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Fanghao Wan
Mingxing Jiang
Aibin Zhan *Editors*

Biological Invasions and Its Management in China

Volume 1

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Invading Nature - Springer Series in Invasion Ecology

Volume 11

Biological Invasions represent one of those rare themes that cut across the disciplines of academic biology, while having profound environmental, philosophical, socioeconomic, and legislative implications at a global scale. There can be no doubt that biological invasions represent the single greatest threat to biodiversity past the activities of humankind itself. The implications are far reaching. Novel ecological and evolutionary forces are now directing the future expression of life itself, as native species and the communities that they comprise contend with invading species. The rules of the game have been suddenly and irrevocably changed.

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Biological Invasions and Its Management in China

Volume 1

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Foreword

China is one of the countries severely affected by biological invasions. By the end of 2016, at least 610 alien invasive species (AIS) had been identified in China, 50 of which are on the list of the world's 100 worst invasive species (IUCN). AIS have caused huge economic losses, estimated to be 17 billion US dollars per year. In addition, AIS negatively influence multiple ecosystems and biodiversity, leading to large-scale degradation of invaded ecosystems. Thus, biological invasions are considered as one of the biggest biosecurity issues in China.

To cope with biological invasions, a great number of research projects have been awarded by central and local governments in China since the beginning of the twenty-first century. These projects cover all aspects of biological invasions, from surveys of species distribution and damage to conducting advanced research on the mechanisms of invasion success and developing control techniques/strategies. Great progress has been made in several fields, including identifying which species have the highest possibility of being introduced into China, why AIS are successful in invasions in different regions/environments, and where they would have a high risk of causing serious damage. Moreover, Chinese scientists have successfully developed techniques for rapid early detection and field monitoring, and most importantly, effective control methods have been developed for highly invasive species. So far, we have clarified the mechanisms underlying successful invasions for several AIS, such as the asymmetric mating interactions in the whitefly *Bemisia tabaci*, and communication between pinewood nematodes, insect vectors, and associated microbes.

As an outcome of extensive researches in this field, Chinese scientists have published more than 1400 papers in ISI-indexed journals. There are also a large number of papers published in Chinese journals. Furthermore, numerous field examples of successful control activities have been implemented but not reported. To present a comprehensive view of these results, the publication of an English monograph that summarizes the major findings/experiences in China is timely. The book *Biological Invasions and Its Management in China* edited by Fanghao Wan, Mingxing Jiang, and Aibin Zhan and their colleagues covers topics of current interest and research progress in the field of biological invasions in China.

The book contains several important themes, such as what invasion problems have occurred in Chinese major ecosystems, what has been done to solve current problems, and what are the major research directions in China. In addition, the book includes findings from other parts of the world to provide comprehensive information to readers. Therefore, readers will find many areas of interesting research in this book. We expect this book to appeal widely to scientists and staff who work in the field of biological invasions.

The arrival of alien species in China and their impacts will undoubtedly continue, mainly owing to increased international trade and travel. The invasions may escalate as some of the plans to open up the country are implemented in China, such as the "One Belt and One Road" (OBOR) policy. As a result, the issues of biological invasions faced by China will also affect other countries, such as those along the OBOR. It is, therefore, crucial to promote exchanges and collaborations between Chinese scientists/governments and those overseas in the field of AIS. From this point of view, this book is expected to become a very valuable shared source of information.

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Preface

During the past decades, China has been greatly challenged by a dramatic increase in alien invasive species (AIS), leading to significant negative impacts on the economy, ecology, and even social development. Many ecosystems in China have been seriously affected by AIS, including agricultural and forest ecosystems. As a consequence, biological invasions have become a major focus for scientific research and administrative management in China, in particular since the beginning of the twenty-first century.

Our purpose in editing this book stems from the research advances that have been achieved in the last two decades in the field of biological invasions in China. These advances relate not only to scientific research but also to the management of invasive species. Our book will provide readers with information on what we have already done and what we propose to do in future studies, by reviewing a large volume of research findings and management experiences in China.

Exchanges between China and other countries are increasing. China has a very diverse range of ecosystems and is developing extensive trade in multiple categories of products. These trends are predicted to persist for the next few decades, particularly after the implementation of "One Belt and One Road" strategy. Human-mediated introductions of AIS create some features of biological invasions specific to China. Clearly, studying the trend of new types of invasions, as well as the possible mechanisms underlying invasions, will contribute to the control and management of AIS and will also enhance international collaborations to mitigate the negative impacts of AIS.

Despite the enormous efforts dedicated to control, the level and rate of invasions are continuing to increase due to the dramatic growth in international trade and travel, as well as in the nationwide transport of multiple categories of products and materials. Central and local governments need to exert more efforts on regulatory and administrative activities. The public will need to increase their awareness of biological invasions and to be more extensively involved in the control of AIS. Overall, some serious invasive species have not been effectively managed and are still causing serious damage to China, while new ones are being introduced that are not yet recognized because their populations are small or they have not caused environmental problems. There is little doubt that many fundamental topics remain to be answered in invasion biology. All these problems are examined in our book, which will benefit readers who want a comprehensive understanding of the position on biological invasions and relevant research in China.

Although we aim to provide a thorough coverage of the topic to readers, this book cannot cover all aspects of biological invasions in China. Articles by Chinese scientists are being published at a rapid rate, and thus readers may find that some valuable results are not included in our book. Moreover, as biological invasion itself is a fast-growing field, readers will find that some issues in the book have not yet been solved or even examined in detail. We hope that this book will promote active discussions in the field and draw attention to the problem of invasive species in China.

This book consists of two major parts: first, Chaps. 2, 3, 4, 5 and 6 that represent biological invasions in different types of ecosystems and, second, Chaps. 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32 and 33 that address the invasion and management of representative invasive species. For each chapter, we include the results of the most relevant studies and management strategies/techniques. An index at the end of the book will help readers to find topics of interest to them. The book will be of interest to researchers, regulatory administrators, environmental managers, and the public.

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Numerous scientific findings described in our book are generated from the research projects financially supported since 2002 by the Ministry of Science and Technology (MOST), Ministry of Agriculture (MOA), National Natural Science Foundation of China (NSFC), etc., particularly the national projects of "National Key Research and Development Programs" (2016YFC1200600, 2016YFC1202100, 2016YFC1201200) and the "948 Program" (2016-X48).

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Chapter 6
Biological Invasions in Nature Reserves in China

Hui Guo, Susan J. Mazer, Xinyu Xu, Xi Luo, Kailing Huang, and Xiaohong Xu

Abstract One consequence of the rapid economic development in China is the rapid increase in the ecological threats posed by alien species. Nature reserves serve as barriers to species invasions, but there is now no reserve in the world that is free from introduced alien species. In this chapter, we review studies of alien species invasions in nature reserves of China, analyze the invasion pattern across reserves, and propose suggestions for the management of invasive species in nature reserves in China. By searching available databases, we found a total of 37 studies focusing on biological invasions in 24 nature reserves in China. The Dinghushan Nature Reserve has the largest number of invasive species, followed by Taohongling, Tianmushan and Ganshiling reserves, whereas Yiwulvshan, Yalujiangkou and Dayudao have the fewest invasive plant species. *Alternanthera philoxeroides, Amaranthus spinosus* and *Euphorbia hirta* are the species most frequently reported to occur in nature reserves, while Compositae, Amaranthaceae and Gramineae are the three most frequently reported families. The number of invasive species reported declines with increasing latitude, but is not significantly correlated with reserve age, elevation, or area. We analyzed an index of invasion (the ratio of invasive to total plant species), which increases with nature reserve age, and decreases with elevation and the number of plant species in reserves; the effect of elevation, however, is not detected when controlling for the number of plant species or reserve area. When controlling for the effect of reserve area, the number of invasive species is positively correlated with the total number of plant species. Although manual, chemical,

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mechanical, and biological methods have been suggested for the control or eradication of invasive species, each method has its own limitation. We suggest that global changes and disturbances (e.g., N deposition) should be taken into account when assessing the risk of alien species and designing management strategies.

Keywords Biological invasion • Degree of invasion • Invisibility • Nature reserve

6.1 Introduction

Since the implementation of the “Reform and opening” policy in the 1970s, China has achieved and maintained a high growth rate in gross domestic product and international trade. Economic development has induced habitat destruction and/or fragmentation as well as air and water pollution, and their combined effects have caused a dramatic decline of plant biodiversity; as many as 5000 species are currently endangered in China (López-Pujol et al. 2006). One of the consequences of rapid economic development in China is the dramatic increase in the threats posed by alien species (Ding et al. 2008). For example, the total numbers of harmful alien animals, plants, and other pest organisms intercepted at Chinese borders grew at least tenfold from 1990 to 2005 (Ding et al. 2008). The invasion of alien species may not only displace native and agricultural species, but it may also cause damage to habitats and ecosystems. In sum, in addition to affecting ecosystems and contributing to the extinction of native species, invasive species can cause major socio-economic damage.

Nature reserves can help to prevent invasions by alien species by providing a buffer of relatively undisturbed vegetation; invasions appear to be most likely in disturbed habitats. For example, in an analysis of more than 27,000 non-native plant presence records in South Africa’s Kruger National Park, Foxcroft et al. (2010) reported that the number of records of non-native invasive plants inside the park declined rapidly beyond 1500 m from the edge.

In China, the first modern nature reserve was founded in 1956 and new reserves were regularly established until 1964 (Zhujing 1989; Fig. 6.1). After a six-year ‘retreat’ stage from 1965 to 1972, the establishment of natural conservation areas in China continued again. In the 1990s, as public awareness of conservation grew, even with growing tension between activities that promoted economic development and practices that promoted conservation of natural resources, the number of national nature reserves constructed per year increased, reaching a peak around 2000 (Fig. 6.1). After 2000, many new nature reserves were set up by provinces or counties rather than by the nation. By the end of 2014, China had established a total of 2718 national and local reserves, primarily forests (52.4%), wildlife refuges (24.5%) and inland wetlands (13.91%) (Fig. 6.2). Compared with the natural conservation areas in developed countries such as United States, those in China are apparently much younger (Appendix I).

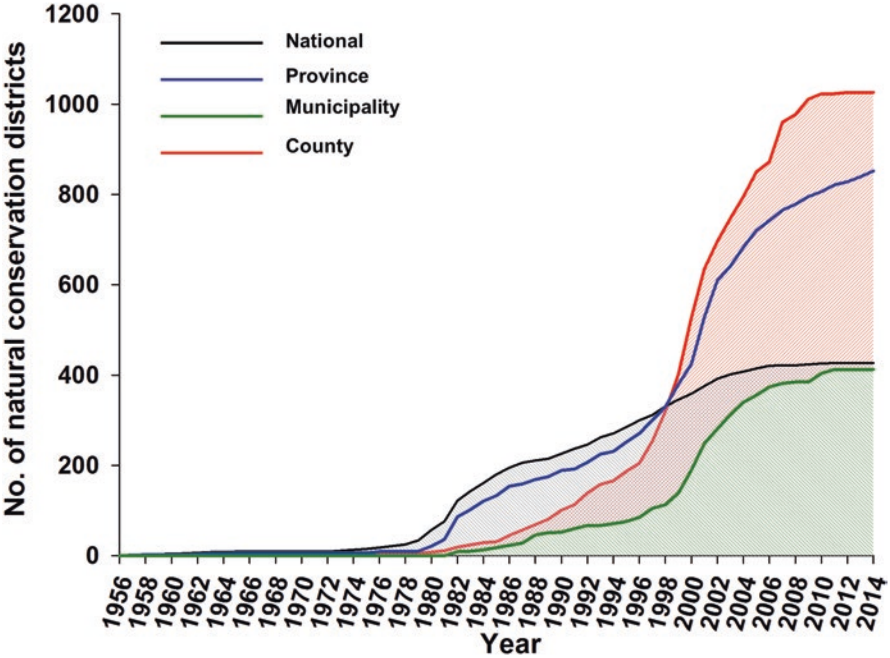

Fig. 6.1 The cumulative number of natural conservation districts set up since 1956

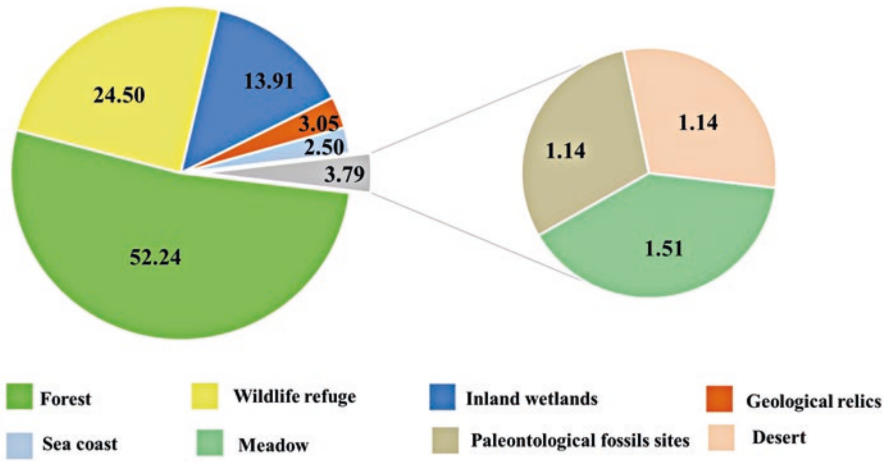

Fig. 6.2 The percentage of different types of natural conservation districts

Because of rugged mountains in the west and vast desert areas in central China, the population is concentrated within a surprisingly small area (Riley 2004). Previous studies in other countries have reported a positive relationship between the extent of exotic species' invasion and human disturbance or visitation. For example, in a survey of 234 New Zealand reserves, Timmins and Williams (1991) found that the proximity of towns, distance from roads/railway lines, human use, reserve shape and habitat diversity were the most important factors determining the degree of invasion. Similarly, others have reported that an increase in the number of human visitors led to an increase in the number of exotic species (Usher 1988; Macdonald et al. 1989; Lonsdale 1999). Given that the introduction of plant species from one region to another is closely related to human activities, China's high population density poses a greater risk of exotic species' invasions into reserves than that faced by countries with small or low-density populations.

High population density and economic growth have also resulted in elevated atmospheric nitrogen deposition in terrestrial and aquatic ecosystems (Liu et al. 2013). Over the past 30 years, China's emissions have increased to the point where it has become by far the largest creator and emitter of nitrogen globally (Liu et al. 2011). N deposition levels have commonly exceeded 20 kg N ha−1 year−1 in central and east China, a level above which ecosystems health is seriously threatened (Bobbink et al. 2010). In ecosystems with predominantly nutrient-poor soils, the addition of nutrients can constitute a major disturbance, which has been shown in many examples to facilitate invasions by non-native species (Hobbs 1992).

In this chapter, we review studies of alien species invasions in nature reserves, analyze the invasion pattern across reserves, and offer several suggestions for the management of invasive species in China.

6.2 Brief Review of the Studies on Alien Species Invasions in Nature Reserves in China

Nature reserves are a suitable "laboratory" for studying the effect of undisturbed habitats on the likelihood of alien species invasions. Indeed, studies in various kinds of nature reserves (e.g., national parks, biosphere reserves, and small-scale nature reserves) have yielded a few generalizations that apply at both global (Lonsdale 1999) and national levels (Pyšek et al. 2002), but few studies have been conducted in China. Here, we first summarize those studies that directly address the process and outcome of biological invasions in nature reserves and conservation areas in China.

By searching the available databases (CNKI, WANFANG DATA and Web of Science) using the keywords, "invasion", "exotic" or "alien" or "introduced" "invasive species", "nature reserve" or "natural conservation area" or "protected area", and "China", we found only 37 studies focusing on biological invasions in 24 nature reserves (Appendix II). In most of these studies, the authors simply listed the names of the invasive plants that had been reported in focal reserves, and briefly introduced their invasion histories or inferred the possible paths of their invasions. For example, invasive alien plant species in the Dinghushan National Nature Reserve were investigated using transects and plot surveys, and a total of 14 invasive alien plant species were found in the experimental, buffer, and core zones (Song et al. 2009). In the Shiwandashan National Natural Reserve, 23 invasive species representing 21 genera and 12 families were reported (Wei et al. 2006). Similar investigations were conducted in the Dashahe nature reserve in Guizhou province; Bawangling and Ganshiling nature reserves in Hainan province; Hengshuihu nature reserves in Hebai province; Jinfoshan nature reserve in Chongqing city; Jinhuacha nature reserve in Guangxi Zhuang Autonomous Region; and Lishan nature reserve in Shanxi province.

