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Research trends, conservation issues and approaches for the endangered Red panda (*Ailurus fulgens*): a systematic review of literatures across their home-range

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Abstract

The red panda (*Ailurus fulgens*), an arboreal mammal belonging to the family Ailuridae, and order Carnivora with herbivorous tendencies is distributed across the mountains of Nepal, Bhutan, China, India, and Myanmar. Due to different anthropogenic activities, the wild populations of *A. fulgens* have declined by 50% across these range countries. There are many gaps in the current knowledge concerning this endangered, elusive, and charismatic animal. We applied a systematic review process to better understand the research trends, conservation threats, and approaches and identified research gaps that potentially impact the long-term conservation of *A. fulgens*. Altogether, we analyzed 168 published papers over 33 years and in different thematic areas. Our study revealed that studies on *A. fulgens* are not evenly distributed across the range of the species, with the majority of them being from China, then Nepal, and very few from Bhutan, India, and Myanmar. The majority of the literature concerning captive and free-ranging populations of *A. fulgens* is skewed toward different aspects of biology including anatomy, general behavior, reproduction, nutrition, and different aspects of habitat including distribution patterns, and habitat use. There is limited information on *A. fulgens* genetics and it is confined to Chinese populations. Studies on diseases, the impact of anthropogenic activities like tourism, infrastructure development, movement ecology, interaction with other associated species, and studies addressing the impact of climate change on this species are very sparse. Hence, for the conservation success of *A. fulgens* understanding, these issues are critical.

Key words: Anthropogenic activities, charismatic animal, conservation, endangered, research trend

Introduction

The red panda (*Ailurus fulgens*) is an arboreal mammal belonging to the family Ailuridae and order Carnivora with herbivorous tendencies chiefly feeding on young leaves and shoots of bamboo (Glatston et al., 2015). *Ailurus fulgens* is categorized as an Endangered (EN) species by the IUCN Red List (Glatston et al., 2015), listed on Appendix I of Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (CITES, 2019) and protected by different regional laws in their range countries. Two subspecies of red panda *Ailurus fulgens fulgens* (Himalayan subspecies) and *Ailurus fulgens styani* (Chinese subspecies) were recorded based on their morphological characteristics (Glatston, 1994; Wei et al., 1999) however, a recent study of 65 whole genomes provided comprehensive evidence for species divergence (Hu et al., 2020). *Ailurus fulgens* here by *A. fulgens* is a habitat and dietary specialist (Yonzon, 1989), that occurs in

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subalpine areas of Asia i.e. Nepal, India, Bhutan, Myanmar, and China (Bista et al., 2017) within the elevation range of 2300–4000 m (Glatston et al., 2015).

Ailurus fulgens dwells in the bamboo understory in temperate conifer forests adjacent to broadleaf forests (Yonzon and Hunter, 1991). Studies of (Yonzon and Hunter, 1991; Dorji et al., 2012; Bista et al., 2017) have reported that *A. fulgens* favors areas with dense forest canopy (over 30%), plentiful bamboo cover (over 37%), the bamboo height of approximately 2.9 m and within 100–200 m of a water source. They prefer to inhabit slopes with north or north-west aspects, however, some research has indicated a preference for southwest aspects too (Yonzon and Hunter, 1991; Zhang et al., 2008). Leaves and shoots of bamboo contribute almost 83% of the overall diet of *A. fulgens* (Reid et al., 1991; Wei et al., 1999). They occur in isolated and fragmented forest patches with a low density despite their wide range of distribution across Asia, mainly because of human-induced stress (Yonzon and Hunter, 1991; Bista et al., 2017; Panthi et al., 2017). Habitat loss, degradation, and fragmentation are identified as major threats to *A. fulgens* (Yonzon and Hunter, 1991; Pradhan et al., 2001). Additionally, overgrazing, unsustainable collection of forest resources, development of infrastructure, poaching and illicit trade, and forest fires have created an unpredictable level of threat to the wild populations of *A. fulgens* (Sharma and Belant, 2010; Sharma et al., 2014; Bista et al., 2017; Acharya et al., 2018).

The wild populations of *A. fulgens* have declined by 50% over the past three decades and this trend is continuing (Glatston et al., 2015). In this study, we carried out a comprehensive review of published peer reviewed articles on *A. fulgens* to understand the trends and current status of research, conservation issues, and approaches to conserve this flagship species of the Himalayas across Asia.

