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Competition between wild and honey bees: Floral resources as a common good providing multiple ecosystem services

Léo Mouillard-Lample [a,b,c,d,*], Gabriel Gonella [e], Axel Decourtye [b,c], Mickaël Henry [a,c], Cécile Barnaud [e]

[a] INRAE, UR 406 Abeilles et Environnement, 84914 Avignon, France
[b] ITSAP – Institut de l'abeille, 84000 Avignon, France
[c] UMT PrADE, Protection des Abeilles Dans l'Environnement, Avignon 84914, France
[d] Université d'Avignon, 84000 Avignon, France
[e] INRAE, UMR DYNAFOR, Université de Toulouse, 31326 Castanet Tolosan, France

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ABSTRACT

It is increasingly acknowledged that bees are declining, notably as a result of global changes such as climate and land-use changes that affect the abundance and diversity of floral resources (i.e. pollen and nectar). Recently, a new concern has gained traction: the negative impact of honeybees on wild bees due to competition over floral resources. Some studies also suggest that there might be intraspecific competition among honeybees themselves. While these issues have mainly been considered by ecological scientists so far, this study aims to address their social dimensions as well. We suggest that viewing floral resources as common-pool resources could pave the way to new governance mechanisms for their management, based on collective action involving the multiple actors that use and modify these floral resources and the associated ecosystem services. Combining conceptual insights on common-pool resources, collective action and ecosystem services, we develop a conceptual model of human–bee–flower social-ecological systems. This model was applied in a case study in the Cévennes National Park, to analyse beekeepers' representations, practices, rules-in-use and social interactions, allowing us to identify critical levers and obstacles for collective governance of floral resources. Our analysis reveals that although there are diverse and controversial perceptions of floral resources and competition among bees, the idea of viewing floral resources as a common-pool resource underlies a range of practices and rules-in-use. In addition, we show that beekeepers' perceptions are changing due to the increasing vulnerability of floral resources. All in all, considering floral resources as a common-pool resource appears a relevant way to study the social interdependencies involved in their management. It is now crucial to develop new forms of governance of floral resources that will reconcile beekeeping and the conservation of wild bees, in coordination with farmers and other land managers.

1. Introduction

In recent years, scientific awareness has grown on the decline of bees[1] (Alaux et al., 2019; Decourtye et al., 2019), their importance for pollination (Senapathi et al., 2021), and the negative impacts of agriculture on both honeybees – managed or not – and wild bees (De Palma et al., 2016; Grab et al., 2019). It is increasingly acknowledged that global changes, such as climate and land-use changes, affect the abundance and diversity of floral resources, i.e. pollen and nectar, which are critical resources for bee reproduction, survival and diversity

* Corresponding author at: INRAE, UR 406 Abeilles et Environnement, 228, chemin de l'Aérodrome – CS 40 509 Domaine Saint Paul – Site Agroparc, 84914 AVIGNON Cedex 09, France.

E-mail addresses: leo.mouillard-lample@inrae.fr (L. Mouillard-Lample), gabriel.gonella@inrae.fr (G. Gonella), axel.decourtye@itsap.asso.fr (A. Decourtye), mickael.henry@inrae.fr (M. Henry), cecile.barnaud@inrae.fr (C. Barnaud).

[1] In this paper, the term "bees" refers to all 20,000 species of bees. "Honeybee" is used as a shorthand to refer to *Apis mellifera* L. in both native or non-native conditions. Although honeybees exist in wild or feral conditions, we mainly consider managed colonies. "Wild bees" are unmanaged native species. We acknowledge that managed bees other than *Apis mellifera* can compete with other bees. In this case, our model can be adapted to consider ecosystem services and beneficiaries in question.

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(Havens and Vitt, 2016).

Recently, a new concern has gained traction: the negative impact of honeybees on wild bees due to competition over floral resources (Mallinger et al., 2017). Numerous studies have shown that colonies managed by beekeepers, especially western honeybees (*Apis mellifera* L.), result in interspecific competition for floral resources (Geldmann and González-Varo, 2018; Geslin et al., 2017). Some studies suggest that there might also be intraspecific competition between western honeybees – although to date this has been less documented (Henry and Rodet, 2018; Lloyd et al., 2017).

These findings have provoked intense debates within both the scientific and professional beekeeping communities. Some authors have suggested that managed colonies of honeybees should be excluded from protected areas in order to preserve wild bees (Geldmann and González-Varo, 2018), while others advocate for more inclusive measures (Alaux et al., 2019; Kleijn et al., 2018). In this context, some ecologists have suggested viewing floral resources as a common good (Henry and Rodet, 2018). Viewing floral resources as a "commons" would pave the way to new governance mechanisms for their management, based on collaboration between the multiple actors that use and modify them (Ostrom, 1990). While the issue of competition among bees over floral resources has been mainly studied from an ecological point of view, this study aims to address its social dimensions and implications.