A few studies focused on single invasive plant species. For example, *Solidago canadensis* (Asteraceae), a noxious invasive plant in the Lushan Natural Reserve of Jiangxi Province, was studied to reveal its pattern of spread and to identify its potential effects on biodiversity in a woodland (Tang et al. 2012). While low sunlight and the predominance of foggy weather of the Lushan Nature Reserve were not suitable for the spread of *S. canadensis,* the herb layer was nevertheless dominated by this species, which caused a significant decline in the diversity of co-occurring species (Tang et al. 2012). Qin et al. (2004) reported the effects of the invasive *Spartina alterniflora* on the flora, fauna, and ecosystem of the Chongming island and Jiuduansha nature reserves, and they proposed strategies for controlling *S. alterniflora* in coastal nature reserves. Bai et al. (2013) reported the consequences of *Phyllostachys edulis* invasions for plant community composition by examining the changes in plant diversity in different communities over a seven-year period (2005–2011) in the Tianmushan Nature Reserve. *P. edulis* negatively affected plant communities by causing significant declines in two measures of diversity: Simpson's Diversity Index and Pielou's Eveness Index (Bai et al. 2013).

We identified only five studies that reported invasions of animals or insects into nature reserves in China (Jiang et al. 2007, 2010; Luo et al. 2007, 2012; Zeng et al. 2013). We found no experimental studies that identified the factors that promote invasive species and no comparative studies examining patterns of invasions across nature reserves. Similarly, we found no studies that identified the process by which any alien species has invaded a nature reserve.

The shortage of relevant studies could be due to several factors. First, the importance and value of nature reserves in resisting biological invasions has not received sufficient attention by plant community ecologists and conservation biologists. Second, there might not be adequate funding available to support the research of plant ecologists engaged in basic scientific research. Our understanding of the effects of invasive species on the structure, composition, and function of natural ecosystems would be improved if more financial resources were allocated to researchers to conduct experimental and comparative studies of the effects of invasive species on species diversity and ecosystem function. Third, the management policies of government-supported nature reserves do not place a high priority on the study and control of invasive species. Fourth, public awareness of the ecological risks posed by introduced species needs to be increased. The preservation of China's biological diversity for future generations can only be ensured if government, media, and educational and research institutions collectively take the responsibility for educating and informing the public of its value.

6.3 Invasive Species in Nature Reserves in China

Our survey of the basic attributes of nature reserves in China is presented in Appendix III. The number of invasive plant species per reserve ranges from 3 to 51, wherein Dinghushan has the largest number of invasive species, followed by Taohongling, Tianmushan and Ganshiling reserves; by contrast, only three invasive species have been reported in Yiwulvshan, Yalujiangkou and Dayudao (Fig. 6.3).

Alternanthera philoxeroides, Amaranthus spinosus and *Euphorbia hirta* are the three exotic species that have been reported most frequently in the 24 well-studied nature reserves in China (these species have been reported in 17,17 and 15 reserves, respectively), followed by *Erigeron annuus*, *Bidens pilosa*, *Chromolaena odorata* and *Ipomoea purpurea* (Table 6.1). Compositae, Amaranthaceae and Gramineae are the three families most frequently reported in the 24 nature reserves, followed by Euphorbiaceae, Solanaceae, Convolvulaceae and Leguminosae (Fig. 6.4). Exotic species representing other families are relatively rare and only occasionally found in these reserves (Fig. 6.4).

Annual invasive plant species have the highest frequency across all nature reserves, accounting for 388 occurrences (Fig. 6.5a; Table 6.1). Perennial invasive plant species also are very high in frequency, accounting for 266 occurrences, whereas biennial invasive plant species are comparatively rare (Fig. 6.5a). When invasive plant species are classified by growth form, herbaceous species have the highest frequency across reserves, while shrubs, trees and climbing vines are rarely recorded (Fig. 6.5b).

Only 11 invasive animal and insect species have been reported in nature reserves in China. Specifically, *Ondatra zibethica* (muskrat), *Neovison vison* (American mink), *Oncorhynchus mykiss* (Steelhead Trout) and *Amphiesma vibakari* (Asian keelback) were reported to invade the Changbaishan reserve and to have large effects on the populations of native species (e.g., wild duck) (Luo et al. 2012); *Procambarus clarkia* (Red Swamp crayfish), *Rana catesbeiana* (Bullfrog) and *Pomacea canaliculata* (Channeled applesnail) were found in the Poyanghu reserve (Zeng et al. 2013); *Pomacea canaliculata, Hemiberlesia pitysophila* (Pine needle scale) and *Oracella acuta* (Mealybug) were reported to invade the Jiulianshan reserve (Jiang et al. 2010); *Rattus norvegicus* were found in the Shedaolaotieshan reserve (Luo et al. 2007) ; and *Hyphantria cunea* (Fall webworm) were found in the Kunyushan reserve (Jiang et al. 2007). *Pomacea canaliculata* was the only species to have been reported in two reserves (Poyanghu and Jiulianshan reserves).

Although there are no invasive species reported in other reserves, this does not mean they are absent. On the contrary, the invasive species listed above have a high probability of having invaded reserves with similar habitats or environments. Additional investigations are urgently needed in other nature reserves, so as to avoid or limit large losses of ecosystem function and economic values that may result from unreported and uncontrolled biological invasions.

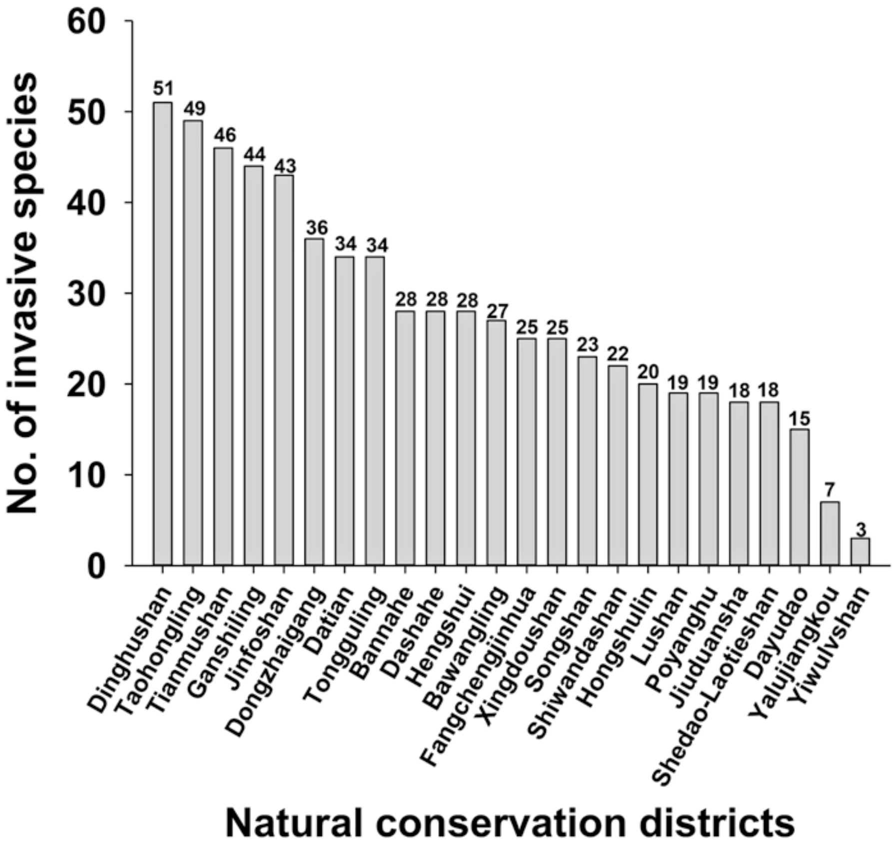

Fig. 6.3 The number of invasive species recorded in each of the 24 natural conservation districts

6.4 Patterns of Plant Invasions in Natural Conservation Districts in China

Although it seems that there is now no nature reserve in the world that is free of introduced alien species, nature reserves were reported to be invaded about half as often as sites outside reserves (Lonsdale 1999). The degree to which a nature reserve is invaded depends on a variety of factors, including the attributes of the alien species, the diversity of native species, the area of a reserve, the degree of human disturbance, ongoing environmental change, etc. (Usher 1988; Lonsdale 1999). As these factors change in the future, the importance of alien species in nature reserves may increase. Here, we synthesize data across reserves in order to identify the primary factors that appear to determine the extent of invasions by alien plant species into China's nature reserves. We compiled and then analyzed a data set based on the published literature; given that there are limited data available for animals and insects, we focus on invasive plants here.

Table 6.1 The frequency of the 20 most commonly reported invasive plant species among 24 nature reserves

Species	Count	Probability
Alternanthera philoxeroides	17	0.025
Amaranthus spinosus	17	0.025
Euphorbia hirta	15	0.022
Erigeron annuus	14	0.021
Bidens pilosa	13	0.019
Chromolaena odorata	13	0.019
Ipomoea purpurea	13	0.019
Ageratum conyzoides	12	0.018
Amaranthus viridis	12	0.018
Chenopodium ambrosioides	12	0.018
Amaranthus retroflexus	11	0.016
Axonopus compressus	10	0.015
Mimosa pudica	10	0.015
Crassocephalum crepidioides	9	0.013
Ipomoea cairica	9	0.013
Oxalis corymbosa	9	0.013
Ricinus communis	9	0.013
Avena fatua	8	0.012
Conyza canadensis	8	0.012
Datura stramonium	8	0.012

Count refers to the number of reserves in which each species has been reported; probability refers to the proportion of occurrence of each species to the overall occurrence of all invasive species

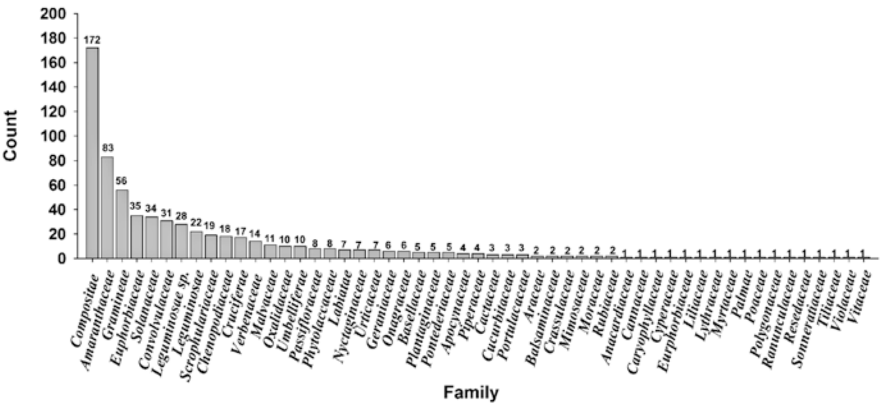

Fig. 6.4 The count of species classified by family reported in natural conservation districts (Count refers to the number of reserves in which each family has been reported)

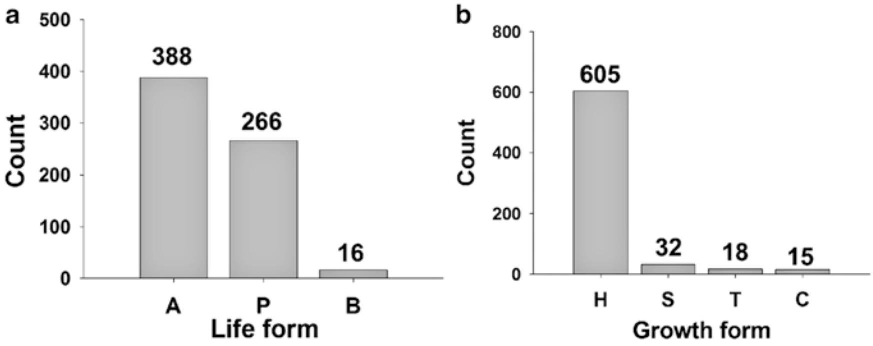

Fig. 6.5 The count of invasive species classified by life form (**a**) and growth form (**b**). *A* annual, *P* perennial, *B* biennial, *H* herb, *S* shrub, *T* tree, *C* climbing vine (Count refers to the number of reserves in which each life form or growth form has been reported)

6.4.1 Data Set

The data used in this section were extracted primarily from the primary scientific literature and from the Ministry of Environmental Protection of the People's Republic of China. Species lists were obtained for each of the 24 nature reserves (Appendix III). The total number of all plant species and the number of invasive plant species were recorded for each reserve. For each nature reserve, the following attributes were also obtained:

Year Established We aimed to determine whether the number of invasive species increases with the age of a reserve. If older nature reserves were established prior to any major disturbance, they may exhibit greater resistance to alien species invasions than younger ones.

Mean Elevation The mean elevation of each nature reserve was estimated as the midpoint between minimum and maximum elevation recorded (Pyšek et al. 2002). Given that habitats and vegetation change with increasing elevation, different elevations may be differentially invasible to alien species. We tentatively hypothesized that nature reserves at higher elevations may be less invasible due to lower temperatures and more stressful abiotic environments.

Latitude We recorded the boundary latitudes including both highest and lowest values across the range of each reserve. Temperate ecosystems are predicted to be more invasible than tropical ecosystems (Lonsdale 1999).

Nature Reserve Area One controversy is whether several small reserves will contain more species than would a single reserve of equal total area. Large reserves are able to harbour larger populations and contain greater habitat diversity but well-designed and carefully managed small reserves can effectively protect more populations of rare species than a single large area that is not well-designed (Primack

2000). By analyzing the relationship between reserve area and the number of invasive species, we tried to evaluate whether small nature reserves are more vulnerable to invasions than large ones. This question has been repeatedly raised but not rigorously answered (Usher 1988).

Native Plant Species Native species richness may predict the degree of exotic species richness because it reflects not only the area of the site but also its habitat diversity (Lonsdale 1999). Here, we examined the correlation between the total number of plant species and the number of invasive species across reserves in order to investigate the effect of the flora's diversity on the degree of invasions. Our primary hypothesis is that – all else being equal – relatively species rich communities are more stable, have fewer vacant niches and are less invasible than relatively depauperate communities; an alternative hypothesis is that communities with more plant species also have higher habitat diversity, which may facilitate the introduction of a greater number of alien species.

Mean Annual Temperature & Mean Annual Precipitation These variables were obtained from the China Meteorological Administration and used to detect whether the extent of plant invasion is correlated with climatic factors.

6.4.2 Data Analyses

Linear bivariate regressions were conducted to detect whether the focal dependent variable (the number of invasive plant species) was correlated with each independent variable, i.e., the attributes of nature reserves represented by year, latitude, reserve area, the number of native plant species, mean annual temperature and precipitation. In addition to using the number of invasive species as the dependent variable, we conducted a separate set of linear bivariate regressions in which we used an index of invasion, V, as the dependent variable, where V is defined as:

$$V = 100 * I / S$$

where I is the number of invasive species, and S is the number of plant species (Usher 1988). Because the Dongzhaigang, Jiuduansha and Hongshulin reserves belong to typical tidal ecosystems characterized by relatively low plant species richness compared to other ecosystems, we excluded these three reserves when analyzing the relationship between V and the independent variables above. We also examined the relationship, among reserves, between the number of invasive species and the residuals of the linear regression of the number of plant species on the reserve area. Using these residuals allowed us to control statistically for the effect of reserve area when examining the relationship between the number of invasive species and the number of plant species per reserve.

6.4.3 *Factors Correlated with the Degree of Plant Invasion in Nature Reserves*

We estimated Pearson pairwise correlations between all pairs of independent variables (Table 6.2). The number of invasive species is significantly correlated only with latitude; reserves at higher latitudes have a lower number of invasive species. The index of invasion, however, is negatively correlated with elevation, the number of native plant species and reserve age (Table 6.2).