Material and Methods

Literature search

We adopted the systematic review procedure recommended by Pullin and Stewart (2006) for conservation and environment management (Fig. 1). We searched for peer-reviewed articles published on *A. fulgens* in their range countries (Nepal, India, China, Bhutan, and Myanmar) utilizing two web-based databases- Google Scholar and Scopus. We used 'Red panda', '*Ailurus fulgens*', 'Red panda - Human conflict', and 'Red panda conservation' as keywords for the searches. Altogether, we found 358 articles in Google Scholar and 153 articles in Scopus (Fig. 1) and excluded the articles that did not meet our selection criterion.

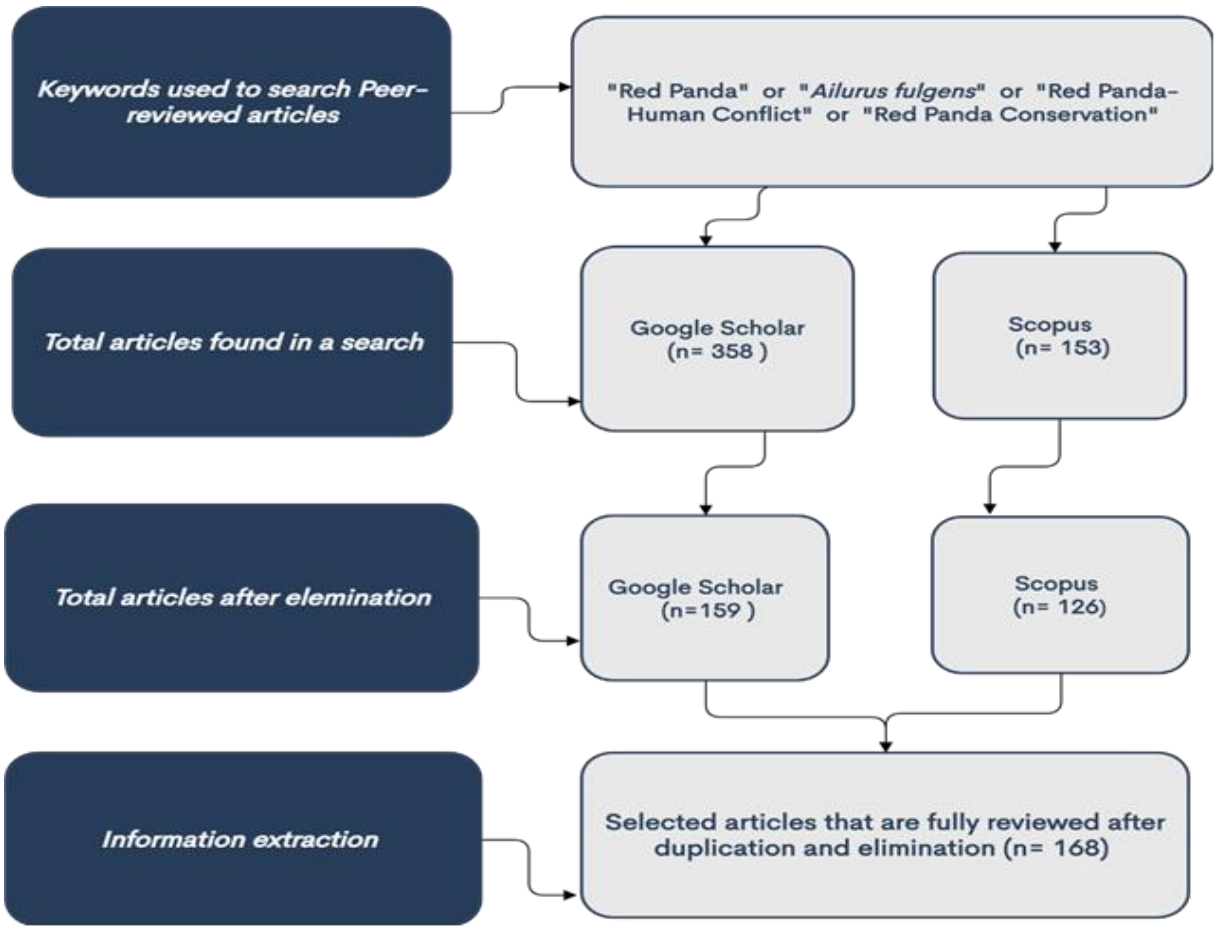

Figure 1: Process of literature search and selection for the systematic review process on Red pandas.

