Human-wildlife conflict in the roof of the world: Understanding multidimensional perspectives through a systematic review.

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BIOSKETCH

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Author contribution: P.S. and N.C. conceived the ideas and designed the methodology; P.S., N.C. and K.W. collected the data; P.S and N.C. analyzed the data; P.S., N.C. and K.W. wrote the manuscript.

Abstract

Aim: Wildlife and their interaction human or human-wildlife conflict, though reported throughout human prehistory, its severity and complexity have increased in recent years. The Hindu Kush Himalaya region, rich and biodiversity and known as roof of the world have gained recognition for many conservation success but also with increasing trends of human-wildlife conflict. But, they are sparsely documented and the severity of its impacts are not known for the region. Hence, we present a systematic review on human-wildlife conflict from the roof of the world.

Methods: We followed the systematic literature review (SLR) approach of qualitative content analysis, using Search, Appraisal, Synthesis, and Analysis (SALSA) framework and also used VOSViewer for spatial and network analysis..

Results: Our results based on 240 peer-reviewed articles till 2019 showed 57% increase of publications in the last decades but with disproportionate geographical and thematic focus. About 82% of the research reported cases are from protected area with large carnivores and mega-herbivores as major causes of the conflict. About 53% of the studies were questionnaire-based household and the results highlight habitat disturbance through land cover change, urbanization, and human population increase as major drivers of human-wildlife conflict. Traditional management techniques like guarding and fencing along with improvement in plans and policies have been reported. Our analysis of 681 keywords revealed prominent focus on 'human-wildlife conflict', 'Nepal', 'Bhutan', 'Snow Leopard' and 'Leopard' indicating the issue are linked with these species and countries. The involvement of 640 authors from 36 countries indicates increasing interest and Nepal and India are playing key role from the region.

Main conclusions:

There is spatial variation in research with limited regional and transboundary focus. Attention is needed on understanding the pattern of interactions including meso animals along with improved management interventions through integrated and transboundary cooperation for tackling the issue.

Keywords: cooperation, human wildlife conflict, knowledge gaps, research trends, spatial and temporal coverage,

1. INTRODUCTION

Wildlife and their interaction with human, the social-ecological linkage, can manifest more commonly into agonistic behavior or conflict (Nyhus 2016; König et al., 2020). Though the existence of human-wildlife conflict (HWC) has been recorded throughout human prehistory and the earliest of human civilization (Berger & McGraw 2007; Gordon 2009), its severity and complexity have increased in recent years (Madden 2004; Sharma et al., 2020). The conflict between humans and wildlife occurs in form of lethal attacks, property damage, crop-raiding, and depredation of livestock. On the other hand, retaliatory killings, hunting, and poaching of the endangered or keystone wild species threaten biodiversity and impose legal issues on humans (Peterson et al., 2010; White & Ward, 2011). HWC is therefore attributed to the economical and psychological disruption for local communities due to loss of life and property, risk of wildlife extinction, and threats posed by the spread of zoonotic diseases (Thirgood et al., 2005; Barua et al., 2013; Nyhus, 2016).

Habitat loss and degradation results from urbanization, intensification of agriculture, and growth in the human population (Nyhus, 2016) and increased human dominance in natural landscapes intensifies competition for space and resources especially for large carnivores like Royal Bengal tiger (*Panthera tigris tigris*) and common leopard (*Panthera pardus)*, inducing conflict (DeFries, 2010; Zimmerman, 2010). Similarly, crop raids and damage by mega-herbivores, non-human primates, and small mammals result from food/forage shortage in the wild (Hill, 2018) and their fragmented habitat (Choudhury, 2004), causing a confrontation between wildlife and human (Acharya et al., 2017). Mitigation of this conflict is therefore central to human safety as well as biodiversity and ecosystem health, which requires an understanding of

92 profound and interrelated social-ecological relations (Treves et al., 2006; Carter & Linnell,
93 2016).

94 Globally, research on HWC and co-existence has exponentially grown over the last
95 decade in form of published peer-reviewed articles and reports (Nyhus, 2016; Holland et al.,
96 2018; König et al., 2020). According to a recent study, 87% of the publications HWC were
97 concentrated over last 10 years in Asian countries of India, Nepal, and Indonesia (Torres et al.,
98 2018). This region accounts for the richest concentrations of earth's biological diversity
99 continuously threatened by the expansion of agriculture and overexploitation of wildlife (Sodhi
100 & Brook, 2006, Monastersky, 2014). The Hindu Kush Himalaya (HKH), stretched across eight
101 countries (namely- Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and
102 Pakistan), is the highest, youngest and one of the richest in terms of species, genetic, and
103 ecosystem diversity among the global mountain biomes (Xu et al., 2019). This roof of the world
104 comprises of four of the 36 global biodiversity hotspots - Himalaya, Indo-Burma, the mountains
105 of Southwest China, and mountains of Central Asia (Mittermeier et al., 2011). In recent years,
106 HKH has been experiencing rapid demographic and economic growth leading to
107 overexploitation of natural resources with significant land use land cover changes (LULC), and
108 forest loss (Xu et al., 2019). Loss of the region's core forest areas has resulted in a reduction in
109 the dispersal ability of wildlife in their home ranges bringing them into human proximity
110 (Acharya et al., 2017). In the HKH, India, Nepal, and Bhutan experience a wide variety of
111 conflict with the wildlife, ranging from the crop-raiding monkeys to man-eating tigers (Sharma
112 et al., 2020). In Nepal, an average of 115 people per year (between 2010 and 2014) were
113 attacked by large mammal species such as Asian elephant (*Elephas maximus)*, Royal Bengal
114 tiger, common leopard, and Asiatic black bear (*Ursus thibetanus)* (Acharya et al., 2016). In