6.4.3.1 Established Time

There is no significant relationship between the number of invasive species and the year in which a reserve was established (Fig. 6.6a). However, the index of invasion was positively related to the year of establishment ($r^2 = 0.21$, $P = 0.030$, $n = 21$; Fig. 6.7a). In younger reserves, the ratio of invasive species to total plant species was significantly higher than in older ones. This pattern suggests that older nature reserves show higher resistance to alien species invasions than younger ones, perhaps because the older reserves were established at locations with less disturbance.

6.4.3.2 Elevation

No significant correlation was found between the number of invasive species and elevation (Fig. 6.6b), whereas the index of invasion significantly decreased with increasing elevation ($r^2 = 0.41$, $P = 0.0012$, $n = 21$; Fig. 6.7b and Table 6.2). The reason is that the total number of plant species increases with increasing elevation, but the number of invasive species remains constant (the correlation is not significant between the number of invasive species and elevation). This result is consistent with the hypothesis that nature reserves at higher elevations may have lower invasibility due to their lower temperatures and more stressful abiotic environments. Consequently, as native species expand their ranges into higher elevations in response to global warming, invasive species may not have the same potential to migrate to higher elevations.

6.4.3.3 Latitude, Annual Temperature and Annual Precipitation

A significant negative relationship was found between the number of invasive species and latitude ($r^2 = 0.18$, $p < 0.0324$, $n = 24$; Fig. 6.6c), but not between the index of invasion and latitude (Fig. 6.7c). These results suggested that the reserves in lower latitudes may be more susceptible to invasions than those in high latitudes. The independence between the index of invasion and latitude indicates that the ratio of invasive to total plant species does not change with increasing latitude; however, we do not know whether other

Table 6.2 The Pearson pairwise correlation coefficients between all focal variables

	Year established	Elevation (m)	Latitude	Area (hm^2)	# of plant species	Average annual Temp. (°C)	Annual precipitation (mm)	# of invasive species	Index of invasion
Year established	1.00	−0.12	0.18	0.20	−0.40	−0.057	−0.43*	−0.26	0.46*
Elevation (m)		1.00	−0.12	0.18	0.67***	−0.12	0.33	0.16	-0.64**
Latitude			1.00	0.24	−0.24	−0.91***	−0.66***	−0.43*	0.016
Area (hm^2)				1.00	0.27	−0.31	−0.02	−0.33	−0.38
# of plant species					1.00	−0.10	0.39	0.37	−0.63**
Average annual Temp. (°C)						1.00	0.56**	0.26	0.17
Annual Precipitation (mm)							1.00	0.25	−0.37
# of invasive species								1.00	0.019
Index of invasion									1.00

Significance levels:*** $P<0.001$; **$P<0.01$; *$P<0.05$

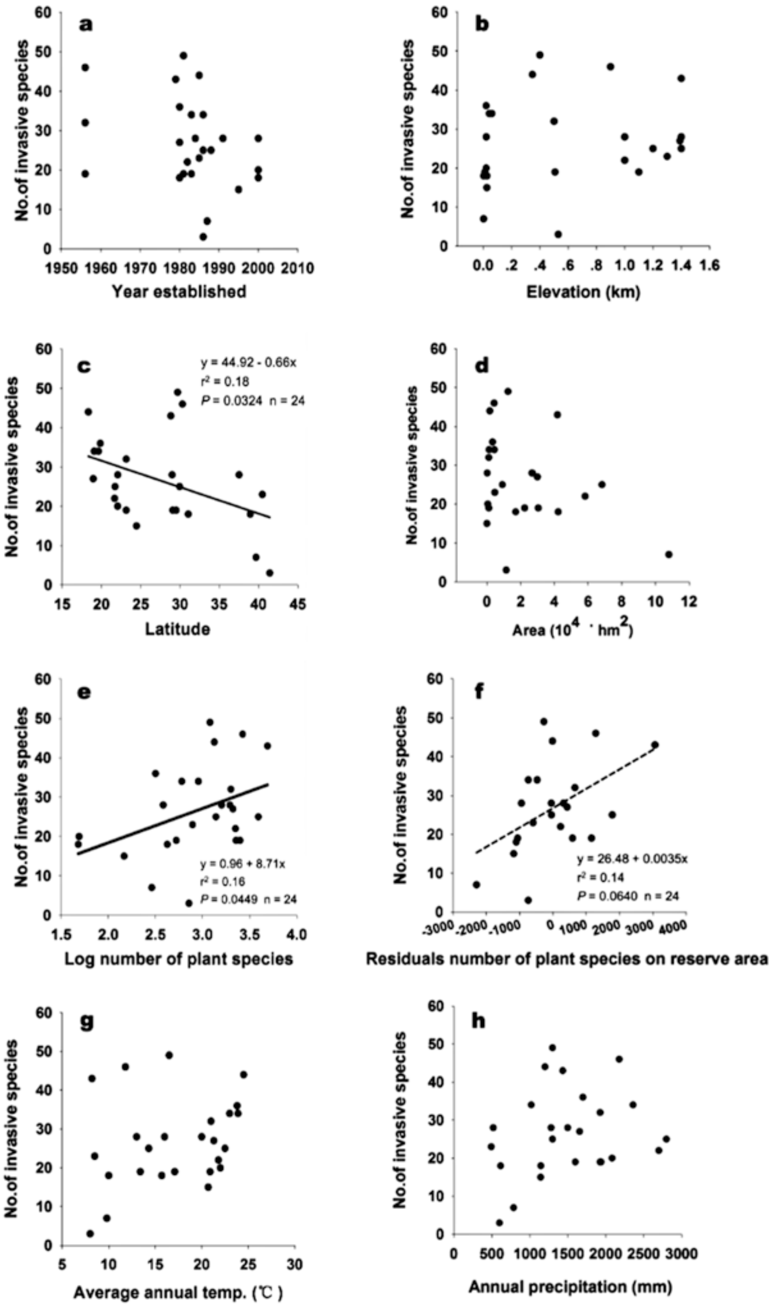

Fig. 6.6 The linear regression relationships between the number of invasive species and (**a**) the established year; (**b**) the elevation; (**c**) the latitude; (**d**) the reserve area; (**e**) the log number of plant species; (**f**) the residuals of the total number of plant species on the reserve area; (**g**) the average temperature and (**h**) the annual precipitation of natural reserves

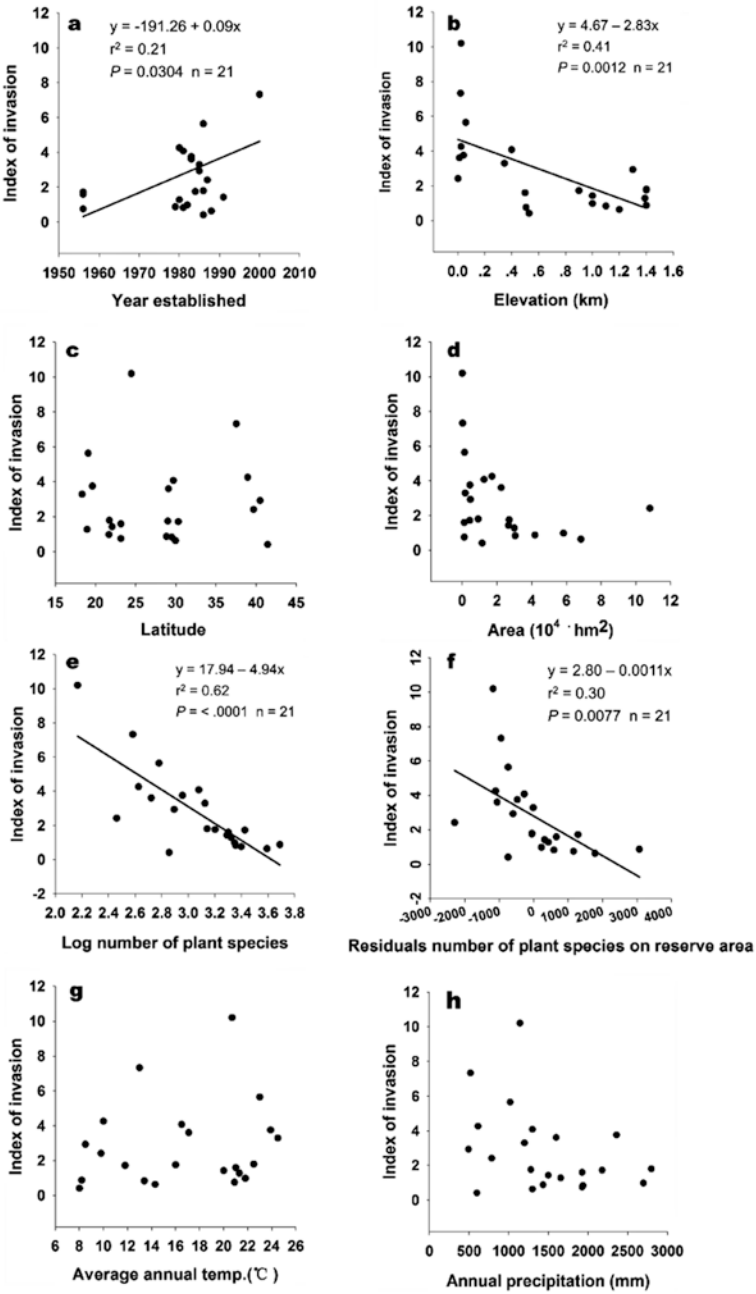

Fig. 6.7 The linear regression relationships between the index of invasive and (**a**) the established year; (**b**) the elevation; (**c**) the latitude; (**d**) the reserve area; (**e**) the log number of plant species; (**f**) the residuals of the total number of plant species on the reserve area; (**g**) the average temperature and (**h**) the annual precipitation of natural reserves

characteristics of native or invasive species may change with latitude. Neither the number of invasive species nor the index of invasion was correlated with mean annual temperature or precipitation (Figs. 6.6g, h and 6.7g, h), but these climatic variables provide only a rough approximation of a large or topographically complex reserve's climate.

6.4.3.4 Nature Reserve Area

The results of this study with respect to reserve area and invasibility of reserves could potentially inform strategies for reserve establishment and design. We found that there was no significant linear relationship between the number of invasive species or index of invasion and reserve area (Figs. 6.6d and 6.7d). However, a nonlinear relationship existed between the index of invasion and reserve area ($y = 4.58–0.01x^{1/2}$; $p < 0.015$, $n = 21$; Fig. 6.7d), indicating that the largest reserves have a dramatically lower number of invasive species and index of invasion than smaller ones.

6.4.3.5 Native Plant Species

We detected a significant relationship between the number of invasive species and the total number of plant species ($r^2 = 0.16$, $P = 0.0449$, $n = 24$; Fig. 6.6e). When controlling for the effect of reserve area, a nearly significant positive linear relationship was detected ($r^2 = 0.14$, $P = 0.0640$, $n = 24$; Fig. 6.6f). The positive relationship between invasive and plant species richness found here is consistent with the hypothesis that richer plant communities are evidence of greater habitat diversity; if so, then both native and alien plant species respond to the greater habitat diversity in a similarly positive way. However, among reserves, the index of invasion was negatively correlated with the number of plant species ($r^2 = 0.62$, $p < 0.0001$, $n = 21$; Fig. 6.7e), which suggests that reserves with higher species richness may be more stable and less susceptible to invasions than those with less plant species. The negative correlation between index of invasion and the number of plant species was independent of reserve area ($r^2 = 0.30$, $p < 0.0077$, $n = 21$; Fig. 6.7f).

The multivariate general linear models also indicated that the number of native plant species was the most important factor in controlling the number of invasive species and index of invasion, independent of variation in elevation or area (Table 6.3).

6.4.3.6 Coastal Reserves

The three coastal reserves – Dongzhaigang, Hongshulin and Jiuduansha – have very high indices of invasion ($v = 11.36$, 40.82 and 37.5, respectively: almost 20 times higher than other reserves (which have a median value of 1.78). These results suggest that the plant communities in reserves located on coasts are characterized by a much larger fraction of invasive plant species. One interpretation is that the coastal

Table 6.3 Multivariable analyses using general linear models

		Number of invasive species			Index of invasion	
Model 1 $R^2 = 0.3622$	**Source**	**DF**	**F Ratio**	**Prob > F**	**F Ratio**	**Prob > F**
	Number of plant species	1	5.82	**0.0267**	1.90	0.1841
	Elevation (m)	1	0.48	0.4960	3.37	0.0826
	Area (hm²)	1	5.51	**0.0305**	1.85	0.1903
Model 2 $R^2 = 0.1669$	**Number of plant species**	1	3.21	0.0890	2.69	0.1171
	Elevation (m)	1	0.40	0.5341	3.25	0.0872
Model 3 $R^2 = 0.3451$	**Number of plant species**	1	6.93	**0.0164**	10.51	**0.0043**
	Area (hm²)	1	5.68	**0.0277**	1.66	0.2125

Model 1: Dependent variable: Number of invasive species and Index of invasion; Factors: Number of plant species, Elevation (m) and Area (hm²); Model 2: Dependent variable: Number of invasive species and Index of invasion; Factors: Number of plant species, Elevation (m). Model 3: Dependent variable: Number of invasive species and Index of invasion; Factors: Number of plant species, Area (hm²)

reserves are more invasible due to their higher vulnerability and diffusibility relative to inland sites; another interpretation is that coastal reserves contain so few native species that even a few invasive species result in a high index of invasion (the average number of native species is 1581 in inland reserves, and 138 in coastal reserves). Coastal and island reserves should receive more attention in preventing and managing invasive species.

6.5 Risk Assessment and Management of Invasive Species in Nature Reserves in China

A central goal of protecting natural areas is to preserve biodiversity and to sustain ecosystem function. While nature reserves or protected areas provide barriers to invasive species (e.g., Foxcroft et al. 2010), the management of invasive vegetation in natural reserves is a significant challenge. Therefore, to assess the risk of alien invasive species and to identify and implement effective methods for managing invaded vegetation are important and urgent objectives. In this section, we review the management strategies previously proposed in studies of nature reserves in China and offer our suggestions based on the most recent publications.

6.5.1 The Management Strategies Proposed by Chinese Government and Researchers

The Ministry of Environmental Protection of the People's Republic of China provides little general advice for controlling alien invasive species. For example, it's suggested that relevant people or departments should investigate alien species regularly; draw up a plan for invasive species prevention and monitoring; replace invasive species by local species when restoring the vegetation; and enhance public education to increase awareness of alien species, etc. While the government is paying more attention and providing more funding to manage alien invasive species, there are few specific policies, regulations, and implementation of the above suggestions in specific reserves.

By reviewing studies of biological invasions in nature reserves in China, we found that most authors proposed methods and strategies for invasive species management, and even discussed the potential effectiveness of each method. For example, in studies of Tongguling, Dongzhaigang, Datian, Shiwandashan, Xingdoushan, Fangchengjinhuacha and Dinghushan reserves, it has been suggested to build databases of alien invasive species and to promote early warning and emergency response systems (Qin et al. 2008; Wei et al. 2006; Lu et al. 2005; Wu and Li 2012; Song et al. 2009). In addition, the authors encourage using manual, mechanical and biological methods to control invasive plants. Manual removal is time-consuming but can be a highly effective method for controlling invasive plants. One of the negative effects is that pulling plants from the ground may cause unintended soil disturbance, and subsequently result in further invasions. Although mechanical removal was always suggested, this method may not be appropriate in natural areas because of the serious disturbance to soils and non-target vegetation caused by heavy equipment. If it's essential to use heavy equipment to remove invasive species, then plans for replanting and monitoring native plants following mechanical removal should be carefully developed prior to mechanical removal. There was no successful case of biological control reported so far, even though it's appealing and may be implemented in the future.

Chemical control of invasive plants was suggested by several authors. For example, herbicides were thought to be effective for the control of invasive plants, as reported in studies of the Dashahe (Lin et al. 2008), Huacha (Wu et al. 2009) and Tianmushan reserves (Chen et al. 2011). While herbicides or pesticides were supposed to be effective, we have not seen relevant laws or regulations that control the training and certification of those who apply these chemicals. Anyone who applies herbicides in natural areas should have basic training in herbicide application technology and be able to comply with all the instructions and directions for use.