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Selection criteria

We inspected the title, abstract, and keywords of each paper and eliminated all the articles that were not associated with the Red Panda *A. fulgens*. After eliminating the duplicates, we found 118 relevant articles common to both databases, 42 from Google Scholar only and 8 from Scopus only. We then reviewed and extracted information from those final 168 articles.

Data compilation and analysis

To understand the research focus and priorities on *A. fulgens* we classified each article into different categories:

a) Country of publication and year of publication.
b) Thematic focus (Table 1).
c) The number of citations on each paper.
d) Study on in-situ or ex-situ or both setup.

Furthermore, to understand the conservation approach we explored the governmental and institutional reports and publications in *A. fulgens* range countries. Selected articles were also explored to find major conservation issues of *A. fulgens* throughout the species range countries. If an article discusses several different themes equally, then the article was counted under multiple primary themes. If an article discusses one major theme but other themes are also covered to a lesser extent, then the other themes are counted as secondary themes. The sample size differs in the thematic analysis because any one article could be recorded under one or multiple primary or secondary themes.

Results and Discussion

Research trends on *Ailurus fulgens*

There is a steady increase in the number of publications on *A. fulgens*, starting with three studies published in China between 1980–1990 (Fig. 2), to 53.57% (n= 93) of research papers published between 2010–2020. During the 1980s and 1990s research was predominantly focused on different aspects of the biology of red pandas including anatomical studies (Wang, 1997; Huichang et al., 1999), feeding behavior (Fuwen et al., 1995; Wei et al., 1999), reproductive biology (Jinchu, 1991), nutrition/energy use or requirements (Wei et al., 1999) and habitats including distribution and habitat use (Reid et al., 1991; Gang, 1998; Fuwen et al., 1999). Similarly, biology research (n= 39) and habitat (n= 33) was dominant in the 2000s including several other aspects such as activity patterns (Zhang et al., 2011; Tenget al., 2013; Khan and Baskaran, 2019), physiology (Yunfang et al., 2009; Xiu et al., 2019), habitat suitability and connectivity (Thapa et al., 2018; 2020; Tobgay and Mahavik, 2020) and habitat overlap (Bista et al., 2018). A significant advancement in research focusing on different aspects of populations including photographic records, identification, and demography (Chalise, 2013; Dorjeeet al., 2014; Shrestha et al., 2015; Dangol and Chalise, 2018; Ghimire et al., 2019;) were noticed. Another aspect of the research was on parasites and pathogens (Lama et al., 2015; Shrestha and Maharjan, 2015; Bista et al., 2017; Shrestha and Maharjan, 2017; Deng et al., 2019) in *A. fulgens*. Publications on *A. fulgens* genetics similarly started during the 2000s; with 25 articles published within two decades focusing on different aspects of genetics, including DNA sequencing (Li et al., 2005; Qin et al., 2007; Guo et al., 2011), inbreeding (Tao et al., 2009), genetic variation (Dalui et al., 2020) and molecular systematics (Nie et al., 2002; Hu et al., 2017; Jin et al., 2019).

Until December 2020, the selected articles (n= 168) were cited 3147 times. The average citation per paper was 18.73 (range 0–154). Among all themes studied, the highest mean citation per publication was for habitat (26.7) and was least for handling and capture (5).

Table 1: Red panda research in different thematic areas with a summary of key content in each thematic area.

Serial number	Thematic area	Key content
1	Biology	Studies on morphological, anatomical, and physiological aspects also general, feeding, and reproductive behaviors.
2	Habitat	Studies relating to distribution, habitat use, dynamics, and suitability.
3	Population	Studies relating to population status, trends, and management perspective.
4	Genetics	Studies relating to the testing of microsatellite loci and preliminary genetic studies, including DNA barcoding and genetic variability.
5	Diseases	Studies relating to diseases, pathogens, parasites, causes, and treatments.
6	Impact on species	Human-*A. fulgens* conflict, climate change, poaching, trade, tourism activities, and socio-economic development of *A. fulgens* habitat.
7	Capture and handling	Capture and handling, translocation, and chemical immobilization.

