hotspot method. Yip et al. (2004, 2006) selected small reserves for the human-dominated region of Hong Kong principally by using complementarity-based methods. These works initiated progresses in the quantitative assessment of the region. Correspondingly, upon the basis of assessing species conservation priority status, important avian areas in China were categorised for two purposes. Firstly, it could be of great help to conservation of tremendously threatened species in China, and secondly it provided a model for analyzing species readily in other areas using my proposed process.

Identifying priority areas, quantitative approaches gained much concern because they excluded subjective attributes in allocating conservation resources. Two main classes of systematic approaches were often used for selecting priority areas: scoring and complementarity principles (Abellán et al. 2005). In the scoring principle, the areas are ranked according to their specific scores (such as richness, rarity, high priority scores). Only the top scoring areas are retained and the selection procedure can be achieved. In contrast, complementarity principle approaches receive growing interests for its high efficiency (Williams et al. 1996).

For the purpose of promoting an integrative conservation assessment system of birds, a simple technical way was utilized to introduce a more robust procedure in conservation planning: firstly, setting conservation priority for each species by multiple criteria, then employing alternative approaches to identify priority areas for threatened birds and detect possible conservation network gaps (Rodríguez et al. 2004, Yip et al. 2006). To sum up, the goals of the study were to make attempts to: 1) identify threatened bird species with high conservation priority that have been overlooked, 2) provide various approaches to rational selection of bird important areas and compare the discrepancies of these approaches, 3) test the efficiency of current protected areas network for protecting threatened birds and recommend some areas that have been previously overlooked.

METHODS

Data

The threatened species were chosen as the target because they gained more attention in practice. Synchronously, I merely considered the well documented and surveyed ones. Threatened bird species were classified using the China Species Red List (Wang & Xie 2004). Only the species that are assigned to following categories: Critical Endangered (CE), Endangered (EN), Vulnerable (VN) and Near to vulnerable (NT) were considered. A total number of 179 threatened birds, identified in China Red List were considered in this study. The distribution records were collected from literature (Cheng et al. 1978, 1987, 1991, 1995, Cheng 2000, MacKinnon et al. 2000), and web-sites: China Species Information Service (CSIS; http://chinabiodiversity.com/), UNEP-WCMC (http://www.unep-wcmc.org/ species/index.htm/). A database involving more than 9000 records (species/distributional locations/precise coordinates) was constructed. I then compiled a matrix, to implement the alternative area prioritization approaches (Beger et al. 2003, Benayas & Montaña 2003, Fox & Beckley 2005, Yip et al. 2006).

Approaches

Bird conservation priority. To assess threatened birds' conservation status, I used the Conservation Priority Index (CPI) (Cofre & Marquet 1999) to assign each bird a priority score. The value of CPI for each bird is a combined priority score by summing the values assigned to each attribute.
The scoring formula is:

$$CPI=\sum_{i=1}^{n} P_i$$

where P_i denotes the score of the i-*th* attribute I considered, n represents the number of attributes. In this study, six attributes were used, five objective and one subjective (Rodríguez et al. 2004). The objective ones were extinction risk (ER), degree of endemicity (DE), taxonomic uniqueness (TU), hierarchy of national protected species lists (HN), and hierarchy of CITES (Convention on International Trade in Endangered Species) (HC). The subjective attribute is public appeal (PA). The assessment value for each attribute is provided in Rodríguez et al. (2004) and explained in Appendix.

Alternative approaches for area prioritization

I used different alternative approaches for selecting priority areas based on two principles (Fox & Beckley 2005): hotspot and complementarity. The territory of China was divided into 583 grid cells (1° × 1°) to perform the following analysis, which include explicit distributional records (Fig. 1).

Fig. 1. All of 583 grid cells used for the study for which threatened bird distribution records existed.