The existence of competition between bees for floral resources has several critical social implications. First, interspecific competition between wild bees and managed honeybees can lead to conflicts between conservation-oriented actors advocating for wild bee protection and beekeepers who earn their living with honey production. Second, intraspecific competition between honeybees might lead to tensions among beekeepers and require new rules of access to apiary locations and floral resources. Finally, since floral resources are provided by ecosystems that are at least partly shaped by human activity, notably agriculture, there are also social interdependencies between farmers and beekeepers, and farmers and conservation-oriented actors. Floral resources can thus be considered the central components of complex social-ecological systems, with multiple stakeholders that co-produce or benefit from the diverse ecosystem services floral resources provide through flower-bee interactions, such as honey production, agricultural production, pollination or biodiversity conservation (Matias et al., 2017; Veldtman, 2018).

Drawing on a case study in the Cévennes National Park in the South of France, this study aims to investigate the social dimensions of these social-ecological systems, notably the governance of floral resources, by exploring the idea of conceptualizing floral resources as a common-pool resource to be governed collectively (Ostrom, 1990). Three main questions are thus addressed in this paper: (*i*) how far is it relevant to consider floral resources as common-pool resources, (*ii*) what are the characteristics of the social-ecological systems centred on these floral resources, notably the key stakeholders, their perceptions, their practices and their social interdependencies, and (*iii*) what are the critical levers and obstacles for collective governance of floral resources.

To answer these questions, the article is organized as follows. The first section introduces our conceptual framework. Drawing on the theoretical insights from collective governance of common-pool resources and ecosystem services, we propose a conceptual model of the complex human-bee-flower social-ecological system. The second section presents our study site in the Cévennes and our methodology for data collection and analysis, drawing on semi-directed interviews. The third section presents our results, i.e. our analysis of the human-bee-flower socio-ecological system in the Cévennes, the beekeepers' perceptions and practices, and the characteristics of the social interdependencies among beekeepers and other stakeholders. Finally, in the last section, we discuss some of the critical levers and obstacles for the collective governance of floral resources as a common-pool resource.

2. Conceptual framework

2.1. Governance of common-pool resources and ecosystem services

A common-pool resource is defined as a resource that is both subtractable (the use of the resource decreases the amount available) and difficult to exclude (it is difficult or costly to exclude a potential beneficiary from using it), like water or common pastures for example (Ostrom, 2009). Because of these properties, common-pool resources present a risk of over-exploitation. However, Ostrom's seminal research shows that such resources can be sustainably managed by communities of users through collective action, for example in community forests. Her pioneer work examines both the formal and informal rules used by communities to govern resources and identifies factors that favour or prevent their collective governance (Ostrom, 2008).

Later on, Ostrom's work has been extended to more complex social-ecological systems including multiple types of resources, actors and multiple instances of governance (McGinnis and Ostrom, 2014). In particular, the concept of ecosystems services, defined as the benefits ecosystems provide to support human well-being, broadens the types of benefits and resources that are considered as commons (Plieninger et al., 2013). Compared to traditionally studied resources such as water or forest, the ecosystem services concept encompasses diverse types of resources and benefits, that tend to be less visible, based on more complex and uncertain ecological processes, and involving interactions among multiple scales (Duraiappah et al., 2014). The ecosystem services concept has therefore the potential to highlight and reveal new forms of interdependencies among people, and triggers new arenas for collective action (Barnaud et al., 2018).

The case of floral resources studied in this study can be seen as a common-pool resource from which multiple types of ecosystem services are derived and involving multiple actors at multiple scales. It appears therefore relevant to combine theoretical insights on collective governance of common-pool resources and ecosystems services. To do so, we draw on a conceptual framework developed by Barnaud et al. (2018) that uses an ecosystem services lens to highlight and characterize social interdependencies among beneficiaries and providers of ecosystem services, so as to reflect on potential or existing collective actions among them.

While we could have opted for other socio-ecological frameworks (McGinnis and Ostrom, 2014; Patel et al., 2020), we favoured the conceptual framework developed by Barnaud et al. (2018) for two main reasons. First, in the case of floral resources, the users of the resource are not necessarily those that influence the resource availability. This framework presents the advantage of emphasizing the different roles of beneficiaries, providers and managers (or intermediaries) of ecosystem services, and their social interdependencies. In addition, the framework of Barnaud et al. (2018) adopts a constructivist perspective, considering ecosystem services not as objective and given, but as socially constructed and contested (Barnaud et al., 2018). This constructivist perspective was particularly relevant for our case because floral resources may or may not be perceived as sources of ecosystem services by its beneficiaries, and there is no consensus on whether or not there is a competition among bees over these resources. There is thus no consensus on whether or not floral resources should be seen as common-pool resources. All in all, combined with the concept of common-pool resources, the framework of Barnaud et al. (2018) served as a backbone to develop a conceptual model of the human–bee–flower social-ecological system, that highlights and characterizes the social interdependencies at stake in bee competition over floral resources.