115 northern West Bengal, India, 62 elephant fatalities were reported from 2004 to 2015 due to train
116 collisions as a result of railway construction through forest corridors (Roy & Sukumar, 2016).
117
118 Several authors employed different scientific approaches to identify sources and causes
119 of HWC and means to mitigate it (Sarker & Røskaft, 2010; Acharya et al., 2017; Bashir et al.,
120 2018). Published literature has covered varied dimensions of the issue related to food and
121 property damage, compensation and insurance schemes, people-park management, and a threat
122 to biodiversity (Limbu & Karki, 2003; Aryal et al., 2014; Carter et al., 2014; Huang et al., 2018).
123 Diligent efforts are made by government bodies, research organizations, NGOs, and local
124 communities to resolve HWC, but their efforts are country and location-specific. Thus, the
125 transboundary nature of HWC is less recognized and the conflicts continue unabated in the
126 HKH. As observed by Wester et al., (2019), countries in the region suffer from inadequate and
127 scattered knowledge generation, a major hindrance to understanding the underlying drivers and
128 effects of HWC. Hence, inadequate and scattered knowledge hinders efforts of collaborative
129 natural resource governance (Davis & White, 2012) and contributes to less understanding of the
130 transboundary nature of HWC. For profound comprehension of transboundary HWC in the
131 HKH, a systematic review and analysis of existing information is inevitable. The review and
132 analysis provide holistic insight into the region's knowledge base, information gaps, and priority
133 areas for future interventions (Kandel et al., 2016). Besides, the findings of review and analysis
134 could foster regional learning and cooperation to address gaps on transboundary HWC. To
135 understand the current state of knowledge, we conducted a systematic review of the literature on
136 HWC in the HKH with two main objectives. The first objective was to characterize and analyze
137 current scientific literature on HWC according to spatial and temporal distribution, scale and

138 theme of research, methodological tools and approaches, wildlife's taxonomical groups, drivers
139 of change, and management actions. The second objective was to analyze the collaborative
140 network of research through keywords co-occurrence, co-authorship links, and country
141 collaboration to better understand research trends, priorities, collaborations and knowledge gaps.

142 ## 2. METHODS

143 We followed the systematic literature review (SLR) approach of qualitative content analysis, as it
144 is systematic, explicit, and reproducible for identifying, evaluating, and synthesizing the existing
145 body of scientific information (Fink, 2019). SLR was conducted using the framework of Grant &
146 Booth, (2009), which involved four sequential steps (Figure 1): Search, Appraisal, Synthesis, and
147 Analysis (SALSA). The steps of the SALSA framework are explained in Table 1. SALSA
148 method is accurate, systematic, exhaustive, and reproducible (Vicente-Saez & Martinez-Fuentes,
149 2018; Mengist et al., 2020).

150 **Figure 1 here**

151 **Table 1 here**

152 ### 2.1. Search

153 In this step, relevant sources of information were identified from various databases using
154 appropriate search strings. The search databases were Scopus (Elsevier), Google Scholar, and
155 Google search engine. We opted for Scopus, the largest database of peer-reviewed literature with
156 more indexed journals (Mongeon & Paul-Hus, 2016). We used google scholar and google search
157 engines to collect all relevant peer-reviewed articles and gray literature (reports, conference
158 proceedings, perspectives, keynotes, and book chapters) which were not indexed in Scopus. The
159 term human-wildlife conflict here refers to both direct interaction of humans with wildlife
160 through encounters and livestock depredation and indirect relationships expressed via people's

attitudes/perceptions and human well-being (Lozano et al., 2019). Therefore, we used various combinations of search strings for an exhaustive and comprehensive literature search covering broad dimensions of HWC. We used the advanced search filter in Scopus with string keywords: "Human-wildlife conflict" and "Nepal". This was done for all the other seven countries' names of the HKH (Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, and Pakistan). We also searched for the highest level of administrative boundaries falling under the defined HKH along with country names e.g. "Nepal" and district "Chitwan". The search string was extended to wildlife species/family specific conflict: "Human-carnivore conflict", "Human-monkey conflict", "Human-elephant conflict", "Human-Rhino conflict" for each of the countries of HKH and their administrative divisions. To include the dimension of livestock depredation and crop damage by wild, keywords "wildlife crop raid", "livestock depredation", "animal attack" were used against each of the country names to reduce the volume of literature to the HKH. The systematic search for these strings was based on the literature's title, abstract, and key-words and was carried up till December 2019 with no upper-year limit. We also restricted our search to only English language articles for this study. For literature search on Google Scholar and Google search engine, we applied a similar strategy, mostly aimed at retrieving gray and unindexed literature.