Hotspot method. This is a scoring manner method. The score for each grid cell was calculated as follow:

$$PA_S = \sum_{i=1}^{N} CP_i$$

where PA_S is the score of the grid cell, CP_i is the priority score for the i-th species occurring in that grid cell, N is the total number of species occurred in that grid cell. In this study, the number of selected hotspots was established as 5% of the total 583 grid cells (Williams et al. 1996, Sfenthourakis & Legakis 2001). So herein only the top 30 grid cells remained could be classified as the most important.

Heuristic method. The heuristic method was implemented taking into account priority scores of particular areas (PA_S). For each grid cell, the priority site score was calculated as follow: the grid cell with the highest priority score was nominally reserved and removed from the matrix, together with all of the species that were present in that grid cell. The priority score for each remaining grid cell was recalculated and the next highest grid cell was continued until all species were represented in the selected grid cells at least one time. If more than one grid cell was selected in iterative time, I selected the one with highest species richness (PA_S/N , where the highest ratio is N the species number in the grid cell); if there were still ties, I selected the adjacency to one of the priority cells that have been maintained in the selection procedure over one that was not.

Optimal method. In this method, species has to be represented in the priority set at least one time, and all the sites were weighted based on the categories of their priority scores. If the priority score of the grid cell was larger than 200 ($PA_S \geq 200$), the value 1 were assigned; moreover if the score was larger than 100 but less than 200 ($100 \leq PA_S < 200$), the value 2 were assigned; others regarded as low priority score sites were weighted value 3 ($PA_S <$ 100).

$$\text{Min} \sum_{j=1}^{n} c_j X_j$$

where n was the number of grid cells, variable X_j was 1 — if cell j was selected and 0 if otherwise; c_j was the weight of priority score of cell j ($c_j = 1$ if categorized into high priority score sites, 2 — if categorized into median priority score sites, and 3 — for other low priority score sites, n = 583). Subject to the constraints:

$$\sum_{j=1}^{n} a_{ij} X_j \geq 1 \quad i=1, 2, \ldots, m$$

$$X_j \in \{0, 1\} \; j=1, 2, \ldots, n$$

where m was the number of species, herein $m = 179$, a_{ij} was 1 — if species i was present in cell j and 0 — if otherwise.

To obtain different combinations of optimal solutions and prevent a set (S) of s grid cells that has already been selected from being selected again, the following constraint was added successively (Rodrigues et al. 2000, Pérez-Arteaga et al. 2005, Yip et al. 2006).

$$\sum_{j \in S} X_j \leq s\text{-}1$$

The analysis was performed by implementing the linear programming software LINDO Release 6.1 (Lindo Systems Inc. 1999).

RESULTS

Conservation priority status of threatened birds

The value of CPI for 179 species ranged from 8 to 21 (Fig. 2). Siberian White Crane *Grus leucogeranus* obtained the highest CPI of 21, Red-crowned Crane *Grus japonensis* of 19, Brown Eared Pheasant *Crossoptilon mantchuricum* and Crested Ibis *Nipponia nippon* both obtained 18. 28 birds belonged to the category of high conservation priority (CPI ≥ 15), and 109 birds belonged to the category of median conservation priority (10 ≤ CPI ≤ 14). The remaining 42 birds were included in the category of low conservation priority (CPI ≤ 9).

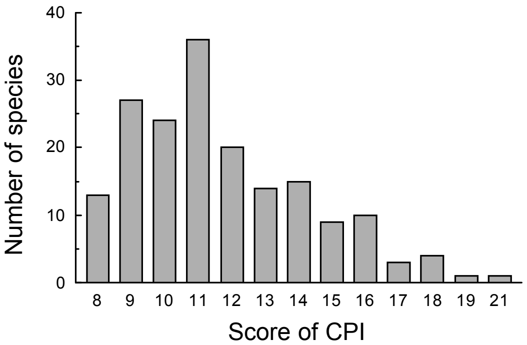

Fig. 2. Histogram of conservation priority index (CPI) for threatened birds in China.