Some researchers suggested that the government should enhance public education (Lu et al. 2005; Qin et al. 2008; Wu and Li 2012). The importation and spread of invasive plants can be significantly reduced by public education. People who are aware of the problems caused by invasive species have the responsibility to educate others about their identity, impacts, and control so as to reduce further ecological destruction or degradation of native ecosystems.

Another method suggested by Chinese researchers is to explore the use of invasive species as natural resources (Liu et al. 2008; Chen et al. 2011). It has been proposed, for example, that some invasive plants may potentially be used as Chinese medicine (Chen et al. 2011).

6.5.2 Suggestions: Consider Global Changes and Disturbance

Global changes and biological invasions are primary threats to global biodiversity that may interact in the future (Dukes and Mooney 1999). For example, a meta-analysis revealed that in terrestrial (primarily plant) systems, native and non-native species responded similarly to environmental changes, but in aquatic (primarily animal) systems, increases in temperature and CO_2 largely inhibited native species (Sorte et al. 2013). As climate change proceeds, aquatic systems may be particularly vulnerable to invasions. Across systems, there could be a higher risk of invasions at sites that become more climatically hospitable, whereas sites shifting towards harsher conditions may become more resistant to invasions (Sorte et al. 2013). Therefore, climate change and its impacts on native vs. alien species should be taken into account when assessing the risk of alien species and drawing up strategies for their management.

In addition, conservation efforts must include explicit consideration of disturbance to preserve biodiversity and ecosystem function. While moderate frequency or intensity of disturbance fosters high species richness, major disturbances in plant communities can promote alien species invasions. For example, input of atmospheric nitrogen was apparently to blame for the increasing dominance of grass species and the loss of many forbs, regardless of management (mowing, grazing and burning) in grassland communities (Lake and Leishman 2004; Bai et al. 2010).

6.6 Take Advantage of Ecology Theories

6.6.1 Allee Effect

The Allee effect refers to a positive relationship between individual fitness and population size or density. The concept of Allee effects can be integral to risk assessments and to the prioritization of resources allocated to manage alien species, as some species with strong Allee effects may be less successful as invaders. While conservation biologists or restoration ecologists may attempt to minimize Allee effects (by maximizing genetic variation) in native species so that their local extinction is less likely, invasion biologists should consider the Allee effect as a factor that can be used to inhibit the establishment success or the spread of an invading species (Tobin et al. 2011). To reduce population size or density below an Allee threshold could be an effective strategy to control invasive species. The reduction of population size or density could simply be induced by the application of herbicide or pesticides or by manual removal. In this way, invasive species with strong Allee effects might be effectively controlled. Other methods could also be chosen to give rise to an Allee effect in invasive species. For example, the disruption of mating can prevent population growth, potentially contributing to population extinction. The release of natural enemies can also lead to widespread population reduction or extinction of an alien species, thereby causing a dramatic population collapse and range retraction of invasive species (Elkinton et al. 2004). Moreover, habitat loss or fragmentation could decrease population size and be exploited to slow down the rates of range extension and population spread, and even promote species eradication (Tobin et al. 2011). For example, propagules that arrive ahead of the expanding front could be strategically fragmented through control tactics or selectively targeted based on their density and spatial extent so that only fragmented colonies remain (Tobin et al. 2011).

6.6.2 Corridors

Habitat corridors that increase species dispersal and richness for many native taxa may have unintended negative effects, potentially increasing the spread of invasive species. In addition, corridors may increase the spread of unwanted disturbances such as fire. Haddad et al. (2014), however, conducted a literature review and meta-analysis to evaluate the prevalence of each of these negative effects, and found no evidence that corridors increase disturbance or non-native species invasions. Another study focused on river corridors, which provide crucial links to the surrounding landscape but are also major conduits for invasion of alien species (Foxcroft et al. 2007). Foxcroft et al. (2007) developed a framework to assess the risk that alien plants in watersheds adjacent to a protected area would invade the protected area along rivers; this framework was then applied to Kruger National Park (KNP) in South Africa. They reported that KNP was facing increasing pressure from alien species in the upper regions of the drainages of neighboring watersheds (Foxcroft et al. 2007). Their framework might be applicable to plants and other passively dispersed species that invade protected areas located in the lower regions of drainage basins. The inconsistency among results calls for more studies to seek evidence of corridor-mediated effects on invasive species or disturbance, and to provide theoretical support for invasive species management.

6.6.3 Invasibility

The success of a given species' invasions into a reserve depends on the invasibility of the focal plant community and on the invasiveness of the alien species. Invasibility can be defined as "the susceptibility of biological communities to colonization and dominance by introduced organisms" (Lonsdale 1999; Fridley 2011), and can be strongly influenced by community features such as species composition, diversity, and biomass. The degree of invasion in any given community is the outcome of previous interactions between its invasibility and the invasiveness of its alien species (e.g., propagule or invader attributes or traits), and depends on the proximity to exotic species sources such as ports and large cities, on disturbance, and on the time since invasions (Guo et al. 2015). To quantify the invasibility and degree of invasion in a given reserve based on unified indices of invasibility and degree of invasion can be used to uncover basic ecological patterns across systems, and to inform land management and ecological restoration (Guo et al. 2015). In future studies, reserve managers or conservation biologists need to measure community features (e.g., species richness, biomass, and area), the degree of invasion, and the invasiveness of alien invasive species in order to evaluate the potential for continued invasions and to generate effective management strategies.

6.7 Other Issues

6.7.1 Encouragement to Establish Non-profit Organizations for the Control of Invasive Species

The Florida Exotic Pest Plant Council (FLEPPC) is a nonprofit professional organization founded in 1984 to increase public awareness of the significant threat that alien invasive plant species pose to native species, communities, and ecosystems, and to develop integrated management and control strategies to halt the spread of exotic species in natural areas. FLEPPC maintains a list of plant species considered by a committee of botanists, ecologists, and land managers to be invasive in Florida. This list is available on the FLEPPC website (http://www.fleppc.org). Similar organizations or councils should be initiated in each province in China, and then integrated into a nationwide network that provides accessible databases of invasive species; such a resource would facilitate studies of invasion mechanisms and invasive species distributions across different spatial scales.

6.7.2 Policy-Making

Policy-making by government or managers should involve scientists (local scientists in particular) from different research disciplines. Local scientists often know most about their region's reserves and invasive species, and scientists with different backgrounds may identify different problems and propose alternative and complementary (or synergistic) solutions. In addition, specific reserves should develop customized strategies for controlling alien species invasion based on their specific attributes.

6.8 Conclusion and Perspectives

Nature reserves represent suitable laboratories for studying the factors that serve as barriers to rapid invasions. By searching the available peer-reviewed literature, we found only 37 studies that focused on biological invasions in 24 nature reserves in China. In particular, there was shortage of studies that identify mechanisms or patterns of biological invasions. In the present study, we found that the age of nature reserves, latitude, and the number of plant species influence the number of invasive species or the index of invasion in nature reserves. The positive relationship between the number of invasive species and total number of plant species found in the present study (Fig. 6.6e) provides indirect support for the hypothesis that richer plant communities contain greater habitat diversity. Moreover, coastal and island reserves should receive greater attention and protection against further invasions due to their relatively high indices of invasion.

Although China's government is paying more attention and providing more funding to manage alien invasive species, the Ministry of Environmental Protection of the People's Republic of China provides little guidance for the control of alien invasive species, and there is a lack of specific policies, regulations, and implementation of management strategies or methods in China's nature reserves.

We suggest that both global change and disturbance (e.g., N deposition) should be taken into account when assessing the risk of alien species and developing management strategies. Meanwhile, ecological concepts such as the Allee effect may be important and potentially applied to controlling alien species in nature reserves.

In this chapter, we first conducted a brief survey of studies regarding biological invasions and nature reserves in China. Many nature reserves that have not been studied yet are likely to have been invaded. More investigations and studies should be conducted in other nature reserves, so as to avoid large losses of ecosystem function and economically important resources from biological invasions that have not yet been reported. To assess the risk of alien invasive species and find viable methods to manage invaded vegetation is important and urgent for the sustainability of China's wild species.

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Appendix I. The basic information of World National Parks and Protected Area.

National Park or National Forest	Country	Year	Size in hectares
Yellowstone	U.S. (Montana)	1872	899118
Yosemite	U.S. (California)	1890	302687
Sequoia National Park	U.S. (California)	1890	350444
Kings Canyon National Park	U.S. (California)	1940	
Mount Rainier National Park	U.S. (Washington)	1899	95354
Crater Lake	U.S. (Oregon)	1902	74148
Glacier	U.S. (Montana)	1919	410178
Rocky Mountain National Park	U.S. (Colorado)	1915	107595
Haleakalā National Park	U.S. (Hawaii)	1916	13878
Arches National Monument	U.S. (Utah)	1929	30901
Badlands Nat'l Monument	U.S. (South Dakota)	1929	98865
Carlsbad Caverns	U.S. (New Mexico)	1930	18926
Death Valley NP	U.S. (California and Nevada)	1994	1375933
Denali (formerly Mt. Mckinley National Park)	U.S. (Alaska)	1917	2458481
Everglades NP	U.S. (Florida)	1957	624239
Glacier Bay Nat'l Monument	U.S. (Alaska)	1925	1327451
Grand Canyon NP	U.S. (Arizona)	1919	492666
Grand Teton NP	U.S. (Wyoming)	1929	125450
Great Smoky Mountains	U.S. (North Carolina and Tennessee)	1934	211204
Katmai Nat'l Monument	U.S. (Alaska)	1918	1627376
Lafayette NP (renamed Acadia)	U.S. (Maine)	1919	20072
Mammoth Cave	U.S. (Kentucky)	1941	21380
Shenandoah	U.S. (Virginia)	1935	79890

Utah NP (renamed Bryce)	U.S. (Utah)	1928	14502
Zion NP	U.S. (Utah)	1919	60190
Everglades National Park	United States (Florida)	1947	610500
Lake Mead National Recreation Area	United States (Arizona and Nevada)	1936	605300
Arctic National Wildlife Refuge	Alaska, United States of America	1960	7800000
Yukon Delta National Wildlife Refuge	Alaska, United States of America	1980	7755000
Noatak National Preserve	United States (Alaska)	1978	2658700
Wrangell–St. Elias National Park and Preserve	United States (Alaska)	1980	5332100
Belovezhskaya National Park	Belarus	1991	87300
Pirin National Park	Bulgaria	1962	27200
České Švýcarsko National Park (Bohemian Switzerland)	Czech Republic	2000	7900
The Broads	England	1989	30300
Dartmoor National Park	England	1951	95300
Exmoor National Park	England	1954	69200
Lake District National Park (England's largest)	England	1951	229200
New Forest National Park	England	2005	56700
Northumberland National Park	England	1956	104900
North York Moors National Park	England	1952	143600
Peak District (Britain's first Nat'l park)	England	1951	143800
South Downs National Park	England	2010	164800
Yorkshire Dales	England	1954	176200
Brecon Beacons	Wales	1957	134700
Loch Lomond and the Trossachs National Park	Scotland	2002	186500
Pembrokeshire Coast National Park	Wales	1952	62000
Snowdonia	Wales	1951	213200

Cairngorms	Scotland	2003	452800
Banff National Park	Alberta, Canada	1885	663960
Cape Breton Highlands National Park	Nova Scotia, Canada	1936	95081
Gros Morne National Park	Newfoundland and Labrador	1973	180452
Jasper National Park	Alberta (largest NP in Canadian Rockies)	1907	1122563
Mingan Archipelago National Park	Quebec, Canada	1984	9998
Nahanni National Park	Northwest Terretories, Canada	1972	167100
Pacific Rim National Park	British Columbia, Canada	1970	51182
St. Lawrence Island National Park	Ontario, Canada	1904	2400
Wapusk National Park	Manitoba, Canada	1996	1147446
Waterton Lakes National Park	Alberta, Canada	1895	50489
Fundy National Park	New Brunswick Canada	1948	20594
Cinque Terre, Italy	Italy	1999	3900
Oulanka National Park	Finland	1956	27000
Cevennes National Park	France	1970	91300
Pyrénées National Park	France	1967	45700
Bavarian Forest National Park	Germany	1970	24100
Saxon Switzerland National Park	Germany	1990	9300
Killarney National Park	Ireland	1932	10600
Etna National Park	Italy	1987	58100
Durmitor National Park	Montenegro	1952	33900
De Hoge Veluwe National Park	The Netherlands	1935	5400
Peneda Geres National Park	Portugal	1971	69700
Aigüestortes i Estany de Sant Maurici National Park	Spain	1955	10200
Doñana National Park	Spain	1969	54200

Garajonay National Park	Canary Islands, Spain	1981	4000
Northeast Greenland National Park	Greenland	1974	97200000
Hoggar National Park	Algeria/Sahara	1987	45000000
Phoenix Islands Protected Area	Kiribati (Phoenix Islands)	2008	40825000
Papahānaumokuākea Marine National Monument	United States (Hawaii and the Midway Atoll)	2006	36000000
Hawaiian Islands National Wildlife Refuge			
Midway Atoll National Wildlife Refuge			
Battle of Midway National Memorial			
Hawaii State Seabird Sanctuary at Kure Atoll			
Northwestern Hawaiian Islands State Marine Refuge			
Kavango-Zambezi Transfrontier Conservation Area	Angola, Botswana, Namibia, Zambia, Zimbabwe	2010	38713200
Luiana Game Reserve			
Mavinga Game Reserve			
Chobe National Park			
Makgadikgadi National Park			
Nxai Pan National Park			
Moremi Game Reserve			
Mamili National Park			
Mudumu National Park			
Bwabwata National Park			
Liuwa Plain National Park			
Kafue National Park			
Mosi-oa-Tunya National Park			
Sioma Ngwezi National Park			
Hwange National Park			

Kazuma Pan National Park			
Zambezi National Park			
Victoria Falls National Park			
Marianas Trench National Monument	Mariana Islands, United States of America	2009	25000000
Great Limpopo Transfrontier Park	Mozambique, South Africa, Zimbabwe	2002	9980000
Limpopo National Park			
Makuleke region			
Banhine National Park			
Zinave National Park			
Maputo Special Reserve			
Kruger National Park			
Gonarezhou National Park			
Manjinji Pan Sanctuary			
Malipati Safari Area			
Senge Communial Land Area			
Air and Ténéré Natural Reserves	Niger	1991	7736000
Aïr and Ténéré National Nature Reserve			
Aïr and Ténéré Addax Sanctuary			
Central Kalahari Game Reserve	Botswana	1961	5280000
Namib Naukluft Park	Namibia	1907	5976800
Great Australian Bight Commonwealth Marine Reserve	Australia (south of South Australia)	2012	4592600
Wood Buffalo National Park	Canada (Alberta and Northwest Territories)	1922	4480700
Selous Game Reserve	Tanzania	1922	4460000
Niassa National Reserve	Mozambique	1954	4200000
Great Arctic State Nature Reserve	Russia	1993	4169200

Gates of the Arctic National Park and Preserve	United States(Alaska)	1980	3946000
Tumucumaque National Park	Brazil	2002	388740
Parima Tapirapecó National Park	Venezuela	1991	3829000
Quittinirpaaq National Park	Canada (Nunavut)	2001	377500
Kgalagadi Transfrontier Park			
Kalahari Gemsbok National Park	Botswana, South Africa	2000	3725600
Gemsbok National Park			
Bernardo O'Higgins National Park	Chile	1969	3525900
Rose Atoll National Monument	American Samoa	1969	3500000
Yukon Flats National Wildlife Refuge	Alaska, United States of America	1969	3500000
Guiana Amazonian Park	French Guiana	2007	33900
Canaima National Park	Venezuela	1962	3000000
Nahanni National Park Reserve	Canada (Northwest Territories)	1976	3000000
Simpson Desert Regional Reserve	Australia (South Australia)	1985	2923900
Boucle du Baoulé National Park	Mali	1982	2533000
Lorentz National Park	West Papua, Indonesia	1997	2505600
Denali National Park and Preserve	United States (Alaska)	1917	2458500
Jaú National Park	Brazil	2000	2300000
Boma National Park	South Sudan	2012	2280000
Kafue National Park	Zambia	1924	2240000
Etosha National Park	Namibia	1907	2227000
Sirmilik National Park	Canada (Nunavut)	2001	2220000
Kluane National Park	Canada (Yukon)	1972	2201300
Auyuittuq National Park	Canada (Nunavut)	2001	2247100
Tsavo National Park	Kenya	1948	2081200