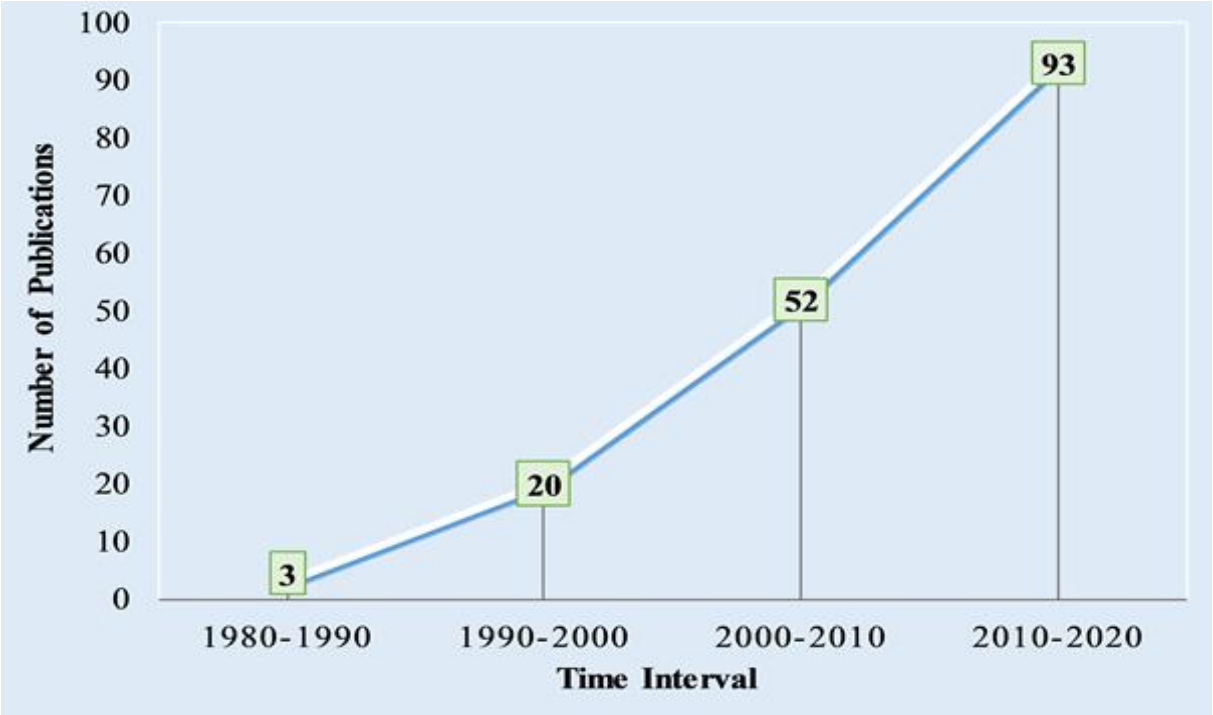

Figure 2: Number of publications on *Ailurus fulgens* between 1980–2020.

We found 5 publications with >100 citations published between 1998–2007, with the majority focusing on habitat and population (n= 2 each) and one on biology. Among the reviewed publications, 32 are not yet cited and 62.5% (n= 20) of them were published between 2014–2020.

The thematic focus of *A. fulgens* research is described in (Fig. 3). Publications on *A. fulgens* are skewed towards its biology (n= 49), especially in the captive setup (n= 29). Studies on free-ranging populations of *A. fulgens* were focused on habitat (n= 37) followed by population (n= 22) and biology and impact on species themes (Fig. 3). The majority of the research papers are published within China (n= 93) followed by Nepal (n= 42), whereas Myanmar has the least number of publications (n= 1) to date (Fig. 4).

The period between 2005 and 2012 was the golden era for *A. fulgens* research in China where many papers (n= 37) were published. The main focus of study during this period was on biology (n= 15) (Wei et al., 2005; Zhi-ping, 2010; Li et al., 2011; Zhang et al., 2011) and genetics (n= 10) (Li et al., 2005; Liu et al., 2005; Zhang et al., 2008; Guo et al., 2011). A further six papers focused on habitat (Zhang et al., 2007; Yang et al., 2008), four on disease (Qin et al., 2007; Lan et al., 2012), and two papers focused on the impact on the species (Wenguang et al., 2008).

The rate of research publication increased between 2013 and 2020 in Nepal (n= 33), Bhutan (n= 6), and India (n= 15) with the majority of the research papers (n= 17) focusing on various aspects of the species habitat (Bhatta et al., 2014; Chakraborty et al., 2015; Kandel et al., 2015; Bista et al., 2017; Dendup et al., 2018; Bista et al., 2019; Dendup et al., 2020) followed by population (n= 13) (Ghose et al., 2011; Shrestha et al., 2015; Bashir et al., 2019; Lama, 2019), 11 papers published on different aspects of impact on the species (Sharma et al., 2014; Acharya et al., 2018; Bhattarai, 2019; Bista et al., 2020; Lama et al., 2020), four papers published on disease (Lama et al., 2015; Shrestha and Maharjan, 2015; Bista et al., 2017; Shrestha and Maharjan, 2017) and two papers published on the genetics of the species in India (Kumar et al., 2016; Dalui et al., 2020). Three papers were published covering the species in multiple countries; two of them on habitat covering the overall range of *A. fulgens* and one on genetics in the mountains of Nepal and China (Hu et al., 2020).