Using calculated birds conservation priority status, it was possible to make a list of birds recommended for further protection that were not listed in the governmental wildlife protected list, but had fairly high CPI value (CPI ≥ 15): Mikado Pheasant *Syrmaticus mikado* (CPI = 17), Chinese Monal *Lophophorus lhuysii* (CPI = 17), Chinese Crested Tern *Sterna bernsteini* (CPI = 16), White-headed Duck *Oxyura leucocephala* (CPI = 15), Great Pied Hornbill *Buceros bicornis* (CPI = 15), Sclater's Monal *Lophophorus sclateri* (CPI = 15), Chestnut-throated Partridge *Tetraophasis obscurus* (CPI = 15), Tibetan Rosefinch *Carpodacus roborowskii* (CPI = 15), Tibetan Eared Pheasant *Crossoptilon harmani* (CPI = 15), Oriental White Stork *Ciconia boyciana* (CPI = 16), Great Bustard *Otis tarda* (CPI = 16), Elliot's Pheasant *Syrmaticus ellioti* (CPI = 16), and Chinese Merganser *Mergus squamatus* (CPI = 15). These 13 birds were recommended to add into the national protected wildlife list or other conservation planning list.

Area prioritization of birds using alternative approaches

Priority scores *PAs* for all grid cells ranged from 9 to 476. 69 grid cells scored above 200 (*PAs* ≥ 200), 135 grid cells scored above 100 but below 200 (100 ≤ *PAs* < 200), and the other 379 grid cells scored below 100 (*PAs* < 100).

Thirty priority areas selected by hotspot approach fairly evenly distributed in southern, eastern and northern areas and none lie in northwestern dry regions (Fig. 3A). One grid cell was not fallen into current protection network. The priority areas could save only about 77.7% (139 birds species) of the total threatened birds.

The heuristic method yielded 27 priority sites for protecting 179 birds at least one time (Fig. 3B). Four grid cells are not included in the current protected area network.

The optimal method generated two alternative solutions which merely selected 25 priority sites that could represent all birds at least one time. The best one was selected based on the greater number of unreserved sites (Fig. 3C). Six grid cells were detected to be unprotected, and were different from those obtained using heuristic method.