Tsavo East National Park			
Tsavo West National Park			
Ukkusiksalik National Park	Canada (Nunavut)	2003	2050000
Ruaha National Park	Tanzania	1964	2020000
Yellabinna Regional Reserve	Australia (South Australia)	1990	2000800
Bosawás Biosphere Reserve	Nicaragua	1991	2000000
Kakadu National Park	Australia (Northern Territory)	1981	1980400
Nullarbor Regional Reserve	Australia (South Australia)	1989	1919800
Katmai National Park and Preserve	United States (Alaska)	1980	1912299
Yugyd Va National Park	Russia (Komi)	1994	1891700
Laguna San Rafael National Park	Chile	1959	1742000
Salonga National Park	Democratic Republic of the Congo	1984	1704600
Skeleton Coast National Park	Namibia	1971	1687000
Maloti-Drakensberg Transfrontier Conservation Area			
Golden Gate Highlands National Park			
QwaQwa National Park			
Sterkfontein Dam Nature Reserve	Lesotho, South Africa	2001	1622600
uKhahlamba Drakensberg Park			
Royal Natal National Park			
Sehlabathebe National Park			
Tuktut Nogait National Park	Canada (Northwest Territories)	1996	1634000
Lake Clark National Park and Preserve	United States (Alaska)	1980	1630900
Central Suriname Nature Reserve	Suriname	1998	1600000
Manú National Park	Peru	1987	1532800
Iona National Park	Angola	1964	1515000

Serengeti National Park	Tanzania	1981	1476300
Hwange National Park	Zimbabwe	1930	1465100
Alberto de Agostini National Park	Chile	2005	1460000
Okapi Wildlife Reserve	Democratic Republic of the Congo	1996	1400000
Kerinci Seblat National Park	Sumatra, Indonesia	1982	1379100
Death Valley National Park	United States (California)	1933	1363000
Innamincka Regional Reserve	Australia (South Australia)	1988	1354000
Kati Thanda-Lake Eyre National Park	Australia (South Australia)	1985	1349100
Glacier Bay National Park and Preserve	United States (Alaska)	1980	1328700
Judbarra/Gregory National Park	Australia (Northern Territory)	1990	1288200
Karlamilyi National Park	Australia (Western Australia)	1977	1283700
Chiribiquete National Park	Colombia	1989	1280000
Fiordland National Park	New Zealand	1952	1250000
Aulavik National Park	Canada (Northwest Territories)	1992	1220000
Banc d'Arguin National Park	Mauritania	1978	1200000
Vatnajökull National Park	Iceland	2008	1420000
Upemba National Park	Democratic Republic of the Congo	1939	1173000
Wapusk National Park	Canada (Manitoba)	1996	1147500
Puinawai Natural Reserve	Colombia (Guainía Department)	1989	1092500
Bering Land Bridge National Preserve	United States (Alaska)	1978	1092200
Jasper National Park	Canada (Alberta)	1907	1087800
Maiko National Park	Democratic Republic of the Congo	1970	1083000
Yaigojé Apaporis Natural Park	Colombia	2009	1055700
Yukon-Charley Rivers National Preserve	United States (Alaska)	1978	1022000
Ivvavik National Park	Canada (Yukon)	1984	1016800

Munga-Thirri National Park	Australia (Queensland)	1967	1012000
Central Karakoram National Park	Skardu District, Gilgit District, Pakistan	1993	1000000
W Transborder Park	Benin, Burkina Faso, Niger	1954	1000000
Quiçama National Park	Angola	1957	996000
Torngat Mountains National Park	Canada (Labrador and Newfoundland)	2005	960000
Laponian Area - UNESCO World Heritage Site	Sweden (Lapland)	1996	940000
Sarek National Park			
Padjelanta National Park			
Stora Sjöfallet National Park			
Muddus National Park			
Sjaunja Nature Reserve (other languages)			
Stubba Nature Reserve (nl/fr)			
Misty Fjords National Monument	United States (Alaska)	1978	924,600
South Luangwa National Park	Zambia	1972	905,000
Yellowstone National Park	United States (Idaho, Montana, and Wyoming)	1872	898,300
Nullarbor Wilderness Protection Area	Australia (South Australia)	2013	894,200
Ngorongoro Conservation Area	Tanzania	1959	828,800
Tadres Reserve	Niger	1940	788,900
Virunga National Park	Democratic Republic of the Congo	1925	780,000
Witjira National Park	Australia (South Australia)	1985	771,100
Grand Staircase-Escalante National Monument	United States (Utah)	1996	757,100
Pechora-Ilych Nature Reserve	Russia	1930	721,300
Nahuel Huapi National Park	Argentina	1934	705,000
Termit Massif Reserve	Niger	1962	700000
Kosciuszko National Park	Australia (New South Wales)	1967	690000

Kobuk Valley National Park	United States (Alaska)	1980	675800
Banff National Park	Canada (Alberta)	1885	664100
Alpine National Park	Australia (Victoria)	1989	646000
Murray-Sunset National Park	Australia (Victoria)	1991	633000
Karijini National Park	Australia (Western Australia)	1991	627400
Mojave National Preserve	United States (California)	1994	621100
Southwest National Park	Australia (Tasmania)	1955	618300
Ai-Ais/Richtersveld Transfrontier Park	Namibia, South Africa	2003	604500
Ai-Ais Hot Springs Game Park			
Richtersveld National Park			
Kahuzi-Biega National Park	Democratic Republic of the Congo	1980	600000
Lake Torrens National Park	Australia (South Australia)	1991	567700
Waterton-Glacier International Peace Park	Canada (Alberta), United States (Montana)	1995	560600
Glacier National Park			
Waterton Lakes National Park			
Vindelfjällen Nature Reserve (other languages)	Sweden (Lapland)	1995	560000
Saoyú-□ehdacho National Historic Site	Canada (Northwest Territories)	1997	558700
Lake Gairdner National Park	Australia (South Australia)	1991	548100
Lakefield National Park	Australia (Queensland)	1979	537000
Glen Canyon National Recreation Area	United States (Arizona and Utah)	1972	507600
Diamantina National Park	Australia (Queensland)	1993	507000
Conkouati-Douli National Park	Republic of Congo	1993	505000
Wollemi National Park	Australia (New South Wales)	1979	501700
Yellabinna Wilderness Protection Area	Australia (South Australia)	2005	500700

Bafing National Park	Mali	2000	500000
Sioma Ngwezi National Park	Zambia	2007	500000
Garamba National Park	Democratic Republic of the Congo	1938	492000
Staaten River National Park	Australia (Queensland)	1977	470000
Oyala Thumotang National Park	Australia (Queensland)	1994	457000
Cairngorms National Park	Scotland	2003	452800
Kahurangi National Park	New Zealand	1996	452000
Drysdale River National Park	Australia (Western Australia)	1974	448300
Katavi National Park	Tanzania	1974	447100
Franklin-Gordon Wild Rivers National Park	Australia (Tasmania)	1908	457000
Los Glaciares National Park	Argentina	1981	445900
Vuntut National Park	Canada (Yukon)	1995	434500
Taman Negara National Park	Malaysia	1938	434300
Nouabalé-Ndoki National Park	Republic of Congo	1993	400000
Sighisoara, Tarnava Mare, Podisul Hartibaciului	Romania	2008	360000

Appendix II. species list reported in nature reserves in China. A: annual; P: Perennial; B: Binnial; H: Herb; H: Shrub; T: Tree; C: Climbing vine.

Species	Family	Life form	Growth form	Natural reservation	Major references
Conyza canadensis	Compositae	A	H	Taohongling	Xu et al. (2012)
Euphorbia maculate	Eurphorbiaceae	A	H	Bawangling	Hu et al. (2011)
Lantana camara	Verbenaceae	P	S	Bawangling	Hu et al. (2011)
Lantana camara	Verbenaceae	P	S	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Leucaena leucocephala	Leguminosae	P	T	Bawangling	Hu et al. (2011)
Manihot esculenta	Euphorbiaceae	P	T	Bawangling	Hu et al. (2011)
Nerium indicum	Apocynaceae	P	S	Bawangling	Hu et al. (2011)
Ricinus communis	Euphorbiaceae	A	H	Bawangling	Hu et al. (2011)
Tamarindus indica	Leguminosae	P	T	Bawangling	Hu et al. (2011)
Abutilon crispum	Malvaceae	P	H	Bawangling	Hu et al. (2011)
Abutilon crispum	Malvaceae	P	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Abutilon crispum	Malvaceae	P	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Acanthospermum australe	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Acanthospermum australe	Compositae	A	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Aegilops squarrosa	Gramineae	A	H	Hengshui	Li. (2008)
Ageratum conyzoides	Compositae	A	H	Bawangling	Hu et al. (2011)
Ageratum conyzoides	Compositae	A	H	Dashahe	Lin et al. (2008)
Ageratum conyzoides	Compositae	A	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Ageratum conyzoides	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Ageratum conyzoides	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Ageratum conyzoides	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Ageratum conyzoides	Compositae	A	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Ageratum conyzoides	Compositae	A	H	Ganshiling	Zhang et al. (2011）
Ageratum conyzoides	Compositae	A	H	Hongshulin	Cao et al. (2007)

Ageratum conyzoides	Compositae	A	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Ageratum conyzoides	Compositae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Ageratum conyzoides	Compositae	A	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Ageratum houstonianum	Compositae	A	H	Nabanhe	Liu et al. (2008)
Ageratum houstonianum	Compositae	A	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Agropyron cristatum	Gramineae	P	H	Songshan	Liu et al. (2012)
Alternanthera philoxeroides	Amaranthaceae	P	H	Bawangling	Hu et al. (2011)
Alternanthera philoxeroides	Amaranthaceae	P	H	Songshan	Liu et al. (2012)
Alternanthera philoxeroides	Amaranthaceae	P	H	Dashahe	Lin et al. (2008)
Alternanthera philoxeroides	Amaranthaceae	P	H	Dayudao	Zhu et al. (2006)
Alternanthera philoxeroides	Amaranthaceae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Alternanthera philoxeroides	Amaranthaceae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Alternanthera philoxeroides	Amaranthaceae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Alternanthera philoxeroides	Amaranthaceae	P	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Alternanthera philoxeroides	Amaranthaceae	P	H	Hengshui	Li. (2008)
Alternanthera philoxeroides	Amaranthaceae	P	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Alternanthera philoxeroides	Amaranthaceae	P	H	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Alternanthera philoxeroides	Amaranthaceae	P	H	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Alternanthera philoxeroides	Amaranthaceae	P	H	Nabanhe	Liu et al. (2008)
Alternanthera philoxeroides	Amaranthaceae	P	H	Poyanghu	Ge et al. (2010) & Zeng et al. (2013)
Alternanthera philoxeroides	Amaranthaceae	P	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Alternanthera philoxeroides	Amaranthaceae	P	H	Taohongling	Xu et al. (2013)
Alternanthera philoxeroides	Amaranthaceae	P	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Alternanthera pungens	Amaranthaceae	A	H	Bawangling	Hu et al. (2011)
Alternanthera pungens	Amaranthaceae	A	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Alternanthera pungens	Amaranthaceae	A	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)

Alternanthera pungens	Amaranthaceae	A	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Amaranthus blitoides	Amaranthaceae	A	H	Hengshui	Li. (2008)
Amaranthus blitoides	Amaranthaceae	A	H	Shedao-Laotieshan	Jiang et al. (2012) & Wu et al. (2014)
Amaranthus caudatus	Amaranthaceae	A	H	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Amaranthus caudatus	Amaranthaceae	A	H	Taohongling	Xu et al. (2014)
Amaranthus hybridus	Amaranthaceae	A	H	Poyanghu	Ge et al. (2010) & Zeng et al. (2013)
Amaranthus hybridus	Amaranthaceae	A	H	Shedao-Laotieshan	Jiang et al. (2012) & Wu et al. (2014)
Amaranthus lividus	Amaranthaceae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Amaranthus lividus	Amaranthaceae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Amaranthus paniculatus L.	Amaranthaceae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Amaranthus polygonoides	Amaranthaceae	A	H	Shedao-Laotieshan	Jiang et al. (2012) & Wu et al. (2014)
Amaranthus retroflexus	Amaranthaceae	A	H	Songshan	Liu et al. (2012)
Amaranthus retroflexus	Amaranthaceae	A	H	Hengshui	Li. (2008)
Amaranthus retroflexus	Amaranthaceae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Amaranthus retroflexus	Amaranthaceae	A	H	Jiuduansha	Jiang et al. (2007) & Qin et al. (2007)
Amaranthus retroflexus	Amaranthaceae	A	H	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Amaranthus retroflexus	Amaranthaceae	A	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Amaranthus retroflexus	Amaranthaceae	A	H	Taohongling	Xu et al. (2015)
Amaranthus retroflexus	Amaranthaceae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Amaranthus retroflexus	Amaranthaceae	A	H	Xingdoushan	Lu et al. (2005)
Amaranthus retroflexus	Amaranthaceae	A	H	Yalujiangkou	Jiang et al. (2007) & Wu et al. (2010)
Amaranthus retroflexus	Amaranthaceae	A	H	Yiwulvshan	Wu et al. (2010)
Amaranthus spinosus	Amaranthaceae	A	H	Bawangling	Hu et al. (2011)
Amaranthus spinosus	Amaranthaceae	A	H	Dashahe	Lin et al. (2008)
Amaranthus spinosus	Amaranthaceae	A	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Amaranthus spinosus	Amaranthaceae	A	H	Dayudao	Zhu et al. (2006)

Amaranthus spinosus	Amaranthaceae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Amaranthus spinosus	Amaranthaceae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Amaranthus spinosus	Amaranthaceae	A	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Amaranthus spinosus	Amaranthaceae	A	H	Ganshiling	Zhang et al. (2011）
Amaranthus spinosus	Amaranthaceae	A	H	Hengshui	Li. (2008)
Amaranthus spinosus	Amaranthaceae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Amaranthus spinosus	Amaranthaceae	A	H	Nabanhe	Liu et al. (2008)
Amaranthus spinosus	Amaranthaceae	A	H	Poyanghu	Ge et al. (2010) & Zeng et al. (2013)
Amaranthus spinosus	Amaranthaceae	A	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Amaranthus spinosus	Amaranthaceae	A	H	Taohongling	Xu et al. (2016)
Amaranthus spinosus	Amaranthaceae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Amaranthus spinosus	Amaranthaceae	A	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Amaranthus spinosus	Amaranthaceae	A	H	Xingdoushan	Lu et al. (2005)
Amaranthus tricolor	Amaranthaceae	A	H	Songshan	Liu et al. (2012)
Amaranthus tricolor	Amaranthaceae	A	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Amaranthus tricolor	Amaranthaceae	A	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Amaranthus tricolor	Amaranthaceae	A	H	Hongshulin	Cao et al. (2007)
Amaranthus tricolor	Amaranthaceae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Amaranthus tricolor	Amaranthaceae	A	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Amaranthus tricolor	Amaranthaceae	A	H	Xingdoushan	Lu et al. (2005)
Amaranthus viridis	Amaranthaceae	A	H	Songshan	Liu et al. (2012)
Amaranthus viridis	Amaranthaceae	A	H	Dashahe	Lin et al. (2008)
Amaranthus viridis	Amaranthaceae	A	H	Dayudao	Zhu et al. (2006)
Amaranthus viridis	Amaranthaceae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Amaranthus viridis	Amaranthaceae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Amaranthus viridis	Amaranthaceae	A	H	Hengshui	Li. (2008)