2.2. Appraisal

The appraisal phase consisted of the selection of literature based on the screening process following inclusion/exclusion criteria. A total of 554 literature data were collected from various database sources, which included peer-reviewed journal articles and grey literature. The initial step then involved separating all the grey literature from the peer-reviewed journal articles. We then checked the database for studies exclusively within the HKH boundary since countries like

India, Bangladesh did account for a large proportion of studies outside the HKH. On, acquiring literature data from within HKH, we removed the duplicates, resulting in a total of 255 journal articles and 24 grey literature. The final 255 journal articles were then selected for abstract reading including 24 grey literature.

A total of 240 out of 255 journal articles qualified the eligibility criteria to be part of the final database. The literature removed after abstract screening was on the basis that these researches did not directly adhere to HWC. All 24 grey literature qualified to be included in the final database.

2.3. Synthesis

The qualitative approach to synthesize the derived knowledge helps to explore, interpret, and present new perspectives on the data (Vicente-Saez & Martinez-Fuentes, 2018). Hence, in this step, we extracted relevant data from 240 journal articles relating to HWC. The data extracted from each selected literature were maintained and managed in MS Excel for data processing. The categorization of extracted data according to various classes and variables of interest to meet the SLR objectives as presented in Table 2. This data was further used for analysis through tabular and graphical representation.

Table 2 here

2.4. Analysis

This phase involved evaluating the synthesized data to gain meaningful information and answer research questions. The categories were quantified and analyzed to explain results (Table 2). This further paved way for discussion and indicated knowledge gaps in HWC in HKH. The study also applied VOSViewer (https://www.vosviewer.com), a desktop-based, open-source software, for constructing and visualizing bibliometric networks (Van Eck & Waltman, 2010). Comma-

separated values (.csv) format of a database comprising 240 selected articles was made compatible for use by VOSViewer. We then investigated the HWC research collaboration network between various countries in HKH and visualized the frequency of keywords to analyze the most researched areas related to HWC.

Map created in VOSViewer consists of one type of item (country names, keywords, or authors) connected by lines or links. Each link has a strength, represented by a positive numerical value. The strength of a link may for example indicate the number of publications two researchers have co-authored (in the case of co-authorship links), the number of publication where two keywords have occurred together (in case of keyword co-occurrence), and the number of publication in which two countries have collaborated (in case of country co-authorship). A closely linked set of items forms clusters which are linked to other clusters that further constitute a network. The size of each item in a network is weighted by the number of documents, citations, or link strength between two items. The color of an item is determined by the cluster to which the item belongs (Van Eck et al., 2013). We used the number of documents as a weight for calculating the size of the items in mapping keywords, authors and countries network for HWC in the HKH. The results adds on the answers to the following questions.

3. RESULTS

3.1. Temporal trend and spatial pattern

In the HKH, the research on HWC had seen steady growth with the earliest peer-reviewed articles dating back to 1982. Over the past 37 years (1982 to 2019), there were two articles in 1982 and 25 articles in 2019 (Figure 2). The highest number of 30 research articles were published in 2018. The research progress from the overall trend could be grouped into three specific phases: Phase I (1982 to 2002) where only maximum of three research papers were

published in 1997. This phase constituted nine percent of the total publication; Phase II (2003 to 2008) saw a slight increase in research papers by 4% compared to the previous phase. This phase, though had an increase up to nine publications in 2008, also witnessed the number of publication as low as two in 2007, suggesting an erratic phase; and Phase III (2009 to 2019) witnessed exponential growth in HWC research publication with an average increase of 1.5 articles per year. This period of 10 years accounted for 78% of publication and an increase of 57% compared to the last two phases on HWC research in the HKH.

Figure 2 here

Research in HWC revealed an uneven pattern across HKH (Figure 3). The highest number of peer-reviewed articles were published from India (n= 87) and Nepal (n=85), followed by Pakistan, Bhutan, and China. Very few studies were recorded from Myanmar (n=3), Afghanistan (n=2), and Bangladesh (n=1). Districts with the highest publication from India were Pauri Garhwal, and Chamoli from the state of Uttarakhand. In Nepal, districts of Chitwan, Mustang, and Bardiya had a higher number of research articles. In Pakistan, more number of publication was from the district of Azad Kashmir, while in Bhutan, the highest number of research studies was from Punakha district.