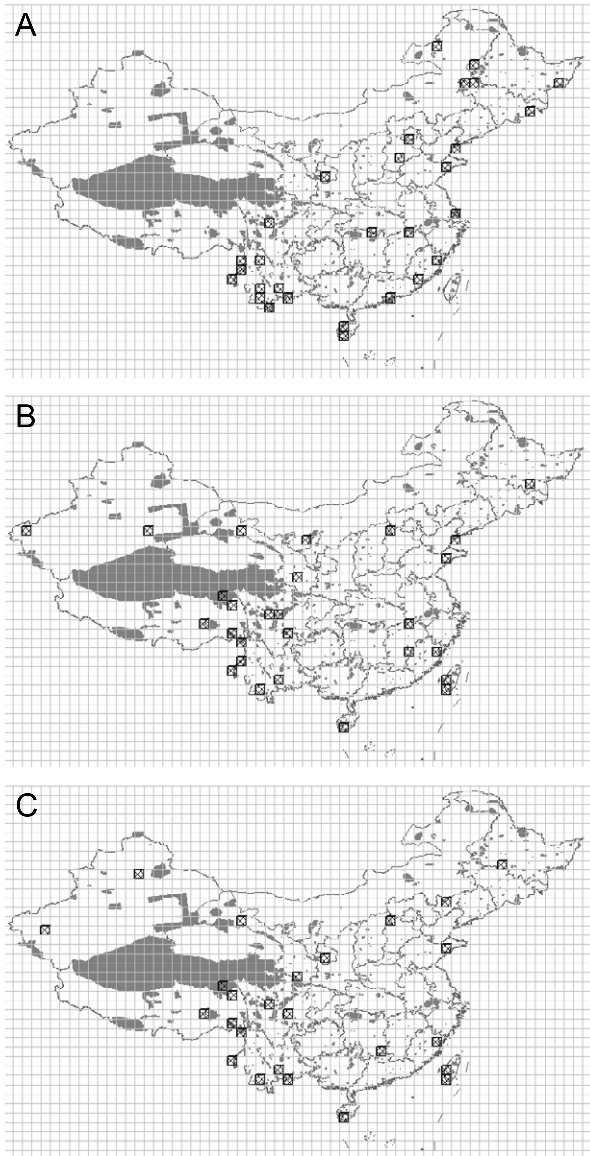

Fig. 3. Priority areas (grid cells filled in diagonal cross lines) obtained from: A — high priority scores hotspots approach. Top 29 cells are remained to represent 155 species. B — heuristic approach. 27 grid cells are selected to represent all 179 species at least one time. C — optimal approach. 25 grid cells could represent 179 species at least one times. Areas marked in grey color represent current nature reserve network.

Comparing the priority areas sets from alternative approaches, 7 grid cells are recommended for protection (Fig. 4), because they were underestimated previously (http://chinabiodiversity.com/) but had important threatened bird resources and rather high priority scores (*PAs* ≥ 100). They should be considered for inclusion in future conservation planning.

DISCUSSION

Assessment of bird conservation priority

Traditionally, in most of previous works, identification of priority areas has been based on equal value of species. However, rare and threatened species should gain higher priority compared with those widely distributed ones. As pointed out by Thiollay (2002), "the conservation value of species, more than their mere number, should be the main criterion for the selection of a protected area". In addition, due to limited budgets, we cannot count on protecting all the large amount of species (Araujo 1999). Representative surrogates are sometimes needed. To reflect birds' different conservation protected merits, in the inequality of linear programming solutions areas are weighted based on their priority value derived from calculation of summed species CPI.

The selection of attributes for assessing bird conservation priority status is still a controversial issue. Attributes were often recognized as objective formerly and the subjective elements were diminished commonly. Nevertheless in practice, species subsistence is strongly affected by human perception. For that reason subjective attributes were integrated in some recent studies (Cofre & Marquet 1999, Rodríguez et al. 2004). Public appeal may be the best of the subjective attributes for it could be quantified by setting classifications of people's awareness to different threatened species. For the purpose of making this subjective attribute more quantitative, I classified the returned queries of internet searching engines as one important criterion. It provides a simple approach to obtain the public awareness degree of the species. This approach is easy and suitable for those who cannot discriminate the species public awareness degree.

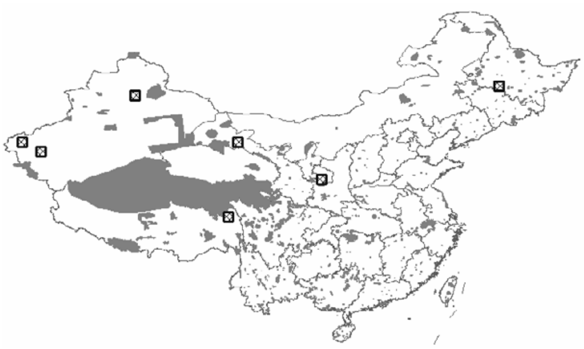

Fig. 4. Seven recommended areas (grid cells filled in diagonal cross lines) to be brought into current protected network. Areas marked in grey color represent current nature reserve network.

Generally, birds with high priority scores are symbols of biodiversity at national or provincial scale *per se*. This is one characteristic for carrying out species conservation priority assessment. Identifying avian conservation priority could promote public awareness of their values. For example, the Crested Ibis has very low populations and is reported that it had only one wild population since 2002 (http://chinabiodiversity.com/). This bird, mainly distributed only in Shananxi and Gansu provinces, has been regarded as a national treasure. Siberian White Crane, one of the most endangered birds worldwide, obtained the highest priority conservation score comparing to other species. More than 95% of the global population occurs within the mainland China. CPI method revealed also thirteen birds as recommended species for further consideration in protection practice. These species have high CPI values but narrow distributional ranges and not listed in key protected wildlife list (China Wildlife Conservation Association, http://www.cwca.org.cn/).