Amaranthus viridis	Amaranthaceae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Amaranthus viridis	Amaranthaceae	A	H	Nabanhe	Liu et al. (2008)
Amaranthus viridis	Amaranthaceae	A	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Amaranthus viridis	Amaranthaceae	A	H	Taohongling	Xu et al. (2017)
Amaranthus viridis	Amaranthaceae	A	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Amaranthus viridis	Amaranthaceae	A	H	Xingdoushan	Lu et al. (2005)
Ambrosia artemisiifolia	Compositae	A	H	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Ambrosia artemisiifolia	Compositae	A	H	Poyanghu	Ge et al. (2010) & Zeng et al. (2013)
Ambrosia artemisiifolia	Compositae	A	H	Shedao-Laotieshan	Jiang et al. (2012) & Wu et al. (2014)
Ambrosia artemisiifolia	Compositae	A	H	Taohongling	Xu et al. (2018)
Ambrosia artemisiifolia	Compositae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Ambrosia trifida	Compositae	A	H	Yalujiangkou	Jiang et al. (2007) & Wu et al. (2010)
Anredera cordifolia	Basellaceae	P	C	Dashahe	Lin et al. (2008)
Anredera cordifolia	Basellaceae	P	C	Dayudao	Zhu et al. (2006)
Anredera cordifolia	Basellaceae	P	C	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Arctium lappa	Compositae	P	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Aster subulatus	Compositae	A	H	Dashahe	Lin et al. (2008)
Aster subulatus	Compositae	A	H	Jiuduansha	Jiang et al. (2007) & Qin et al. (2007)
Aster subulatus	Compositae	A	H	Xingdoushan	Lu et al. (2005)
Atropa belladonna	Solanaceae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Avena fatua	Gramineae	A	H	Dashahe	Lin et al. (2008)
Avena fatua	Gramineae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Avena fatua	Gramineae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Avena fatua	Gramineae	A	H	Jiuduansha	Jiang et al. (2007) & Qin et al. (2007)
Avena fatua	Gramineae	A	H	Poyanghu	Ge et al. (2010) & Zeng et al. (2013)
Avena fatua	Gramineae	A	H	Taohongling	Xu et al. (2019)

Avena fatua	Gramineae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Avena fatua	Gramineae	A	H	Xingdoushan	Lu et al. (2005)
Axonopus compressus	Gramineae	P	H	Bawangling	Hu et al. (2011)
Axonopus compressus	Gramineae	P	H	Songshan	Liu et al. (2012)
Axonopus compressus	Gramineae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Axonopus compressus	Gramineae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Axonopus compressus	Gramineae	P	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Axonopus compressus	Gramineae	P	H	Ganshiling	Zhang et al. (2011）
Axonopus compressus	Gramineae	P	H	Hongshulin	Cao et al. (2007)
Axonopus compressus	Gramineae	P	H	Nabanhe	Liu et al. (2008)
Axonopus compressus	Gramineae	P	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Axonopus compressus	Gramineae	P	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Basella alba	Basellaceae	A	H	Ganshiling	Zhang et al. (2011）
Basella alba	Basellaceae	A	H	Taohongling	Xu et al. (2020)
Bidens frondosa	Compositae	A	H	Songshan	Liu et al. (2012)
Bidens frondosa	Compositae	A	H	Songshan	Liu et al. (2012)
Bidens frondosa	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Bidens frondosa	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Bidens frondosa	Compositae	A	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Bidens frondosa	Compositae	A	H	Hongshulin	Cao et al. (2007)
Bidens frondosa	Compositae	A	H	Yalujiangkou	Jiang et al. (2007) & Wu et al. (2010)
Bidens pilosa	Compositae	A	H	Dashahe	Lin et al. (2008)
Bidens pilosa	Compositae	A	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Bidens pilosa	Compositae	A	H	Dayudao	Zhu et al. (2006)
Bidens pilosa	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Bidens pilosa	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)

Bidens pilosa	Compositae	A	H	Hongshulin	Cao et al. (2007)
Bidens pilosa	Compositae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Bidens pilosa	Compositae	A	H	Nabanhe	Liu et al. (2008)
Bidens pilosa	Compositae	A	H	Poyanghu	Ge et al. (2010) & Zeng et al. (2013)
Bidens pilosa	Compositae	A	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Bidens pilosa	Compositae	A	H	Taohongling	Xu et al. (2021)
Bidens pilosa	Compositae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Bidens pilosa	Compositae	A	H	Xingdoushan	Lu et al. (2005)
Bryophyllum pinnatum	Crassulaceae	P	H	Bawangling	Hu et al. (2011)
Bryophyllum pinnatum	Crassulaceae	P	H	Ganshiling	Zhang et al. (2011）
Canna indica	Cannaceae	P	H	Bawangling	Hu et al. (2011)
Cannabis sativa	Moraceae	A	H	Songshan	Liu et al. (2012)
Cannabis sativa	Moraceae	A	H	Hengshui	Li. (2008)
Capsella bursa-pastoris	Cruciferae	A	H	Taohongling	Xu et al. (2022)
Capsicum annuum	Solanaceae	A	H	Ganshiling	Zhang et al. (2011）
Capsicum annuum	Solanaceae	A	H	Taohongling	Xu et al. (2023)
Cassia leschenaultiana	Leguminosae	P	S	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Cassia leschenaultiana	Leguminosae	P	S	Yalujiangkou	Jiang et al. (2007) & Wu et al. (2010)
Cassia mimosoides	Leguminosae	P	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Cassia mimosoides	Leguminosae	P	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Cassia occidentalis	Leguminosae	P	S	Bawangling	Hu et al. (2011)
Cassia occidentalis	Leguminosae	P	S	Datian	Jinag et al. (2007) & Qin et al. (2008)
Cassia occidentalis	Leguminosae	P	S	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Cassia occidentalis	Leguminosae	P	S	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Cassia occidentalis	Leguminosae	P	S	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Catharanthus roseus	Apocynaceae	P	H	Ganshiling	Zhang et al. (2011）

Catharanthus roseus	Apocynaceae	P	H	Ganshiling	Zhang et al. (2011）
Catharanthus roseus	Apocynaceae	P	H	Taohongling	Xu et al. (2024)
Celosia argentea	Amaranthaceae	A	H	Bawangling	Hu et al. (2011)
Celosia cristata	Amaranthaceae	A	H	Taohongling	Xu et al. (2025)
Cenchrus pauciflorus	Gramineae	A	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Centrosema pubescens	Leguminosae	P	C	Ganshiling	Zhang et al. (2011）
Chaerophyllum villosum	Umbelliferae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Chenopodium album	Chenopodiaceae	A	H	Hengshui	Li. (2008)
Chenopodium album	Chenopodiaceae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Chenopodium ambrosioides	Chenopodiaceae	P	H	Bawangling	Hu et al. (2011)
Chenopodium ambrosioides	Chenopodiaceae	A	H	Dashahe	Lin et al. (2008)
Chenopodium ambrosioides	Chenopodiaceae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Chenopodium ambrosioides	Chenopodiaceae	A	H	Hengshui	Li. (2008)
Chenopodium ambrosioides	Chenopodiaceae	P	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Chenopodium ambrosioides	Chenopodiaceae	P	H	Jiuduansha	Jiang et al. (2007) & Qin et al. (2007)
Chenopodium ambrosioides	Chenopodiaceae	P	H	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Chenopodium ambrosioides	Chenopodiaceae	P	H	Nabanhe	Liu et al. (2008)
Chenopodium ambrosioides	Chenopodiaceae	P	H	Poyanghu	Ge et al. (2010) & Zeng et al. (2013)
Chenopodium ambrosioides	Chenopodiaceae	P	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Chenopodium ambrosioides	Chenopodiaceae	P	H	Taohongling	Xu et al. (2026)
Chenopodium ambrosioides	Chenopodiaceae	P	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Chenopodium hybridum	Chenopodiaceae	A	H	Dashahe	Lin et al. (2008)
Chenopodium hybridum	Chenopodiaceae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Chromolaena odorata	Compositae	P	H	Bawangling	Hu et al. (2011)
Chromolaena odorata	Compositae	P	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Chromolaena odorata	Compositae	P	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)

Chromolaena odorata	Compositae	P	H	Ganshiling	Zhang et al. (2011）
Chromolaena odorata	Compositae	P	H	Jiuduansha	Jiang et al. (2007) & Qin et al. (2007)
Chromolaena odorata	Compositae	P	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Chromolaena odorata	Compositae	P	H	Bawangling	Hu et al. (2011)
Chromolaena odorata	Compositae	P	S	Datian	Jinag et al. (2007) & Qin et al. (2008)
Chromolaena odorata	Compositae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Chromolaena odorata	Compositae	P	H	Ganshiling	Zhang et al. (2011）
Chromolaena odorata	Compositae	P	S	Nabanhe	Liu et al. (2008)
Chromolaena odorata	Compositae	P	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Chromolaena odorata	Compositae	P	S	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Cissampelopsis volubilis	Compositae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Cocos nucifera	Palmae	P	T	Ganshiling	Zhang et al. (2011）
Coix lacryma-jobi	Poaceae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Conyza bonariensis	Compositae	A	H	Ganshiling	Zhang et al. (2011）
Conyza bonariensis	Compositae	A	H	Hongshulin	Cao et al. (2007)
Conyza bonariensis	Compositae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Conyza bonariensis	Compositae	A	H	Xingdoushan	Lu et al. (2005)
Conyza canadensis	Compositae	A	H	Dashahe	Lin et al. (2008)
Conyza canadensis	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Conyza canadensis	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Conyza canadensis	Compositae	A	H	Ganshiling	Zhang et al. (2011）
Conyza canadensis	Compositae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Conyza canadensis	Compositae	A	H	Shedao-Laotieshan	Jiang et al. (2012) & Wu et al. (2014)
Conyza canadensis	Compositae	A	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Conyza canadensis	Compositae	A	H	Xingdoushan	Lu et al. (2005)
Conyza canadensis (L.) Cronq.	Compositae	A	H	Hengshui	Li. (2008)

Conyza canadensis(L.) Cronq.	Compositae	A	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Conyza canadensis(L.) Cronq.	Compositae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Conyza canadensis(L.) Cronq.	Compositae	A	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Conyza sumatrensis	Compositae	A	H	Dashahe	Lin et al. (2008)
Conyza sumatrensis	Compositae	A	H	Dashahe	Lin et al. (2008)
Conyza sumatrensis	Compositae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Corchorus capsularis	Tiliaceae	A	H	Taohongling	Xu et al. (2027)
Coreopsis grandiflora	Compositae	P	H	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Coreopsis grandiflora	Compositae	P	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Coreopsis lanceolata	Compositae	P	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Coriandrum sativum	Umbelliferae	A	H	Taohongling	Xu et al. (2028)
Coronopus didymus	Cruciferae	A	H	Dayudao	Zhu et al. (2006)
Coronopus didymus	Cruciferae	A	H	Jiuduansha	Jiang et al. (2007) & Qin et al. (2007)
Coronopus didymus	Cruciferae	A	H	Poyanghu	Ge et al. (2010) & Zeng et al. (2013)
Coronopus didymus	Cruciferae	A	H	Taohongling	Xu et al. (2029)
Coronopus didymus	Cruciferae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Crassocephalum crepidioides	Compositae	A	H	Dayudao	Zhu et al. (2006)
Crassocephalum crepidioides	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Crassocephalum crepidioides	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Crassocephalum crepidioides	Compositae	A	H	Hongshulin	Cao et al. (2007)
Crassocephalum crepidioides	Compositae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Crassocephalum crepidioides	Compositae	A	H	Nabanhe	Liu et al. (2008)
Crassocephalum crepidioides	Compositae	A	H	Taohongling	Xu et al. (2030)
Crassocephalum crepidioides	Compositae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Crassocephalum crepidioides	Compositae	A	H	Xingdoushan	Lu et al. (2005)
Cuphea balsamona	Lythraceae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)

Cyperus rotundus	Cyperaceae	P	H	Taohongling	Xu et al. (2031)
Datura metel	Solanaceae	A	H	Taohongling	Xu et al. (2032)
Datura metel	Solanaceae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Datura stramonium	Solanaceae	A	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Datura stramonium	Solanaceae	A	H	Hengshui	Li. (2008)
Datura stramonium	Solanaceae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Datura stramonium	Solanaceae	A	H	Nabanhe	Liu et al. (2008)
Datura stramonium	Solanaceae	A	H	Shedao-Laotieshan	Jiang et al. (2012) & Wu et al. (2014)
Datura stramonium	Solanaceae	A	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Datura stramonium	Solanaceae	A	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Datura stramonium	Solanaceae	A	H	Xingdoushan	Lu et al. (2005)
Daucus carota	Umbelliferae	B	H	Dashahe	Lin et al. (2008)
Daucus carota	Umbelliferae	B	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Daucus carota	Umbelliferae	B	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Daucus carota	Umbelliferae	B	H	Jiuduansha	Jiang et al. (2007) & Qin et al. (2007)
Daucus carota	Umbelliferae	B	H	Taohongling	Xu et al. (2033)
Daucus carota	Umbelliferae	B	H	Xingdoushan	Lu et al. (2005)
Eichhornia crassipes	Pontederiaceae	P	H	Dashahe	Lin et al. (2008)
Eichhornia crassipes	Pontederiaceae	P	H	Hongshulin	Cao et al. (2007)
Eichhornia crassipes	Pontederiaceae	P	H	Poyanghu	Ge et al. (2010) & Zeng et al. (2013)
Eichhornia crassipes	Pontederiaceae	P	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Eichhornia crassipes	Pontederiaceae	P	H		
Eleusine indica	Gramineae	A	H	Bawangling	Hu et al. (2011)
Eleusine indica	Gramineae	A	H	Hongshulin	Cao et al. (2007)
Eleusine indica	Gramineae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Eleusine indica	Gramineae	A	H	Taohongling	Xu et al. (2034)

Eleusine indica	Gramineae	A	H	Xingdoushan	Lu et al. (2005)
Eleusine indica	Gramineae	A	H	Yiwulvshan	Wu et al. (2010)
Erechtites hieracifolia	Compositae	A	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Erechtites valerianaefolia (Wolf) DC.	Compositae	A	H	Ganshiling	Zhang et al. (2011）
Erigeron annuus	Compositae	A	H	Bawangling	Hu et al. (2011)
Erigeron annuus	Compositae	A	H	Songshan	Liu et al. (2012)
Erigeron annuus	Compositae	A	H	Dashahe	Lin et al. (2008)
Erigeron annuus	Compositae	A	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Erigeron annuus	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Erigeron annuus	Compositae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Erigeron annuus	Compositae	A	H	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Erigeron annuus	Compositae	A	H	Poyanghu	Ge et al. (2010) & Zeng et al. (2013)
Erigeron annuus	Compositae	A	H	Shedao-Laotieshan	Jiang et al. (2012) & Wu et al. (2014)
Erigeron annuus	Compositae	A	H	Taohongling	Xu et al. (2035)
Erigeron annuus	Compositae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Erigeron annuus	Compositae	A	H	Xingdoushan	Lu et al. (2005)
Erigeron annuus	Compositae	A	H	Yalujiangkou	Jiang et al. (2007) & Wu et al. (2010)
Erigeron annuus	Compositae	A	H	Yiwulvshan	Wu et al. (2010)
Eryngium foetidum	Umbelliferae	P	H	Nabanhe	Liu et al. (2008)
Eryngium foetidum	Umbelliferae	P	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Eupatorium adenophorum	Compositae	P	H	Nabanhe	Liu et al. (2008)
Eupatorium catarium	Compositae	A	H	Bawangling	Hu et al. (2011)
Eupatorium catarium	Compositae	A	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Eupatorium catarium	Compositae	A	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Eupatorium catarium	Compositae	A	H	Ganshiling	Zhang et al. (2011）
Eupatorium catarium	Compositae	A	H	Hongshulin	Cao et al. (2007)