Conservation threats

In reviewing the literature, we indexed the major threats that are directly or indirectly affecting the survival of *A. fulgens* in its range countries. Nine categories of threat are identified in the published literature including both natural and anthropogenic threats. Several studies have been conducted on each threat category with a major focus on habitat loss and fragmentation (n= 28), poaching and hunting (n= 26), livestock pressure and grazing (n= 20), and bamboo flowering and collection (n= 19) (Fig. 5). We identified that *A. fulgens* is more threatened in Himalayan countries i.e. Nepal, India, and Bhutan whereas few threats are reported from China. Prime habitat loss and fragmentation for *A. fulgens* is a major issue in Nepal (Panthi et al., 2012; 2017; Bista, 2018; Bhattarai, 2019), India (Ghose et al., 2011; Jha, 2011; Joshi et al., 2020), Bhutan (Dorji et al., 2012; Dendup et al., 2020), and China (Wei et al., 1999; Hu et al., 2011; Zhou et al., 2013).

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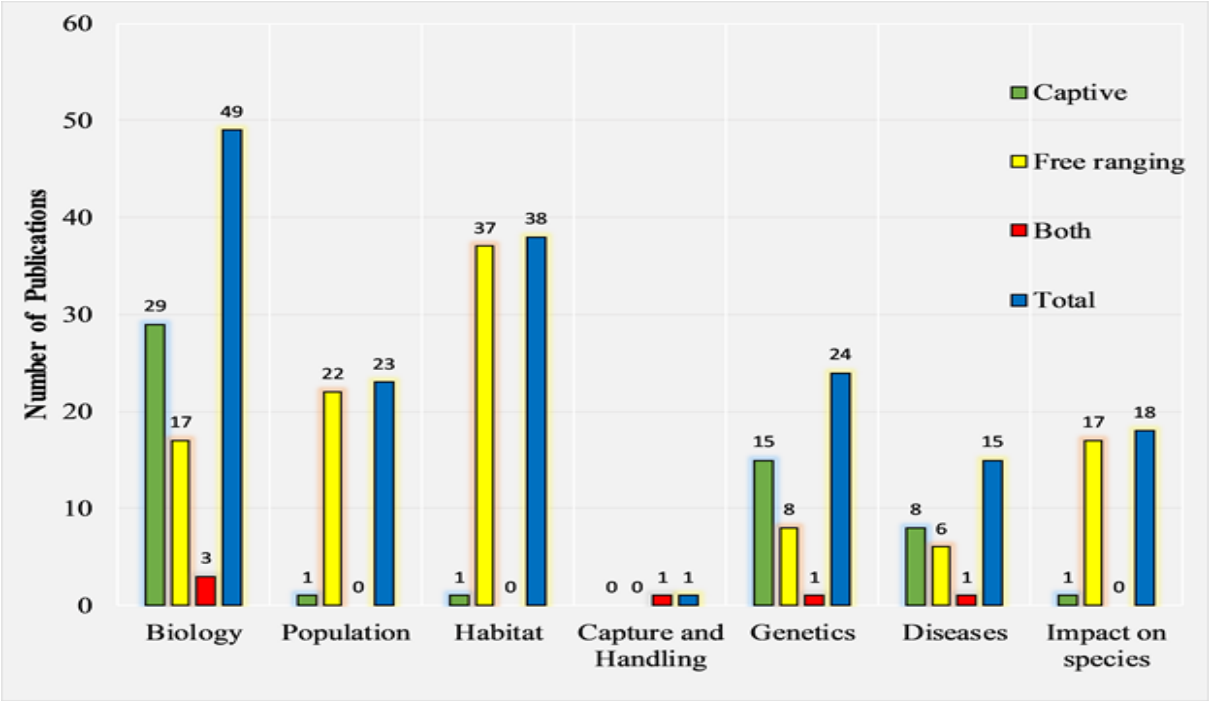
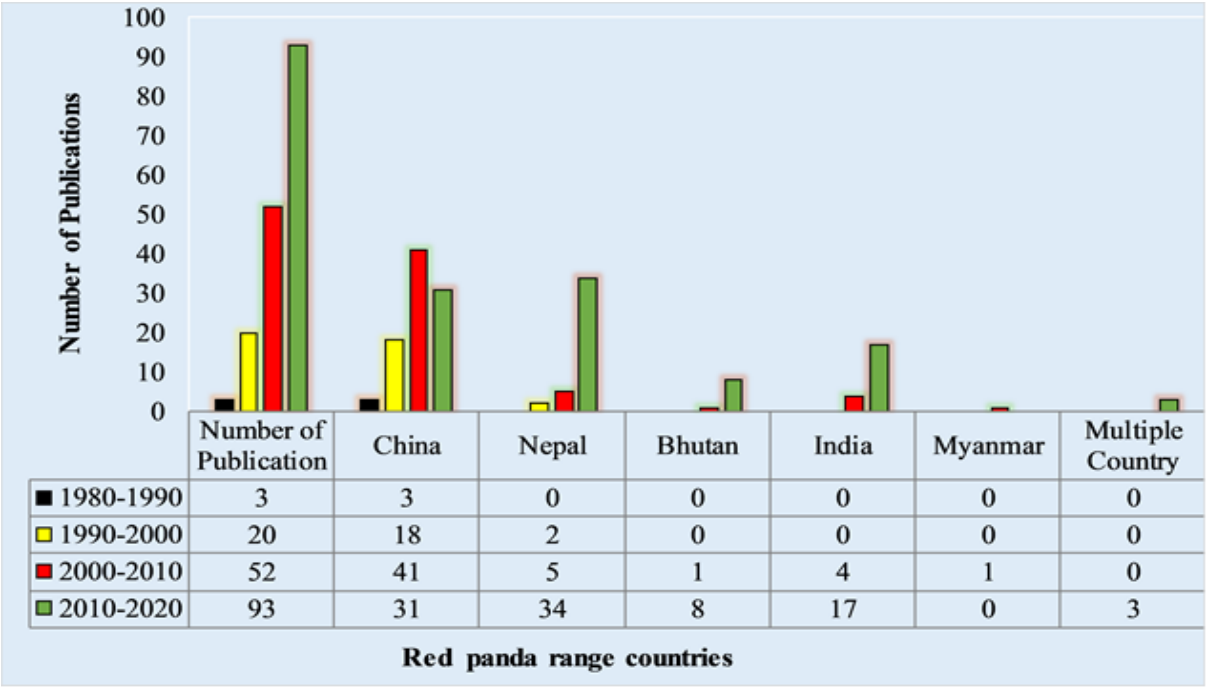