Figure 3 here

3.2. Spatial scale and theme

The research sites were analyzed based on its scale - local, country and transboundary following Martinez-Harms & Balvanera, (2012) and management regimes -protected area, corridors and outside protected areas. Majority of the research in the HKH on HWC were local level studies

252 (82%), followed by country level (11%) and very few at transboundary level (n=15, i.e. 6%)
253 (Figure 4a). According to regimes of the study sites, nearly half of the studies (49%) conducted
254 were in outside protected areas such as villages, towns and localities. Studies within and along
255 protected area boundary such as wildlife sanctuaries, national park, conservation area biosphere
256 reserve etc. covered 48% while studies within wildlife corridors accounted for three percent of
257 the total publications. A comparative analysis of scale and regime of study sites revealed that
258 most local level studies were conducted within and along protected area boundary (56%),
259 followed by outside protected area (43%) (Figure 4b). High number of country level studies
260 conducted were for places not within protected areas (81%). Transboundary level studies that
261 constituted least amount of publications, represented most of its studies outside protected areas
262 (53%), followed by a few number of studies from wildlife corridors (n=4, i.e. 27%) and some
263 studies from within protected areas (20%). There were no studies reported for the corridors at
264 country level.

265 **Figure 4 here**

266 Regarding the type of conflict, 50% of the articles described conflict-related to damage to human food
267 (mainly attacks on livestock, poultry, and crop raids), followed by a threat to biodiversity (27%). Conflict
268 relating to human safety (lethal attacks, property damage, and psychological disruption) accounted for
269 15% while human-human conflict (stakeholder disagreements) was mentioned in eight percent of the
270 articles (Fig 5a).

271 ### 3.3. Research methods applied

272 Over half of the articles (53%) used data from interviews based on questionnaires and focus
273 group discussion. About 16% of published articles used secondary data from reports, journal
274 articles, and documents from government and non-government organizations. And 12% of the

articles surveyed for biological samples like hair, scat, scrapes, and footprint of wild animals in the study while 8% of articles relied on direct observation or sightings of animals for data collection. There was a limited number of articles that depended on camera trapping (5%) and GIS-based satellite data (4%) for the study. The GPS radio coloring method for data collection accounted for only 2% of publication on HWC studies in the region (Fig 5b). Analyses of studies used various approaches where statistical analysis of data comprised 73% of research articles. This was followed by spatial mapping (14%) using GIS tools and statistical modelling (11%) techniques like logistic regression, generalized linear mixed models etc. DNA based molecular tracking of biological samples for understanding dietary composition of wild animals comprised 4% of the total approaches used in HWC research (Fig 5c).

Figure 5 here

3.4. Focused species or taxonomical group

Classification of studies based on wildlife taxonomical group following (Peterson et al., 2010) revealed that the high percentage of studies focused on large carnivores (46%) (Table 3) such as Snow Leopard, common leopard, Royal Bengal tiger, grey wolf (*Canis lupus*) and dhole (*Cuon alpinus*). This was followed by omnivores (27%) species such bears {Asiatic and brown (*Ursus arctos*)}, monkeys (*Macaca mulatta)* and boar (*Sus scrofa)*. Mega-herbivores such as elephant and one horned rhinoceros (*Rhinoceros unicornis)* constituted 16% percentage of HWC studies. Few studies concerned over crop raids and illegal poaching of herbivores such as ungulates and antelopes (7%). Meso mammals such as porcupine (*Hystrix brachyuran)* and marmot (*Marmota himalayana)* were part of 4% of studies while small carnivores like Himalayan lynx (*Lynx lynx isabellinus)* and yellow throated marten (*Martes flavigula)* were mentioned in 1% of the articles.

Table 3 here

3.5. Possible drivers for the conflict

Over half of the articles (60%) considered at least one driver of change underpinning HWC (Fig 6). Most frequent driver reported are disturbance of natural landscape (27%) due to human population increase, urbanization and land use change. Shortage of food such as forage and wild prey was another major reason (24%) for HWC. Proximity of settlements to protected areas leading to dependence of forest communities for firewood and medicines were also important factor (23%) for conflict between human and wildlife. Other drivers mentioned by the research articles were retaliatory killing and illegal poaching of wild animals (13%), changes in conservation policies (7%) and culture (4%). Only 2% of research articles mentioned climate change as a driver of HWC in the region.

Figure 6 here

3.6. Management interventions

Relatively few articles (n=48) comprising 20% of total selected literature specifically discussed or recommended HWC mitigation strategies (Fig 7). Each of these articles recommended two or more management actions. Most commonly recommended interventions (43%) included better livestock management strategies that involved deterrents as watchdogs and scarecrows to guard field and livestock against wild. Growing alternative cash crops such as tea, chili, and tobacco were also recommended along with strengthening infrastructures by building electric or bio fence, water towers, and better sheds/corrals for livestock. 23% of articles recommended community intervention such as ecotourism, local management, and setting up of response team. Some articles (19%) developed management plans and suggested to improve compensation

policies for tackling HWC. Few articles recommended interventions (15%) such as relocation, selective culling, radio-collaring, and captive breeding of wild animals (Fig 7).