Comparison of bird priority sites selected by alternative approaches

Conservation achievement could not merely assign a value and status of each species. In fact, the true realization of preserving the species in practical activities should fell back on the establishment of priority areas for them. The foundation of priority protected areas could afford the species permanent settlements. Though the sizes and numbers of protected areas have increased greatly recently in China, there must be lots of underestimated gaps in the network. These gaps is that what affects the efficiency of reserve network (Wang & Xie 2004).

To find possible gaps in the protected areas and select important sites for birds, I used several comparative quantitative approaches. Since the conservation values of birds have provided helpful conservation information, my priority areas analysis treated birds unequally. In the performance of alternative approaches, hotspot method selected sites which had high summed value of species' CPI. Heuristic method employed the complementary scores of the sites that were calculated from species CPI. Optimal approach was carried out upon the basis of the category of sites which were grouped by species CPI. All methods have a prerequisite that birds have different conservation priority and are allocated different weight.

Priority set yielded from hotspot method showed relatively limited efficiency (Turpie et al. 2000) but offered useful priority areas information in the first place. This conclusion has been drawn analogously in Lombard et al. (1999) and Dunk et al. (2006), albeit thirty priority areas (5% of investigated grid cells) protect no more than 70% of total threatened birds. Interestingly, areas identified by hotspot method are shown robust when applying to other species groups (i.e. amphibians, reptiles and mammals, own data). In fact, areas regarded as high priority score hotspots are profound specific biomes driven by historical geological events (Eeley et al. 2001) where concentrated a great amount of high conservation value species. Some remarkable geological events in China, e.g. Quaternary Period, uplift of Qinghai-Tibet plateau and so on, drove most southwestern areas (mostly Yunnan and Sichuan provinces) to be the refuge areas for propagation of rare and endemic species. It has been reported (Wang & Xie 2004) that these special regions were priority areas for many taxonomic groups by alternative approaches, and particularly their prioritization could be well explored through hotspot method.

Heuristic method revealed 27 priority sites and found 4 currently unprotected areas, whereas linear programming method retained only 25 sites to protect all species and found 6 currently unprotected areas. Both methods could optimally select fewer grid cells to preserve total species comparing to hotspot method. The results also demonstrated the disadvantage of heuristic approaches, and the power of linear programming in reserve selection. In addition, heuristic approaches could not achieve some constraints easily, such as satisfying the representative times of species in priority set etc, reversely optimal method could achieve multiple objectives and seek out all optimal solutions easily by adding constraint successively. Sets resulting from approaches based on complementarity principle could obtain some areas that have never been considered previously. These areas should gain more attentions in posterior steps of conservation programming. More importantly, seven grid cells should be brought into the current protected area network because there are many threatened species inhabited these grid cells but have not been covered by the network yet.

It is essential to improve data quality before carrying out area prioritization procedure. Distributional data completeness can greatly affect priority sites selection (Yip et al. 2006). The reason is explicit: Because the priority areas selection is based on the current sites, when adding new sites for consideration, the approaches are needed to re-implement and the sites re-selected. Before carrying out the study, a detailed distributional survey for each species is essential. In China, bird checklists have been well documented by several generations of specialists (Wang & Xie 2004). The data selected for the study were confirmed through literature-based validation.