Figure 3: Red panda research on seven different thematic areas.



	Number of Publication	China	Nepal	Bhutan	India	Myanmar	Multiple Country
1980-1990	3	3	0	0	0	0	0
1990-2000	20	18	2	0	0	0	0
2000-2010	52	41	5	1	4	1	0
2010-2020	93	31	34	8	17	0	3

Figure 4: Publications by country in different time intervals for Ailurus fulgens.

Similarly, poaching and hunting are reported as existing threats in China (Wei et al., 1999; Liang et al., 2007; Hu et al., 2011; Zhou et al., 2013), India (Mallick, 2015; Budithi et al., 2016; Khan and Baskaran, 2019; Pilia et al., 2020), Nepal (Acharya et al., 2018; Bista, 2018; Bhattarai, 2019; Bista et al., 2020), Myanmar (Zaw et al., 2008) and Bhutan (Dorji et al., 2012). In different studies across the range countries (Liang et al., 2007; Gyeltshen, 2010; Bista and Paudel, 2013; Chalise, 2013; Wangchuk, 2013; Mallick, 2015; Dendup et al., 2017; Bashir et al., 2019; Bhattarai, 2019; Ghimire et al., 2019; Tobgay and Mahavik, 2020) livestock pressure and grazing have been identified as critical issues for the survival of *A. fulgens*. Likewise, bamboo loss, unmanaged harvesting, and bamboo flowering are other key threats to *A. fulgens* (Bista and Paudel, 2013; Sharma et al., 2014; Dendup et al., 2017; Drukpa, 2018; Bashir et al., 2019; Ghimire et al., 2019; Lama, 2019).