Figure 7 here

3.7. Co-occurrence of keywords, co-authorship linkages and country collaboration

A total of 681 keywords were found in the selected HWC literature out of which 533 keywords appear only once. 'Activity pattern', 'anthropogenic threats', 'agro-pastoralism', 'aggressive behavior', 'alternatives' are examples of keywords that appear only once (Fig. 8). The most frequently occurring keyword, expectedly, is 'human-wildlife conflict' (occurrence, n=48) followed by 'conservation' (n=32) and 'Nepal' (n=25'). The total strength of co-occurrence link or the total link strength of these keywords were high compared to the keywords with low occurrences. 'India', 'livestock depredation', 'snow leopard', 'Himalaya', 'Asian elephant' were among the top 100 keywords with the highest total link strength apart from the keywords with high occurrence

Figure 8 here

HWC research in the HKH showed contribution by a total of 640 authors. Among these, only 228 authors were connected forming 21 clusters of authors (Fig 9). Most of the articles published on HWC in the region (22%, n=52) were co-authored by only two authors. About 4 percent of research contained more than ten authors (n=9) while about 10% of the articles (n=25) were written by a single author. The dataset contains an article with 14 authors, the highest, followed by one article with 12 authors. The study also analyzed the authors with the highest contribution to research on HWC through the number of articles produced. Aryal A., Lamichhane B.R., Mishra C., and Sathyakumar S., were three prominent authors on HWC in the

region co-authoring two percent of total research. Researchers with the next- highest number of published research articles were Raubenheimer D., Dhakal M and Subedi N. A list of top fifteen authors in terms of the total number of articles authored and co-authored is presented in Table 4.

Table 4 here

Figure 9 here

Research on HWC in the HKH region has some degree of country collaborating networks (Fig 10). Our study identified authors from 36 different countries collaborating on HWC research. The highest number of countries were from Asia (n=17) followed by Europe (n=11) and remaining from Africa, North America, Australia, and Oceania. Notably, there was no collaboration with countries in South America. In terms of the number of articles published by collaborating countries, India was at the highest (n=87) followed by Nepal (n=64) and the United States. The size of the circle is indicative of the number of articles published by each country, illustrated in VOSviewer. Among the nine clusters of countries in the collaboration network, Nepal had the highest number of collaborations with other countries (also known as the total link strength, total =81) followed by the United States and India. Nepal collaborated with three other HKH countries -India, Pakistan, and China as well as other countries from America, Africa, Asia, and Europe. The United States with the second-highest collaboration link (total =65), partnered with authors from five HKH countries namely Bhutan, China, India, Nepal, and Pakistan along with other international collaborators. Third in the list was India with a collaboration with HKH countries of China, Myanmar, and Nepal along with a few other international collaborations. One study identified from the HKH region of Bangladesh was not part of the co-authors' country collaboration network.

Figure 10 here

4. DISCUSSIONS

A continuous increase in the number of research articles since 1982 on HWC from the region is attributable to the growing interest of scholars towards HWC and management and increasing incidence of the conflicts as also revealed by Seoraj-Pillai & Pillai, (2017). Though the research publication remained low in the initial phases, their rates have considerably increased over the last decade by 57%. This trend coincides with an increase in the severity and frequency of HWC in several parts of HKH (Inskip & Zimmermann, 2009) as a result of growing human dependency on natural resources and degradation of wildlife habitats (Manral et al., 2016; Xu et al., 2019). About 465 human fatalities reported in five years from Nepal highlights the growing severity of HWC (Acharya et al., 2016). Considerable increase in livestock population, especially goats in the mountains of Bhutan, India, and Pakistan have affected depredation and their subsequent persecution (Tulachan et al., 2001). On the other hand, Nepal has also made significant progress, in terms of conservation by reversing the decreasing trend of rhinoceros for three consecutive years to achieve zero poaching (Acharya, 2016). Hence, owing to such a diversity of factors, a substantial amount of research has been directed toward human-wildlife interaction and conservation (e.g. Maheshwari & Sathyakumar, 2019).