Limitations and notations of the present study

Attribute scoring methods are known to give misleading results and have been discredited in the scientific literature (Pressey & Nicholls 1989, Burgman et al. 1999, Pressey 2002, Wolman 2006). Attribute scoring methods and combining attributes allocated to multiple criteria by summing them together is not ecologically meaningful. The main problem is that it is unclear what the combined values actually represent; the confusion can be demonstrated the lack of measurement units. Mathematically, these methods are not correct because it is unavoidable that the attributes may not be independent (e.g., extinction risk and hierarchy of national protected species list are likely to be dependent) and so should not be combined by addition. Moreover, a point scoring index does not provide any information about interactions between the criteria. The Conservation Priority Index presented in this study is actually a point scoring method so may suffer from these inadequacies. The employed attributes should be reconsidered to eliminate the intersection probability if the conservation priority setting here is expected to have wider application in practice.

This study focuses on conserving national biodiversity, thus why the degree of endemicity was included as a conservation priority attribute, the purpose of setting conservation priority is for constructing more robust national conservation network. Although it is the responsibility of all the nations worldwide to conserve global species, it is also the responsibility for all the nations to conserve their own species. Therefore it is eligible to pay necessary attentions to national or regional important species to reflect national attitude of biodiversity within its boundary due to governmental budgets.

Further implication for bird conservation

The advantage of using grid cell-based areas for study is that it can avoid the bias of different sizes of study areas. However, its shortcoming is that it does not consider the aspect of boundaries of priority areas. Most the boundaries of bird protected areas are polygons. How large areas should be used for protecting species economically? The grid cell-based approach cannot address the problem. In further study, I might emphasize on the sizes and boundaries of bird nature reserve integrating ecogeographical, biogeographical and climatological parameters.

The criteria of setting conservation priority status herein were considerably suitable for analysis of birds. However the same standards could not be used to investigate other taxa. For example, the method of scoring the public awareness by searching on the web cannot be simply applied to the study of invertebrate. Additional useful information should be allocated to decide their scores. For attribute taxonomic uniqueness, if I employ the same criteria to classify plant species, I find that many genera contain large amount of species, and therefore most of them are grouped into class 1 in the old criteria.

Thus far, I have exhibited a simple process for birds conservation assessment and associated habitat areas protection. However, further works are still necessary. It is significantly indispensable to take more attributes into account for comprehensive evaluation of the bird conservation status and consider their appropriateness. In general, some further works could focus on reassessment of priority areas integrating uncertainty analysis, selection of more biological, ecological or socioeconomic attributes for evaluating bird conservation status, construction of a database involving most ecological information on the threatened birds, which could contain detailed distribution ranges, physiological condition, habitat types, breeding types and their extinction estimation etc. and carrying out field studies as early as possible to find the ecological factors affecting threatened birds' survival.

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STRESZCZENIE

[Porównanie sposobów określania terenów ważnych dla ochrony ptaków na przykładzie Chin]

Proces ilościowego określania terenów ważnych dla ptaków w Chinach przeprowadzono w oparciu o analizy występowania 179 gatunków ptaków o wysokiej kategorii zagrożenia (od krytycznie zagrożonych do niemal narażonych). Do przeprowadzenia analiz przygotowano bazę danych obejmującą dokładne informacje o rozmieszczeniu tych gatunków. Następnie, dla każdego gatunku określono jego współczynnik "pierwszeństwa ochrony" (conservation priority index CPI) biorąc pod uwagę 6 cech: ryzyko wymarcia (ER), stopień endemiczności (DE), unikalność taksonomiczną (TU), stopień ochrony w Chinach (HN), stopień ochrony wg CITES (HC) oraz zainteresowanie społeczne (PA). Sposoby przypisywania określonych wartości poszczególnym cechom — patrz Appendix.