Eupatorium catarium	Compositae	A	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Euphorbia helioscopia	Euphorbiaceae	A	H	Taohongling	Xu et al. (2036)
Euphorbia helioscopia	Euphorbiaceae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Euphorbia helioscopia	Euphorbiaceae	A	H	Xingdoushan	Lu et al. (2005)
Euphorbia hirta	Euphorbiaceae	A	H	Bawangling	Hu et al. (2011)
Euphorbia hirta	Euphorbiaceae	A	H	Dashahe	Lin et al. (2008)
Euphorbia hirta	Euphorbiaceae	A	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Euphorbia hirta	Euphorbiaceae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Euphorbia hirta	Euphorbiaceae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Euphorbia hirta	Euphorbiaceae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Euphorbia hirta	Euphorbiaceae	A	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Euphorbia hirta	Euphorbiaceae	A	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Euphorbia hirta	Euphorbiaceae	A	H	Ganshiling	Zhang et al. (2011）
Euphorbia hirta	Euphorbiaceae	A	H	Hongshulin	Cao et al. (2007)
Euphorbia hirta	Euphorbiaceae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Euphorbia hirta	Euphorbiaceae	A	H	Nabanhe	Liu et al. (2008)
Euphorbia hirta	Euphorbiaceae	A	H	Poyanghu	Ge et al. (2010) & Zeng et al. (2013)
Euphorbia hirta	Euphorbiaceae	A	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Euphorbia hirta	Euphorbiaceae	A	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Euphorbia maculata	Euphorbiaceae	A	H	Dashahe	Lin et al. (2008)
Euphorbia maculata	Euphorbiaceae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Euphorbia maculata	Euphorbiaceae	A	H	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Euphorbia maculata	Euphorbiaceae	A	H	Shedao-Laotieshan	Jiang et al. (2012) & Wu et al. (2014)
Euphorbia maculata	Euphorbiaceae	A	H	Taohongling	Xu et al. (2037)
Euphorbia maculata	Euphorbiaceae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Fagopyrum esculentum	Polygonaceae	A	H	Songshan	Liu et al. (2012)

Flaveria bidentis (L.) Kuntze	Compositae	A	H	Hengshui	Li. (2008)
Galinsoga parviflora	Compositae	A	H	Dashahe	Lin et al. (2008)
Galinsoga parviflora	Compositae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Galinsoga parviflora	Compositae	A	H	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Galinsoga parviflora	Compositae	A	H	Taohongling	Xu et al. (2038)
Galinsoga parviflora	Compositae	A	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Galinsoga parviflora	Compositae	A	H	Yalujiangkou	Jiang et al. (2007) & Wu et al. (2010)
Galinsoga quadriradiata	Compositae	A	H	Xingdoushan	Lu et al. (2005)
Gaura lindheimeri	Onagraceae	P	H	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Gaura parviflora	Onagraceae	P	H	Shedao-Laotieshan	Jiang et al. (2012) & Wu et al. (2014)
Gentianopsis contorta	Geraniaceae	A	H	Songshan	Liu et al. (2012)
Geranium carolinianum	Geraniaceae	A	H	Dashahe	Lin et al. (2008)
Geranium carolinianum	Geraniaceae	A	H	Jiuduansha	Jiang et al. (2007) & Qin et al. (2007)
Geranium carolinianum	Geraniaceae	A	H	Poyanghu	Ge et al. (2010) & Zeng et al. (2013)
Geranium carolinianum	Geraniaceae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Geranium carolinianum	Geraniaceae	A	H	Xingdoushan	Lu et al. (2005)
Gomphrena celosioides	Amaranthaceae	A	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Gomphrena celosioides	Amaranthaceae	A	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Gomphrena celosioides	Amaranthaceae	A	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Gralinsoga parviflora	Compositae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Helianthus annuus	Compositae	A	H	Taohongling	Xu et al. (2039)
Helianthus tuberosus	Compositae	P	H	Hongshulin	Cao et al. (2007)
Helianthus tuberosus	Compositae	P	H	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Helianthus tuberosus	Compositae	P	H	Taohongling	Xu et al. (2040)
Helianthus tuberosus	Compositae	P	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Hemerocallis fulva	Liliaceae	P	H	Songshan	Liu et al. (2012)

Hibiscus trionum	Malvaceae	A	H	Hengshui	Li. (2008)
Hibiscus trionum	Malvaceae	A	H	Poyanghu	Ge et al. (2010) & Zeng et al. (2013)
Hibiscus trionum	Malvaceae	A	H	Shedao-Laotieshan	Jiang et al. (2012) & Wu et al. (2014)
Humulus scandens	Malvaceae	P	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Hyptis brevipes Poit.	Labiatae	A	H	Ganshiling	Zhang et al. (2011）
Hyptis rhomboidea	Labiatae	A	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Hyptis rhomboidea	Labiatae	A	H	Ganshiling	Zhang et al. (2011）
Hyptis suaveolens	Labiatae	A	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Hyptis suaveolens	Labiatae	A	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Hyptis suaveolens	Labiatae	A	H	Ganshiling	Zhang et al. (2011）
Impatiens balsamina L.	Balsaminaceae	A	H	Taohongling	Xu et al. (2041)
Impatiens balsamina L.	Balsaminaceae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Ipomoea cairica	Convolvulaceae	P	H	Bawangling	Hu et al. (2011)
Ipomoea cairica	Convolvulaceae	P	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Ipomoea cairica	Convolvulaceae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Ipomoea cairica	Convolvulaceae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Ipomoea cairica	Convolvulaceae	P	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Ipomoea cairica	Convolvulaceae	P	H	Ganshiling	Zhang et al. (2011）
Ipomoea cairica	Convolvulaceae	P	H	Hongshulin	Cao et al. (2007)
Ipomoea cairica	Convolvulaceae	P	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Ipomoea cairica	Convolvulaceae	P	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Ipomoea nil	Convolvulaceae	A	H	Songshan	Liu et al. (2012)
Ipomoea nil	Convolvulaceae	P	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Ipomoea nil	Convolvulaceae	P	H	Xingdoushan	Lu et al. (2005)
Ipomoea purpurea	Convolvulaceae	A	H	Bawangling	Hu et al. (2011)
Ipomoea purpurea	Convolvulaceae	A	H	Songshan	Liu et al. (2012)

Ipomoea purpurea	Convolvulaceae	A	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Ipomoea purpurea	Convolvulaceae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Ipomoea purpurea	Convolvulaceae	A	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Ipomoea purpurea	Convolvulaceae	A	H	Hengshui	Li. (2008)
Ipomoea purpurea	Convolvulaceae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Ipomoea purpurea	Convolvulaceae	A	H	Jiuduansha	Jiang et al. (2007) & Qin et al. (2007)
Ipomoea purpurea	Convolvulaceae	A	H	Nabanhe	Liu et al. (2008)
Ipomoea purpurea	Convolvulaceae	A	H	Shedao-Laotieshan	Jiang et al. (2012) & Wu et al. (2014)
Ipomoea purpurea	Convolvulaceae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Ipomoea purpurea	Convolvulaceae	A	H	Xingdoushan	Lu et al. (2005)
Ipomoea purpurea	Convolvulaceae	A	H	Yiwulvshan	Wu et al. (2010)
Jacquemontia tamnifolia	Convolvulaceae	A	H	Taohongling	Xu et al. (2042)
Jussiaealinifolia Vahl.	Onagraceae	A	H	Songshan	Liu et al. (2012)
Kochia scoparia	Chenopodiaceae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Kochia scoparia	Chenopodiaceae	A	H	Taohongling	Xu et al. (2043)
Lablab purpureus (L.) Sweet.	Leguminosae	P	C	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Lactuca sativa	Compositae	A	H	Taohongling	Xu et al. (2044)
Lantana camara	Verbenaceae	P	S	Dayudao	Zhu et al. (2006)
Lantana camara	Verbenaceae	P	S	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Lantana camara	Verbenaceae	P	S	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Lantana camara	Verbenaceae	P	S	Ganshiling	Zhang et al. (2011）
Lantana camara	Verbenaceae	P	S	Hongshulin	Cao et al. (2007)
Lantana camara	Verbenaceae	P	S	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Lantana camara L.	Verbenaceae	P	S	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Lepidium sativum	Cruciferae	A	H	Dashahe	Lin et al. (2008)
Lepidium virginicum	Cruciferae	B	H	Jiuduansha	Jiang et al. (2007) & Qin et al. (2007)

Lepidium virginicum	Cruciferae	B	H	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Lepidium virginicum	Cruciferae	B	H	Poyanghu	Ge et al. (2010) & Zeng et al. (2013)
Lepidium virginicum	Cruciferae	B	H	Taohongling	Xu et al. (2045)
Lepidium virginicum	Cruciferae	B	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Lepidium virginicum	Cruciferae	B	H	Xingdoushan	Lu et al. (2005)
Lepidium virginicum	Cruciferae	B	H	Yalujiangkou	Jiang et al. (2007) & Wu et al. (2010)
Lepidium virginicum	Cruciferae	B	H		
Leucaena glauca (L.) Benth.	Mimosaceae	P	T	Datian	Jinag et al. (2007) & Qin et al. (2008)
Leucaena glauca (L.) Benth.	Mimosaceae	P	T	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Leucaena leucocep halavar. salvador	Leguminosae	P	T	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Leucaena leucocephala	Leguminosae	P	T	Ganshiling	Zhang et al. (2011）
Lolium multiflorum	Leguminosae	A	H	Hengshui	Li. (2008)
Lolium perenne	Gramineae	P	H	Songshan	Liu et al. (2012)
Lolium temulentum	Gramineae	A	H	Hengshui	Li. (2008)
Ludwigia prostrata	Onagraceae	A	H	Songshan	Liu et al. (2012)
Lycopersicon esculentum	Solanaceae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Malvastrum coromandelianum	Malvaceae	P	H	Bawangling	Hu et al. (2011)
Malvastrum coromandelianum	Malvaceae	P	H	Nabanhe	Liu et al. (2008)
Malvastrum coromandelianum	Malvaceae	P	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Malvastrum coromandelianum	Malvaceae	P	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Medicago sativa L.	Leguminosae	P	H	Hengshui	Li. (2008)
Medicago sativa L.	Leguminosae	P	H	Jiuduansha	Jiang et al. (2007) & Qin et al. (2007)
Medicago polymorpha L.	Leguminosae	A	H	Poyanghu	Ge et al. (2010) & Zeng et al. (2013)
Medicago polymorpha L.	Leguminosae	A	H	Xingdoushan	Lu et al. (2005)
Melilotus albus Desr.	Leguminosae sp.	A	H	Jiuduansha	Jiang et al. (2007) & Qin et al. (2007)
Mimosa bimucronata	Leguminosae	P	S	Ganshiling	Zhang et al. (2011）

Mimosa invisa	Leguminosae sp.	P	H	Ganshiling	Zhang et al. (2011）
Mimosa sepiaria	Leguminosae	P	S	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Mimosa pudica Linn.	Leguminosae sp.	P	H	Bawangling	Hu et al. (2011)
Mimosa pudica Linn.	Leguminosae sp.	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Mimosa pudica Linn.	Leguminosae sp.	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Mimosa pudica Linn.	Leguminosae sp.	P	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Mimosa pudica Linn.	Leguminosae sp.	P	H	Ganshiling	Zhang et al. (2011）
Mimosa pudica Linn.	Leguminosae sp.	P	H	Hongshulin	Cao et al. (2007)
Mimosa pudica Linn.	Leguminosae sp.	P	H	Nabanhe	Liu et al. (2008)
Mimosa pudica Linn.	Leguminosae sp.	P	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Mimosa pudica Linn.	Leguminosae sp.	P	H	Taohongling	Xu et al. (2046)
Mimosa pudica Linn.	Leguminosae sp.	P	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Mirabilis jalapa L.	Nyctaginaceae	A	H	Dashahe	Lin et al. (2008)
Mirabilis jalapa L.	Nyctaginaceae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Mirabilis jalapa L.	Nyctaginaceae	A	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Mirabilis jalapa L.	Nyctaginaceae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Mirabilis jalapa L.	Nyctaginaceae	A	H	Nabanhe	Liu et al. (2008)
Mirabilis jalapa L.	Nyctaginaceae	A	H	Taohongling	Xu et al. (2047)
Mirabilis jalapa L.	Nyctaginaceae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Monarda fistulosa L.	Labiatae	A	H	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Nicandra physalodes	Solanaceae	A	H	Shedao-Laotieshan	Jiang et al. (2012) & Wu et al. (2014)
Oenothera biennis	Onagraceae	B	H	Shedao-Laotieshan	Jiang et al. (2012) & Wu et al. (2014)
Oenothera parviflora L.	Onagraceae	B	H	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Opuntia stricta var dillenii	Cactaceae	P	T	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Opuntia stricta var dillenii	Cactaceae	P	T	Taohongling	Xu et al. (2048)
Opuntia stricta var dillenii	Cactaceae	P	T	Tongguling	Jiang et al. (2007) & Qin et al. (2008)

Oxalis corymbosa	Oxalidaceae	P	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Oxalis corymbosa DC.	Oxalidaceae	P	H	Bawangling	Hu et al. (2011)
Oxalis corymbosa DC.	Oxalidaceae	P	H	Dashahe	Lin et al. (2008)
Oxalis corymbosa DC.	Oxalidaceae	P	H	Dayudao	Zhu et al. (2006)
Oxalis corymbosa DC.	Oxalidaceae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Oxalis corymbosa DC.	Oxalidaceae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Oxalis corymbosa DC.	Oxalidaceae	P	H	Ganshiling	Zhang et al. (2011）
Oxalis corymbosa DC.	Oxalidaceae	P	H	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Oxalis corymbosa DC.	Oxalidaceae	P	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Oxalis corymbosa DC.	Oxalidaceae	P	H	Taohongling	Xu et al. (2049)
Pachyrhizus erosus (Linn.) Urb.	Leguminosae sp.	P	C	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Panicum maximum	Gramineae	P	H	Ganshiling	Zhang et al. (2011）
Panicum repens L.	Gramineae	P	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Panicum repens L.	Gramineae	P	H	Dayudao	Zhu et al. (2006)
Panicum repens L.	Gramineae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Panicum repens L.	Gramineae	P	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Panicum repens L.	Gramineae	P	H	Taohongling	Xu et al. (2050)
Panicum repens L.	Gramineae	P	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Parthenium hysterophorus	Compositae	A	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Parthenium hysterophorus	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Parthenium hysterophorus	Compositae	A	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Parthenocissus quinquefo lia (L.) Planch.	Vitaceae	P	C	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Paspalum conjugatum	Gramineae	P	H	Bawangling	Hu et al. (2011)
Paspalum conjugatum	Gramineae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Paspalum conjugatum	Gramineae	P	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)

Paspalum conjugatum	Gramineae	P	H	Nabanhe	Liu et al. (2008)
Paspalum conjugatum	Gramineae	P	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Paspalum dilatatum	Gramineae	P	H	Hongshulin	Cao et al. (2007)
Passiflora edulis Sims	Passifloraceae	P	C	Ganshiling	Zhang et al. (2011）
Passiflora foetida L.	Passifloraceae	P	C	Bawangling	Hu et al. (2011)
Passiflora foetida L.	Passifloraceae	P	C	Datian	Jinag et al. (2007) & Qin et al. (2008)
Passiflora foetida L.	Passifloraceae	P	C	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Passiflora foetida L.	Passifloraceae	P	C	Ganshiling	Zhang et al. (2011）
Passiflora foetida L.	Passifloraceae	P	C	Hongshulin	Cao et al. (2007)
Passiflora foetida L.	Passifloraceae	P	C	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Passiflora foetida L.	Passifloraceae	P	C	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Peperomia pellucida (L.) Kunth	Piperaceae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Peperomia pellucida (L.) Kunth	Piperaceae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Peperomia pellucida (L.) Kunth	Piperaceae	A	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Peperomia pellucida (L.) Kunth	Piperaceae	A	H	Nabanhe	Liu et al. (2008)
Pharbitis nil (L.) Choisy	Convolvulaceae	A	H	Songshan	Liu et al. (2012)
Pharbitis nil (L.) Choisy	Convolvulaceae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Pharbitis nil (L.) Choisy	Convolvulaceae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Pharbitis nil (L.) Choisy	Convolvulaceae	A	H	Shedao-Laotieshan	Jiang et al. (2012) & Wu et al. (2014)
Pharbitis nil (L.) Choisy	Convolvulaceae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Phaseolus coccineus L.	Leguminosae sp.	P	H	Songshan	Liu et al. (2012)
Phaseolus lunatus Linn.	Leguminosae sp.	P	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Phaseolus vulgaris L.	Leguminosae sp.	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Phleum pratense L.	Gramineae	P	H	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Phy to lacca americana	Phytolaccaceae	P	H	Dashahe	Lin et al. (2008)
Physalis angulata L.	Solanaceae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)