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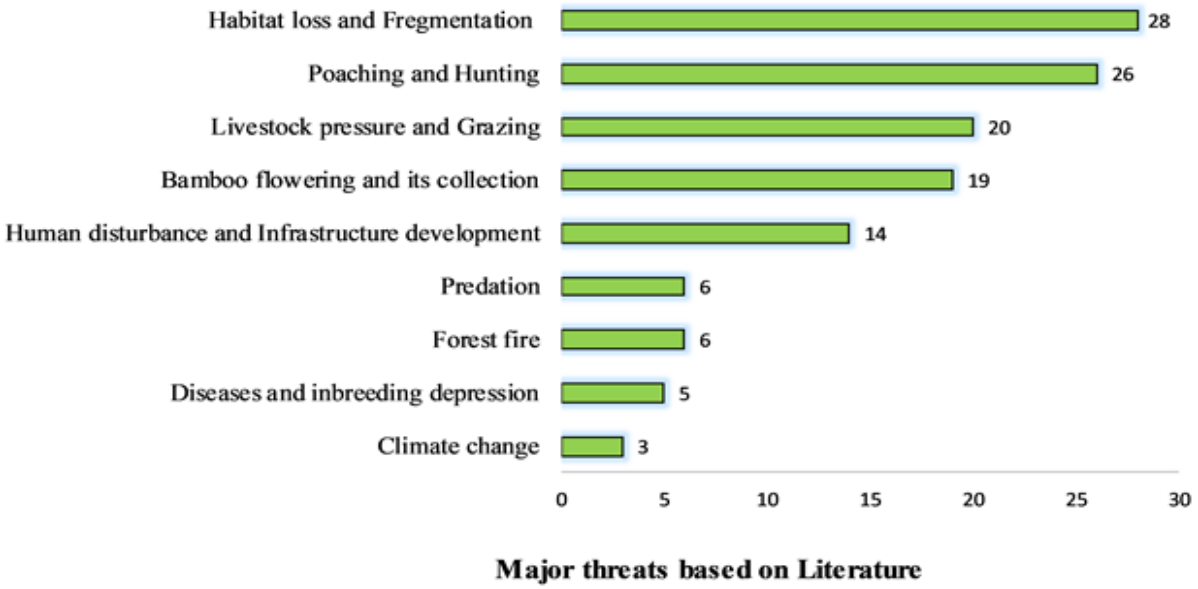

Figure 5: Major conservation threats to *Ailurus fulgens*.

Moreover, diseases, inbreeding depression, predation by its natural predators and house dogs, infrastructure development, climate change, and forest fires have also been reported as conservation challenges (Adhikari, 2009; Ghose and Dutta, 2011; Panthi et al., 2012; Wangchuk, 2013; Kandel et al., 2015; Shrestha and Maharjan, 2015; Drukpa, 2018; Bista et al., 2019; Dendup et al., 2020).

Conservation approaches

Conservation of *A. fulgens* has been prioritized in various conservation-related documents and various conservation strategies have been adopted by Asian countries for the conservation of *A. fulgens*. It is legally protected by the governments of the countries within their habitat range and the hunting of the species is illegal (Glatston et al., 2015). The establishment of protected areas for *A. fulgens* has been a prior conservation approach.

In Nepal, various conservation-related documents, including the National Conservation Strategy (1988) (GoN/MFSC, 1988), the Master Plan for Forestry Sector (1988) (GoN/MFSC, 1998), the Plan for the Conservation of Ecosystems and Genetic Resources (1988), the Nepal Environmental Policy and Action Plan (1993), and the Nepal Biodiversity Strategy (2002) (GoN/MFSC, 2002) have emphasized the preservation of rare or endangered species like *A. fulgens*, through mechanisms such as population surveys, monitoring, protecting key habitats, and relocation and restoration of such species. The Constitution of Nepal (2007) has also made the provision for the maintenance of 40% of the forest in the country, along with the protection of associated rare wildlife species. *Ailurus fulgens* is protected in Nepal by the National Park and Wildlife Conservation Act, 1973 (GoN, 1973) which prohibits killing or capture of the species dead or alive (Bista and Paudel, 2013). In section 26 (2) of the act, there is a provision for a fine of up to Nepalese Rupees 100,000–500,000, or jail for 1–10 years, or both, to any person who kills or tries to kill *A. fulgens*.