Most of the research on HWC were from India and Nepal, constituting 72% of the total publications. Pauri Garhwal and Chamoli districts, in India, affected by large carnivores, account for some of the highest rates of HWC in the Himalayan belt and is a major area of interest for researchers (Sondhi et al., 2016; Naha et al., 2018; Gupta et al., 2009; Agarwal, 2016). Chitwan district in Nepal is a prominent district with a high number of studies for management and mitigation of HWC in and around Chitwan National Park (Sapkota et al., 2014, Lamichhane,

386 2019). Almost half of HWC studies in HKH have taken place within and along protected area
387 boundaries. There are network of 488 protected areas (PAs) in the region with varying degrees of
388 protection and status, occupy 39% of HKH terrestrial land (Chettri et al., 2008). Though these
389 PAs are home to many globally significant animal species, they are also under tremendous
390 pressure from livelihood-dependent communities living outside and within its boundaries
391 (Sharma & Yonzon, 2005; Gu et al., 2020). Intensification of land use for agriculture and
392 livestock rearing within and along the periphery of protected areas increases the depredation of
393 crops and livestock by wild animals. Only a small percentage of studies (3%) carried out in the
394 wildlife corridors relates to the presence of less number of such conservation passes. The only
395 wildlife corridors reported are the Rajaji-Corbett corridor, Laljhadi-Mohana corridor, Khata
396 corridor, and Wakhan corridor. Most of these studies were at the local level indicating a small
397 scale of research. HWC, though being an issue concerning all the member countries of the HKH,
398 has received very little attention in terms of studies at regional or transboundary level (6%). An
399 important gap in HWC research is the lack of understanding of the transboundary nature of
400 HWC, due to the migratory nature of wild species, across national and international borders
401 (ICIMOD, WCD, GBPNIHESD, RECAST 2017; Sharma et al., 2020).

402 Half of the research conducted in the region focused on the food damage caused by
403 HWC. Depredation of livestock and crop damage are major types of conflicts related to food
404 damage. In the HKH, Bhutan alone experiences an annual crop loss of up to 25% of total
405 household income due to crop raids by foraging animals (Tobgay et al., 2019) and about 10-19%
406 through livestock depredation (Jamtsho & Katel, 2019). Such huge losses are a challenge to the
407 local food system, people's livelihood, and their food and nutrition security (Sharma et al.,
408 2020). Hence, to address this problem, a large volume of research was conducted to understand

409 foraging characteristics of animals, the pattern of livestock depredation, assessment of their
410 habitats, and wild preys and methods of co-existence of humans with wildlife (Rao et al., 2002;
411 Bhattacharjee & Parthasarathy, 2013; Aryal et al., 2015; Bargali & Ahmed, 2018). Besides
412 stressing on conserving endangered species, researchers have also emphasized the threat to
413 biodiversity in the region due to illegal hunting, killing and trade (Rao et al., 2010; Bhattarai et
414 al., 2012; Thapa, 2014; Rimal et al., 2018; Uprety et al., 2021). Globally, researchers have
415 highlighted the need for shifting attention toward human-wildlife coexistence, a sustainable state
416 in which humans and wildlife co-adapt to living in shared landscapes (Peterson et al., 2010;
417 König et al., 2020). Other types of conflict involving human safety and property damage have
418 also been covered. A discord between biodiversity conservation and wildlife damage,
419 particularly observed in the region, dichotomizes humans and nature, leading to human-human
420 type of conflict. Comparatively smaller amount of research (15%) has also covered this aspect
421 of HWC showcasing disagreement between communities, stakeholders, and policies that requires
422 an understanding of socio-political processes affecting conservation management (Rastogi et al.,
423 2018). This type of conflict is significant for the region's indigenous forest-dependent
424 communities who have a sense of stewardship for their forest and grasslands. Disagreements
425 between communities and forest departments on policies of resource utilization and
426 compensation heighten HWC and challenge effective conflict management.

427 Researchers in the region have used their full potential to collect primary level data
428 (~53%) and also supplement research with existing secondary data since a large number of
429 studies are dependent on household surveys and focus group discussions. Only a small
430 percentage of data collected was with the aid of GPS radio-collaring, GIS-based satellite
431 imaging, and camera trapping. Though data on HWC in the region is not generally deficit, it is

mostly skewed towards an understanding of the human dimension of HWC. There is a gap in the use of better technologies for data collection in analyzing wildlife's pattern of interaction with surrounding, their migratory routes, and diet that would affect HWC. This is also evident in methods used for data analysis were mostly statistical (~73%) followed by some percentage of spatial mapping and modeling. Advance methods such as DNA tracking of biological samples to understand the dietary habits of wild species still incorporates a small proportion in HWC research. Inferences on feeding behavior of wild species are helpful to understand their impacts on the ecosystem, their relationship with local livestock, the prediction of potential HWC, and reliable management programs.