Na tej podstawie, używając trzech różnych metod określano hierarchie ważności poszczególnych terenów pod względem ochrony występujących tam ptaków. Terytorium Chin podzielono na 583 kwadraty wielkości 1° x 1° (Fig. 1), i porównywano obecnie istniejącą sieć terenów chronionych z tą otrzymaną w wyniku analiz. Zastosowano trzy metody: 1) "najważniejszych miejsc" (hotspots) — dla każdego kwadratu liczono sumę współczynników CPI wszystkich gatunków w nim występujących określaną jako *PAs*, następnie kwadraty uszeregowano względem najwyższego *PAs*, przyjęto 5% kwadratów z najwyższym *PAs* jako najważniejsze dla ptaków; 2) model heurystyczny — brano pod uwagę zarówno *PAs*, ale także liczbę gatunków występujących w kwadracie. Na początek wybrano kwadrat mający największy *PAs*, następnie usunięto z analiz wszystkie występujące w nim gatunki, co spowodowało, że ponownie przeliczono *PAs* dla wszystkich kwadratów i znowu wybrano kolejny kwadrat z najwyższym *PAs* usuwając następnie gatunki w nim występujące. Operację powtarzano do momentu, gdy wszystkie gatunki wystąpiły przynajmniej w jednym kwadracie; 3) metoda optymalizacyjna — szukano zestawu

kwadratów, w których każdy gatunek wystąpił przynajmniej w jednym kwadracie, i kwadraty charakteryzowały się wysokim *PAs*.

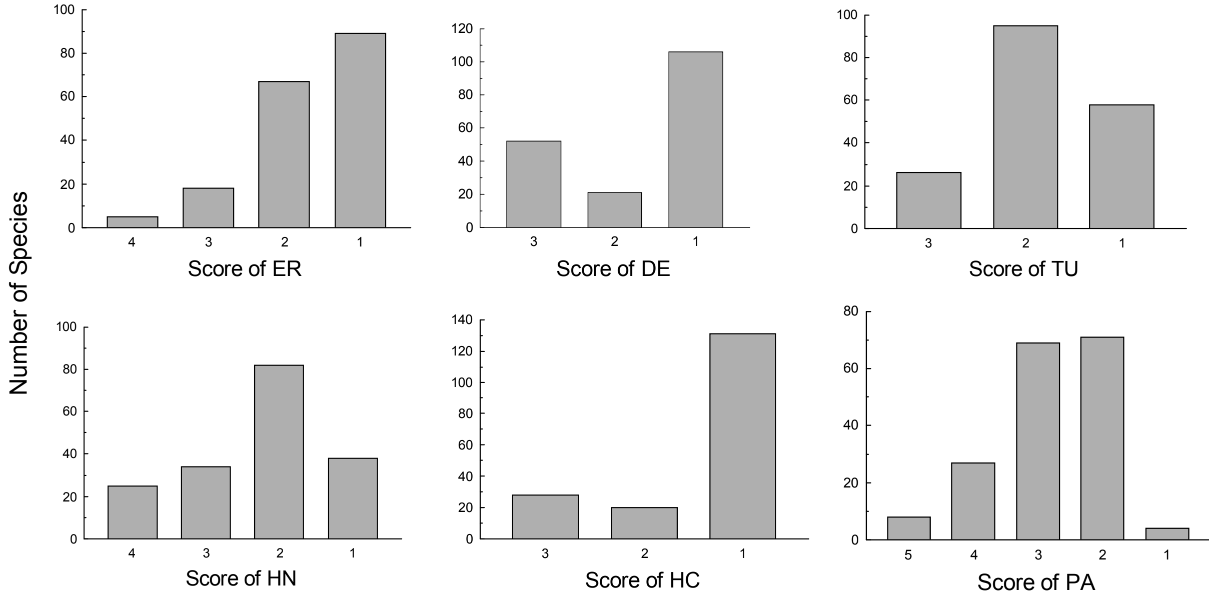
Wartość CPA wyliczona dla179 gatunków przybierała wartości od 6 do 21 (Fig. 2). najwyższą wartość przypisano żurawiowi białemu. 28 gatunków zaliczono do kategorii "wysokiej ważności" ze współczynnikiem CPI > 15. Stwierdzono, że 28 gatunków powinno być klasyfikowane jako te, które mają największe "pierwszeństwo ochronne", zaś 13 z nich powinno zostać włączone na krajową listę gatunków chronionych.