The establishment of an *A. fulgens* conservation area inside the Langtang National Park (LNP) by the Department of National Park and Wildlife Conservation (DNPWC) in 1990 was another milestone for the conservation of *A. fulgens* in Nepal (Bista and Paudel, 2013). The *A. fulgens* Conservation Plan for LNP and its Buffer Zone in Nepal (2009–2013) was implemented by DNPWC but the plan was unable to reach its targeted objectives (Bista and Paudel, 2013). Realizing the need for *A. fulgens* conservation in Nepal, a five-year conservation action plan (2019–2023) was launched (GoN/DNPWC, 2018). This action plan has provided a framework for engaging local communities and strengthening coordination among conservation actors at both national and international levels. Also, Protected Area (PA) governing authorities have designed buffer zone areas in all the PAs in which *A. fulgens* is distributed. Community-based *A. fulgens* monitoring and community-based anti-poaching units have been established to monitor wildlife in mountainous PAs where official human resources are inadequate (Acharya and Dhakal, 2012). Outside PAs, the Red Panda Network (RPN) began conservation initiatives in the eastern part of Nepal in 2007 through research and community-based monitoring with the coordination and mobilization of Community Forest User Groups

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(CFUGs) (Williams et al., 2011). The Department of Forest (DoF) and DNPWC of the Nepal government surveyed the distribution status of *A. fulgens* at a national scale in 2016, which has added further positive efforts in panda conservation (Mahato et al., 2011).

In Bhutan, *A. fulgens* has been included in Schedule I species of the Forest and Nature Conservation Act of Bhutan 1995 under which it receives the highest legal protection (GoB, 1995). The Act has established a network of corridors between all PAs that include panda habitat (Wangchuk, 2007). The government of Bhutan, in collaboration with the RPN, has launched a five-year (2018–2023) action plan to conserve *A. fulgens* (NCD, 2019). The action plan has highlighted efforts to strengthen transboundary collaboration with an emphasis on habitat management and protection, enhancing rural livelihood, conservation education, improved coordination with stakeholders, and strengthening local *A. fulgens* stewardship for species conservation. In China, *A. fulgens* has been classified as a category II species under the Wild Animal Protection Law (Wei et al., 1999). *Ailurus fulgens* was not included on the list of the key protected animal project in China (Wei and Zhang, 2011) but the huge investment of the Chinese government to protect the habitat of giant pandas would be beneficial to both panda species. Various conservation projects, such as the Natural Forest Protection Project (NEPP), Grain to Green Project, National Wildlife Conservation and Natural Reserves Construction Project, and the China Rural Energy Enterprise Development would be beneficial to the protection of wild fauna and flora including *A. fulgens* in China (Wei and Zhang, 2011).

In India, *A. fulgens* is protected under Schedule I of the Indian Wildlife Protection Act 1972 (Ghose and Dutta, 2011). *A. fulgens* is the state animal of Sikkim state in India, hence it has received additional attention for its conservation. *A. fulgens* conservation activities are carried out in collaboration with the Forest, Environment, and Wildlife Management Department (FEWMD), the Government of Sikkim, and the World Wildlife Fund (WWF)-India (Ghose and Dutta, 2011).

Many Population and Habitat Viability Assessment (PHVA) workshops have been conducted in *A. fulgens* range countries of China (2012), India (2013), and Nepal (2010), with participation from Myanmar and Bhutan (Jnawali et al., 2012; Jha et al., 2014; Wei et al., 2014). Conservation organizations, such as WWF, in collaboration with government authorities, have provided technical skills to forest rangers, park managers, and local communities to monitor and patrol endangered fauna. Wildlife monitoring and patrolling activities are conducted at a local level in different panda range countries. PAs have been establishing wildlife corridors between them, associated buffer zones, and specific conservation zones to ensure the protection of *A. fulgens* outside of PAs.

Conclusion

Our review of *A. fulgens* literature over the past 33 years disclosed that 160+ peer-reviewed articles are published across red panda range countries including both captive and free-ranging populations. The published articles are cited over 3147 times and the investigation shows that there is a steady increase in the number of publications on *A. fulgens*, with 53.57% of research papers being published between 2010–2020. The majority of the research focus is on species biology followed by their habitat. Genetic research is currently more confined to China. Further, our review revealed habitat loss and fragmentation, hunting and poaching, bamboo flowering, and its collection from red panda habitat as major threats across the range of countries. Legal and institutional conservation initiatives have been put forward in many different countries. Recently, the Government of Bhutan and Nepal, in collaboration with the Red Panda Network (RPN) have launched an action plan to conserve *A. fulgens* with an emphasis on strengthening transboundary collaboration. Further, research on population genetics and phylogeography, the impact of anthropogenic activities on *A. fulgens* and their habitats, interaction with associated species, and transboundary conservation efforts are inevitable for conservation of this charismatic species.

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Conflict of interest

The authors declare that there are no conflicting issues related to this review article.

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