The majority of HWC research (46%) in the HKH dwells on large carnivores. The snow leopard is the species highly researched (20%), followed by leopards (18%), and tigers (15%). A large number of research articles on snow leopard conflict is the result of increased research in human-snow leopard in the Himalayas and Karakoram range since 1994 (Rashid et al., 2020). Occurring throughout the high mountains of China and South Asia, declining availability of snow leopard's wild prey and their retaliatory killings have inflicted conflict with high mountain communities and pastoralist (Chetri et. al., 2019; Rosen et al., 2012). Wolves and dholes, though forming a small proportion of species studied, are important predators in central-western parts of Himalayas and the eastern Himalayas, respectively (Johnsingh et al., 2007; Xu et al., 2015). About 27% of articles on HWC show omnivores such as bears, monkeys, and boars to conflict with communities due to their roles in raiding livestock and damaging crops. Research in the HKH also covers mega herbivores like elephant and rhinoceros that have frequent conflicts with communities within fringe areas of forest and along their migratory route in the terrai lowland of Nepal, India, and Bhutan (Sharma et al.; 2020). In Nepal alone, up to 20,000 people in the

455 southern lowlands are affected by conflicts with elephants (Yonzon, 2008), suggesting the
456 conflict with mega-herbivores s an issue of big concern (~16%). The region lacks adequate
457 research on conflict with small carnivores, meso-mammals, and birds or reptiles. Only about 1%
458 of articles cover small carnivores such as marten and lynx as agents of conflict. It is because
459 small carnivores are perceived to pose less dangers than large carnivores, though Sunar et al.,
460 (2012) found Yellow-throated marten alone to cause about 50% of wildlife depredation on
461 village livestock in and around the Senchal Wildlife Sanctuary. However, these carnivores have
462 a narrow habitat range, commonly within 1700-2000 meters amsl and their survival in many part
463 of HKH is threatened by degradation of habitat, shortage of food in the wild, and poaching.
464 Similarly, HWC studies on meso-mammals, birds, and reptiles are limited in the region though
465 animals like porcupine, peafowls, marmots, civets have been reported to create menace in
466 farmlands in parts of HKH (ICIMOD, WCD, GBPNIHESD, RECAST, 2017; Pradhan, 2018).

467 The HKH is one of the most affected areas in terms of human death due to HWC (Torres
468 et al., 2018). To foster improved management of HWC, it is important to understand the
469 processes that drive the relation between humans and wildlife. Globally, experts suggest that the
470 presence of human activities on natural landscape influences daily activity budgets and Spatial-
471 temporal use of habitat by wildlife, eliciting conflict (Clinchy et al., 2016; Suraci et al., 2019;
472 Nickel et al., 2020). However, the factors that drive HWC are region-specific and highly
473 complex depending on the socio-ecological behavior of humans, wildlife, and resource
474 availability (Dickman, 2010; Nyhus, 2016). Among the various drivers, most articles suggest
475 habitat disturbance as a result of land cover change and forest fragmentation, population
476 increase, and urbanization as major drivers of change. These drivers arise from a rapid increase
477 in urban population in the HKH due to industrialization and rural-urban migration, thus, exerting

pressures on natural resources and leading to conflict (Reshamwala et al., 2018). Industrialization demands infrastructure development in biodiversity-rich areas and impacts species diversity through habitat fragmentation and forest loss (Xu et al., 2019). Unavailability of food in the wild in human-modified landscapes drives the wildlife to a nearby settlement (Acharya et al., 2016). The presence of human habitation in the vicinity of most forests and protected areas in the region facilitate frequent human encounters with animals, livestock, and crop raids. Only about 2% of the literature discuss climate change as a factor driving HWC, although HKH is a hotspot for climate change (Sharma et al., 2019). Climate change effects phenology of forage in the wild and causes a shift in habitat that potentially induces conflict with fringe communities (Bashir et al., 2018).

Many scholars in the HKH suggest various management strategies that are mostly traditional and practiced in the region for decades. As recommended by most articles, the communities in the HKH rely on watchdogs, guards, and fences to safeguard their livestock and crops. In Nepal, farmers find guarding on watchtowers flaming sticks and noise effective against elephants, whilst barriers (net wires, trenches) were useful against smaller mammals (Dhakal & Thapa, 2019). As suggested by SAARC Forestry Centre, (2014), many local communities prone to HWC in the HKH have installed barriers like electric and solar fences to mitigate conflict. However, often these actions alone do not prevent attack on crops and livestock as it requires manual efforts by farmers to be alert, maintain barriers, and have resources for repairing. A recent study noted no significant difference in the cost of crop loss between guarded and non-guarded agriculture fields (Perrotton et al., 2017). On contrary, the community-based guarding system of larger farming blocks through collaborative community-led approaches deemed more useful in parts of Indo-Gangetic India (Gross et al., 2019). As suggested in a few articles,

community intervention and adaption methods relating to eco-tourism and local management of resources have the potential to uplift local livelihood as well as sustainably develop ecosystem services (Bhalla et al., 2016). Compensation policies and programmes have also been recommended to increase tolerance towards wildlife, decreases retaliatory killings, and builds community support for conservation (Naughton-Treves et al., 2003; Agarwala et al., 2010; Persson et al., 2015). However these compensation policies are often vulnerable to corruption and people are subjected to long administrative delays that fail to account for transaction costs. Further, in many HKH countries, the compensation policies that are limited and restricted in scope are targeted towards losses from large carnivores and mega-herbivores (Upadhyay, 2013). The conflict response system of various government agencies in the HKH could be strengthened through a better mechanism for complaint submission by conflict victims, lowering of transaction costs, the inclusion of relevant conflict-prone species, and standardization of policies (Karanth et al., 2018).