Physalis pubescens	Solanaceae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Phytolacca americana	Phytolaccaceae	P	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Phytolacca americana	Phytolaccaceae	P	H	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Phytolacca americana	Phytolaccaceae	P	H	Nabanhe	Liu et al. (2008)
Phytolacca americana	Phytolaccaceae	P	H	Poyanghu	Ge et al. (2010) & Zeng et al. (2013)
Phytolacca americana	Phytolaccaceae	P	H	Shedao-Laotieshan	Jiang et al. (2012) & Wu et al. (2014)
Phytolacca americana	Phytolaccaceae	P	H	Taohongling	Xu et al. (2051)
Phytolacca americana	Phytolaccaceae	P	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Pilea microphy lla	Urticaceae	A	H	Ganshiling	Zhang et al. (2011）
Pilea microphylla	Urticaceae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Pilea microphylla	Urticaceae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Pilea microphylla	Urticaceae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Pilea microphylla	Urticaceae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Pilea microphylla	Urticaceae	A	H	Nabanhe	Liu et al. (2008)
Pilea microphylla	Urticaceae	A	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Pistia stratiotes	Araceae	P	H		
Pistis stratiotes	Araceae	P	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Plantago aristata	Plantaginaceae	A	H	Taohongling	Xu et al. (2052)
Plantago lanceolata	Plantaginaceae	P	H	Shedao-Laotieshan	Jiang et al. (2012) & Wu et al. (2014)
Plantago virginica	Plantaginaceae	A	H	Hongshulin	Cao et al. (2007)
Plantago virginica	Plantaginaceae	A	H	Poyanghu	Ge et al. (2010) & Zeng et al. (2013)
Plantago virginica	Plantaginaceae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Psidium guajava Linn.	Myrtaceae	P	T	Ganshiling	Zhang et al. (2011）
Raphanus raphanistrum	Cruciferae	A	H	Poyanghu	Ge et al. (2010) & Zeng et al. (2013)
Reseda lutea L.	Resedaceae	A	H	Shedao-Laotieshan	Jiang et al. (2012) & Wu et al. (2014)
Rhus typhina	Anacardiaceae	P	T	Songshan	Liu et al. (2012)

Rhynchelytrum repens	Gramineae	P	H	Bawangling	Hu et al. (2011)
Rhynchelytrum repens	Gramineae	P	H	Ganshiling	Zhang et al. (2011）
Rhynchelytrum repens	Gramineae	P	H	Nabanhe	Liu et al. (2008)
Richardia brasiliensis	Rubiaceae	A	H	Ganshiling	Zhang et al. (2011）
Ricinus communis	Euphorbiaceae	A	H	Dashahe	Lin et al. (2008)
Ricinus communis	Euphorbiaceae	A	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Ricinus communis	Euphorbiaceae	A	H	Ganshiling	Zhang et al. (2011）
Ricinus communis	Euphorbiaceae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Ricinus communis	Euphorbiaceae	A	H	Nabanhe	Liu et al. (2008)
Ricinus communis	Euphorbiaceae	A	H	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Ricinus communis	Euphorbiaceae	A	H	Taohongling	Xu et al. (2053)
Ricinus communis	Euphorbiaceae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Ricinus communis	Euphorbiaceae	A	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Robinia pseudoacacia	Leguminosae sp.	P	T	Songshan	Liu et al. (2012)
Robinia pseudoacacia	Leguminosae sp.	P	T	Jiuduansha	Jiang et al. (2007) & Qin et al. (2007)
Robinia pseudoacacia	Leguminosae sp.	P	T	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Robinia pseudoacacia	Leguminosae sp.	P	T	Xingdoushan	Lu et al. (2005)
S.verbascifolium L.	Sonneratiaceae	P	T	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Scoparia dulcis L.	Scrophulariaceae	P	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Scoparia dulcis L.	Scrophulariaceae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Scoparia dulcis L.	Scrophulariaceae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Scoparia dulcis L.	Scrophulariaceae	P	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Scoparia dulcis L.	Scrophulariaceae	P	H	Ganshiling	Zhang et al. (2011）
Scoparia dulcis L.	Scrophulariaceae	P	H	Hongshulin	Cao et al. (2007)
Scoparia dulcis L.	Scrophulariaceae	P	H	Nabanhe	Liu et al. (2008)
Setaria palmifolia	Gramineae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)

Setaria palmifolia	Gramineae	P	H	Ganshiling	Zhang et al. (2011）
Setaria palmifolia	Gramineae	P	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Setaria palmifolia	Gramineae	P	H	Taohongling	Xu et al. (2054)
Setaria parviflora	Gramineae	P	H	Taohongling	Xu et al. (2055)
Silybum marianum	Compositae	A	H	Jiuduansha	Jiang et al. (2007) & Qin et al. (2007)
Sisymbrium altissimum	Cruciferae	A	H	Taohongling	Xu et al. (2056)
Solanum aculeatissimum	Solanaceae	A	H	Bawangling	Hu et al. (2011)
Solanum aculeatissimum	Solanaceae	A	H	Dashahe	Lin et al. (2008)
Solanum aculeatissimum	Solanaceae	A	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Solanum aculeatissimum	Solanaceae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Solanum aculeatissimum	Solanaceae	A	H	Nabanhe	Liu et al. (2008)
Solanum aculeatissimum	Solanaceae	A	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Solanum americanum	Solanaceae	A	H	Ganshiling	Zhang et al. (2011）
Solanum capsicoides	Solanaceae	P	S	Datian	Jinag et al. (2007) & Qin et al. (2008)
Solanum capsicoides	Solanaceae	P	S	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Solanum erianthum	Solanaceae	P	S	Ganshiling	Zhang et al. (2011）
Solanum torvum Swartz	Solanaceae	P	S	Datian	Jinag et al. (2007) & Qin et al. (2008)
Solanum torvum Swartz	Solanaceae	P	S	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Solanum torvum Swartz	Solanaceae	P	S	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Solanum torvum Swartz	Solanaceae	P	S	Ganshiling	Zhang et al. (2011）
Solanum torvum Swartz	Solanaceae	P	S	Nabanhe	Liu et al. (2008)
Solanum torvum Swartz	Solanaceae	P	S	Shiwandashan	Wei et al. (2006) & Jiang et al. (2007) & Ye et al. (2008)
Solidago canadensis L.	Compositae	P	H	Jiuduansha	Jiang et al. (2007) & Qin et al. (2007)
Solidago canadensis L.	Compositae	P	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Soliva anthemifolia	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Soliva anthemifolia	Compositae	A	H	Poyanghu	Ge et al. (2010) & Zeng et al. (2013)

Sonchus asper (L.) Hill.	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Sonchus asper (L.) Hill.	Compositae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Sonchus oleraceus L.	Compositae	A	H	Bawangling	Hu et al. (2011)
Sonchus oleraceus L.	Compositae	A	H	Hengshui	Li. (2008)
Sonchus oleraceus L.	Compositae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Sonchus oleraceus L.	Compositae	A	H	Taohongling	Xu et al. (2057)
Sonchus oleraceus L.	Compositae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Sonneratia apetala	Solanaceae	P	S	Hongshulin	Cao et al. (2007)
Sorghum halepense(L.) Pers.	Gramineae	P	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Sorghum halepense(L.) Pers.	Gramineae	P	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Sorghum halepense(L.) Pers.	Gramineae	P	H		
Spartina alterniflora	Gramineae	P	H	Dayudao	Zhu et al. (2006)
Spartina alterniflora	Gramineae	P	H	Jiuduansha	Jiang et al. (2007) & Qin et al. (2007)
Spermacoce latifolia	Rubiaceae	P	H	Nabanhe	Liu et al. (2008)
Stachy tarpheta jamaicensis	Verbenaceae	P	H	Ganshiling	Zhang et al. (2011）
Stachytarpheta jamaicensis (L.) Vahl.	Verbenaceae	P	H	Bawangling	Hu et al. (2011)
Stachytarpheta jamaicensis (L.) Vahl.	Verbenaceae	P	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Stachytarpheta jamaicensis (L.) Vahl.	Verbenaceae	P	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Stylosanthes guianensis (Aubl.) Sw.	Leguminosae sp.	P	H	Ganshiling	Zhang et al. (2011）
Synedrella nodiflora	Compositae	A	H	Bawangling	Hu et al. (2011)
Synedrella nodiflora	Compositae	A	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Synedrella nodiflora	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Synedrella nodiflora	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Synedrella nodiflora	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Synedrella nodiflora	Compositae	A	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Synedrella nodiflora	Compositae	A	H	Nabanhe	Liu et al. (2008)

Synedrella nodiflora	Compositae	A	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Tagetes erecta	Compositae	A	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Tagetes erecta	Compositae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Tagetes patula	Compositae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Tagetes patula	Compositae	A	H	Taohongling	Xu et al. (2058)
Talinum paniculatum	Portulacaceae	P	H	Ganshiling	Zhang et al. (2011）
Talinum paniculatum	Portulacaceae	P	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Talinum paniculatum	Portulacaceae	P	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Thalictrum aquilegifolium Linn.	Ranunculaceae	P	H	Songshan	Liu et al. (2012)
Tithonia diversifolia	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Tithonia diversifolia	Compositae	A	H	Nabanhe	Liu et al. (2008)
Tridax procumbens	Compositae	P	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Tridax procumbens	Compositae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Tridax procumbens	Compositae	P	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Tridax procumbens	Compositae	P	H	Ganshiling	Zhang et al. (2011）
Tridax procumbens	Compositae	P	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)
Trifolium pratense	Leguminosae sp.	P	H	Xingdoushan	Lu et al. (2005)
Trifolium repens	Leguminosae sp.	P	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Trifolium repens	Leguminosae sp.	P	H	Jiuduansha	Jiang et al. (2007) & Qin et al. (2007)
Trifolium repens	Leguminosae sp.	P	H	Lushan	Deng et al. (2009) & Zheng et al. (2011) & Tang et al. (2012)
Trifolium repens	Leguminosae sp.	P	H	Xingdoushan	Lu et al. (2005)
Trifolium repens	Leguminosae sp.	P	H	Yalujiangkou	Jiang et al. (2007) & Wu et al. (2010)
Trifoliumrepens	Leguminosae sp.	P	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Vaccaria segetalis	Caryophyllaceae	A	H	Hengshui	Li. (2008)
Verbena tenera Spreng.	Verbenaceae	P	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Veronica polita	Scrophulariaceae	A	H	Dashahe	Lin et al. (2008)

Veronica polita	Scrophulariaceae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Veronica polita	Scrophulariaceae	A	H	Taohongling	Xu et al. (2059)
Veronica polita	Scrophulariaceae	A	H	Xingdoushan	Lu et al. (2005)
Veronica arvensis	Scrophulariaceae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Veronica arvensis	Scrophulariaceae	A	H	Jiuduansha	Jiang et al. (2007) & Qin et al. (2007)
Veronica arvensis	Scrophulariaceae	A	H	Taohongling	Xu et al. (2060)
Veronica arvensis L.	Scrophulariaceae	A	H	Tianmushan	Chen et al. (2011) & Li et al. (2011) & Bai et al. (2013)
Veronica persica	Scrophulariaceae	A	H	Dashahe	Lin et al. (2008)
Veronica persica	Scrophulariaceae	A	H	Jinfoshan	Lin et al. (2007) & Sun et al. (2009)
Veronica persica	Scrophulariaceae	A	H	Jiuduansha	Jiang et al. (2007) & Qin et al. (2007)
Veronica persica	Scrophulariaceae	A	H	Taohongling	Xu et al. (2061)
Viola tricolor L.	Violaceae	P	H	Taohongling	Xu et al. (2062)
Waltheria indica L. (W. americana L.)	Cucurbitaceae	P	H	Bawangling	Hu et al. (2011)
Waltheria indica L. (W. americana L.)	Cucurbitaceae	P	H	Datian	Jinag et al. (2007) & Qin et al. (2008)
Waltheria indica L. (W. americana L.)	Cucurbitaceae	P	H	Dongzhaigang	Jinag et al. (2007) & Qin et al. (2008)
Wedelia prostrata	Compositae	A	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Wedelia trilobata (Hook. et Arn.) Hemsl.	Compositae	P	H	Dinghushan	Song et al. (2009) & (He et al. (2004) & Jiang et al. (2007)
Wedelia trilobata (Hook. et Arn.) Hemsl.	Compositae	P	H	Ganshiling	Zhang et al. (2011）
Wedelia trilobata (Hook. et Arn.) Hemsl.	Compositae	P	H	Hongshulin	Cao et al. (2007)
Wedelia trilobata (Hook. et Arn.)	Compositae	P	H	Tongguling	Jiang et al. (2007) & Qin et al. (2008)

Hemsl.					
Xanthium italicum	Compositae	A	H	Shedao-Laotieshan	Jiang et al. (2012) & Wu et al. (2014)
Xanthium spinosum	Compositae	A	H	Shedao-Laotieshan	Jiang et al. (2012) & Wu et al. (2014)

Appendix III. The basic environmental information of 24 natural conservation districts.

Natural conservation districts	Year	elevation (m)	Latitude (Low)	Latitude (High)	Area (hm^2)	Distance to city (km)	No. of plant species	Annual temp. (℃)	Annual Precipitation (mm)	No.of invasive species
Bannahe	1991	1000	22.07	22.28	26660.0	538	1954	20.0	1500	28
Bawangling	1980	1390	18.95	19.18	29980.0	226	2103	21.3	1657	27
Dashahe	1984	1400	29.00	29.22	26990.0	331	1591	16.0	1280	28
Datian	1986	60	19.08	19.28	1314.0	222	602	23.0	1019	34
Dayudao	1995	25	24.46	24.47	0.2	2	147	20.7	1143	15
Dinghushan	1956	507	23.16	23.19	1133.0	86	2500	20.9	1927	51
Dongzhaigang	1980	20	19.85	20.02	3 337.6	30	317	23.8	1700	36
Fangchengjinhua	1986	1400	21.73	21.83	9159.0	164	1387	22.5	2800	25
Ganshiling	1985	347	18.33	18.35	1715.5	262	1334	24 .5	1200	44
Hengshui	2000	21	37.53	37.70	187.9	200	382	13.0	518.9	28
Hongshulin	20	20	22.05	23.12	533. 33	90	49	22.0	2085	20

	00									
Jinfoshan	1979	1400	28.83	29.15	41850.0	107	4883	8.2	1434	43
Jiuduansha	2000	3	31.05	31.28	42320.0	47	48	15.7	1145	18
Lushan	1981	1100	29.50	29.68	30466.0	122	2269	13.4	1939	19
Poyanghu	1983	12	29.08	29.25	22400.0	29	526	17.1	1600	19
Shedao-Laotieshan	1980	25	38.95	38.95	17073.0	432	422	10.0	614.5	18
Shiwandashan	1982	1000	21.67	22.07	58 277.1	135	2233	21.8	2700	22
Songshan	1985	1300	40.49	38.56	4671.0	90	783	8.5	493	23
Taohongling	1981	400	29.70	29.88	12500.0	210	1200	16.5	1300	49
Tianmushan	1956	900	30.31	30.42	4284.0	87	2665	11.8	2179	46
Tongguling	1983	42.5	19.62	19.69	4400.0	107	904	23.9	2361	34
Xingdoushan	1988	1200	29.95	30.18	68339.0	52	3906	14.3	1300	25
Yalujiangkou	1987	2	39.68	40.83	108057.0	285	289	9.8	786	7

Yiwulvshan	1986	530	41.43	41.77	11459.0	224	718	8.0	600	3