Wartości *PAs* dla poszczególnych kwadratów wahały się 9 do 476. Większość kwadratów wyznaczonych metodą "najważniejszych miejsc" znajdowała się na południu, wschodzie i północnym wschodzie Chin. Wszystkie prócz jednego pokrywały się z już istniejącymi terenami chronionymi (Fig. 3A). Wyznaczone w ten sposób tereny chroniły tylko 139 gatunków ptaków. Metoda heurystyczna wskazała 27 kwadratów koniecznych dla ochrony wszystkich 179 gatunków (Fig. 3B). Metoda optymalizacyjna wskazała ok. 25 terenów, na których wszystkie gatunki były przynajmniej raz reprezentowane. Metoda ta wykazała 6 terenów dotychczas nie objętych ochroną (Fig. 3C).

Metoda optymalizacji wyboru miejsc ważnych dla ptaków wydaje się być lepszą niż metoda heurystyczna lub poszukiwania "najważniejszych miejsc", ponieważ wykazuje więcej obecnie nie chronionych terenów o wysokim stopniu ważności, jednocześnie utrzymując liczbę tych miejsc na niskim poziomie. Na podstawie analiz stwierdzono, że 7 nowych Ostoi Ptasich (Important Birds Areas IBA) powinno być wyznaczonych i włączonych do sieci terenów chronionych Chin (Fig. 4).

Appendix. The detailed assessment value for each conservation attribute:

1. Extinction risk (ER): Taxa classified as Near to Vulnerable, Vulnerable, Endangered and Critically Endangered at the national level were assigned scores of 1, 2, 3 and 4 respectively.
2. Degree of Endemicity (DE): taxa that occupies less than 50% of the world are assigned a score of 1, taxa occupying more than 50% but less than 90% of the world are assigned 2, and bird that are completely endemic to China or of which > 90% of the global population falls with China are assigned 3.
3. Taxonomic Uniquenesses (TU): Birds belonging to a large genus (≥ 11 species, including sub-species) were assigned a score of 1, those belonging to a medium-sized genus (2–10 species, including sub-species) were assigned 2, and others belonging to a monospecific genus were assigned 3.
4. Hierarchy of National Protected Species List (HN): I consider species that listed in the national protected classification 1 have the score 4, species listed in classification 2 obtain score 3, species listed in Three Values Species (http://www.foresty.gov.cn/; http://www.cwca.org.cn/) are assigned the score 2, and others score 1.
5. Hierarchy of CITES (HC): This attribute reflects that species have commercial implications which should be paid attention to. Species listed in rank 1 of CITES are assigned score 3, listed in rank 2 are assigned score 2, and others are assigned score 1.
6. Public Appeal (PA): Species' public appeal is a critical attribute in contributing the success of species protection. Empirical knowledge could be used to discriminate people's favoritism for each species (Rodríguez et al. 2004). However, for each bird I use bird's name as query to seek the greater returned number of suited websites in Google (http://www.google.com/) or Baidu (http://www.baidu.com/) to decide which scores should be assigned. To avoid possible interferential returns, I set the query keywords using species scientific names not common names. I assigned a score of 5 to species most likely to become conservation symbols within China because they are highly valued by people. Scores from 2 to 4 were assigned to species that may obtain human attention degree from low to high respectively. A score of 1 was assigned to species that completely did not attract the interests of people. Hence score 5 denotes that the number of returned matched websites is ≥ 10 0000, and in turn score 4, 3, 2 and 1 denote the returned matching numbers ≥ 10 000 but < 10 0000, ≥ 1 000 but <10 000, ≥ 100 but < 1 000 and < 100, respectively. High score species that have more suited websites related with are often used as pets, hunted as food or commercial trade, or are part of significant cultural traditions.



Appendix. Fig. Histograms of each attribute. ER — extinction risk, DE — degree of endemicity, TU — taxonomic uniquenesses, HN — hierarchy of national protected species list, HC — hierarchy of CITES, PA — public appeal.