HWC research in the HKH encompasses various topics. It is concerned with 'conservation', problems of depredation of livestock and focused on species like 'snow leopard', 'elephant', 'Asiatic black bear' and countries name 'India' and 'Nepal' that are frequently visualized in the network (Fig 9). Though being a hotspot for climate change (Sharma et al., 2019), the issue of climate-related changes, its impact on habitat shift, and subsequent conflict with human did not appear in HWC research in HKH. There was also little effort towards the promotion of human-wildlife co-existence through effective wildlife management and creation of human-wildlife interface through tools and techniques. Authorship analysis on the other hand showed that out of 640 total authors who worked on HWC, only 228 of them co-authored HWC publication in the HKH to form a collaboration network. This network of authors for HWC

research (visualized in Fig 10) is less connected as compared to other areas of research like Eco-system services in the HKH (Kandel et al., 2020). Most authors with the highest publication including Aryal A., Lamichhane B.R, Misra C, and Sathyakumar S are from Nepal and India. The top authors from Nepal are affiliated with institution in the developed countries while the ones from India are mainly related to government organizations. The highest number of publications on HWC in HKH is from India whereas Nepal is the principal collaborator with the highest number of research collaboration with other countries. Nepal collaborated with three countries of HKH-India, Pakistan, and China. There is a missing link of networks of HWC studies in between HKH countries of India, Pakistan, Myanmar and Bangladesh. Since HWC is a transboundary issue, it requires co-operation by countries at regional and transboundary level. The recent study by Sharma et al., (2020) is evidence of first transboundary collaboration involving authors from Bhutan, India and Nepal in a transboundary landscape of Kanchenjunga. Such regional level HWC studies could be beneficial in other transboundary landscapes of Karakoram and Pamir knots and Kailash sacred landscape in the HKH (Hussain et al., 2018; Din et al., 2019).

5. CONCLUSION

This study consolidated the status, analyzed trends, and identified gaps in HWC research in the HKH. It is evident that the HKH is one of the hotspot of HWC with severe loss from both human, crops as well as the wildlife and so far, there is no silver bullet option available. Given disproportional focus on both geographical and thematic topic such as protected areas, large carnivore and herbivores, there is a huge knowledge gap exists. Therefore, more research on HWC is needed in the western and far eastern Himalayas mainly fussing on pattern of interaction and mitigation options. To date, studies are regional and most studies originate from outside or

within the boundaries of protected areas. The escalating HWC in HKH demands greater emphasis on a larger scale and more importantly through transboundary approach to resolve the issue, focusing on conflicts at protected areas, corridors and the community lands. There is an opportunity to reinforce the methodologies and precision of studies in the HKH through the adoption of technologically advanced tools such as camera traps and DNA-molecular-based trackers of wildlife. The successful HWC management in the region requires the use of improved reporting and monitoring tools for recording the movement of wildlife and commitment to cross-border cooperation.

Most studies on HWC in the HKH are on large mammals like snow leopard, leopard, elephant, and bears. Small mammals and birds associated with crop damages and livestock depredation are equally important to be considered in future studies. As the region is prone to habitat degradation and shift in species habitat to higher elevation, the climate-change-induced conflict may need in-depth investigation. The role of gender is known to influence policies and programs of communities, but to date, it has not been adequately captured in HWC research. HKH countries are in a common eco-system and there is an urgent need for better collaboration among countries to mitigate the transboundary HWC. The collaboration provides opportunities to enable countries with little or no academic capacities to address transboundary issues. Towards the long-term mitigation, the communities with shared boundaries must be educated and empowered to manage transboundary HWC.

DATA ACCESSIBILITY STATEMENT

This paper used bibliography data generated from Scopus and google scholar for analysis and interpretations. The data will be published either in the institutional dataset through Regional database Initiative or if needed then as annex of this publication.

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Legends to figures

Figure 1. Flow diagram for systematic literature review under SALSA framework literature for text screening.

Figure 2. Temporal trend of the number of peer-reviewed articles and grey literature on HWC in the HKH

Figure 3. Spatial pattern of research articles related to HWC research in HKH

Figure 4. Percentage of research publications according to scale and regime of study sites.

Fig 5. Percentage of reviewed articles according to their a) types of conflict b) methods used for analysis of data c) methods used for collection of data

Fig 6. Drivers of change considered by peer-reviewed articles

Fig 7. Management actions on HWC recommended by research articles

Fig 8. Keywords co-occurrence network for HWC research in the HKH

843 Fig 9. Co-authorship network between researchers on HWC in the HKH

844 Fig 10. Co-authorship collaboration country networks on HWC research in the HKH