2.2. A conceptual model of the human–bee–flower social-ecological system

Our conceptual model includes several components and interactions that make up a generic human–bee–flower social-ecological system: the

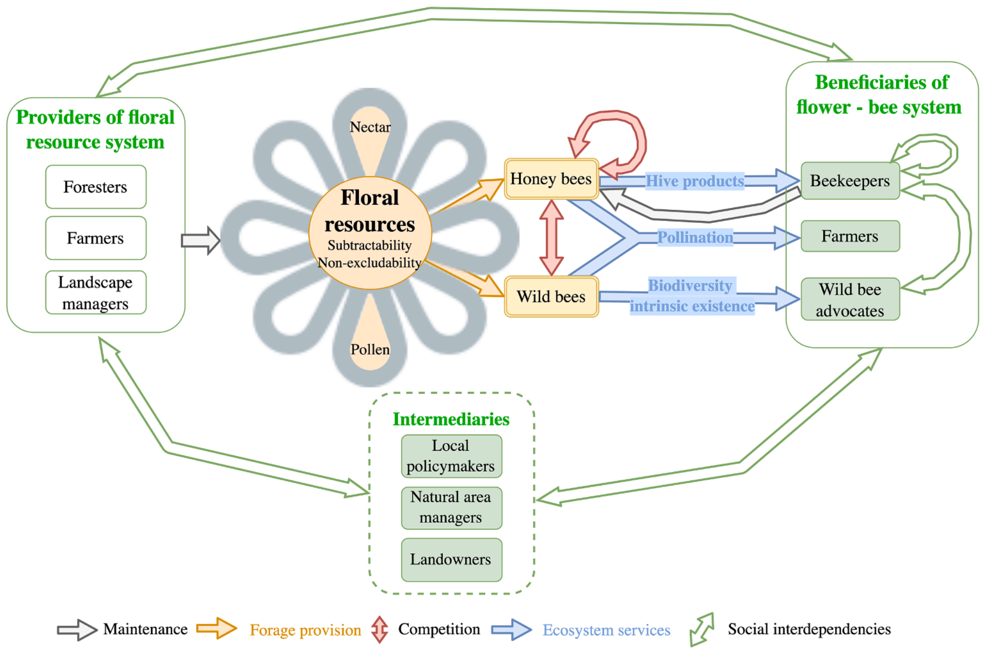

Fig. 1. Conceptual model of the human–bee–flower social-ecological system drawing on common-pool resource theory (Ostrom, 1990) and a framework by Barnaud et al. (2018) on ecosystem services and social interdependencies.

floral resources as a central common good, the diverse ecosystem services derived from the combination of floral resources and bees, the main concerned stakeholders (beneficiaries and providers of ecosystem services) and their social interdependencies (Fig. 1).

2.3. Main components of the human-bee-flower social-ecological model

Floral resources are the central component of our conceptual model. They are primarily forage resources for bees and other insects, providing nectar and pollen. Since bees are free to fly anywhere, it is difficult to exclude them from accessing floral resources. Floral resources are thus of the "difficult to exclude" type. In addition, recent ecological studies on inter- as well as intraspecific competition suggest that there is a finite supply of pollen and nectar (Geslin et al., 2017; Henry and Rodet, 2018). Floral resources might thus also be considered as subtractable. Given these two properties, from an ecological point of view, floral resources can be considered common-pool resources.

Our conceptual model then highlights the various ecosystem services derived from floral resources, as well as their beneficiaries. Indeed, humans only indirectly benefit from floral resources. They actually benefit from the ecosystem services provided by the nexus floral resource – bee. Three main ecosystem services are considered in our model.[2] The first one is the production of honey and hive products, a provisioning service that benefits beekeepers. The second one is the regulating ecosystem service of pollination, which mainly benefit farmers, notably fruit growers (Gallai et al., 2009). In some case, it could be relevant to consider also beekeepers as beneficiaries of pollination, as they can earn an income from it through pollination contracts with farmers. When pollination is done by honeybees that are managed and moved by beekeepers, some authors are reluctant to consider it as an ecosystem service. They consider instead forage provision as a provisioning ecosystem service provided by floral resources, on which farmers and beekeepers rely to provide a service of managed pollination (Melin et al., 2018; Veldtman, 2018). We made a different conceptual choice, in line with the literature acknowledging that ecosystem services are often co-produced by both ecosystems and human activities (Bennett et al., 2015; Lavorel et al., 2020; Palomo et al., 2016). We thus consider that even if it is managed by beekeepers, honeybee pollination remains an ecosystem service, which is co-provided by the beekeepers, the floral resources and the honeybees.

The third ecosystem service we highlight in our conceptual model is the intrinsic existence of bee diversity. Considering only pollination and provisioning services is insufficient to address the benefits of the flower-wild bee nexus (Senapathi et al., 2015). Indeed, only 2% of bee species – generally common species – provide 80% of the crop pollination (Kleijn et al., 2015). There are also benefits and values associated with the very existence of wild bee diversity (Matias et al., 2017; Patel et al., 2021). This intrinsic existence of biodiversity is considered as a cultural ecosystem service (Chan et al., 2012), which potentially benefits the whole society. In our model, we consider that the main beneficiaries of this cultural service are the wild bee advocates, i.e. the stakeholders – ecological scientists, conservationists, bee naturalists or natural area managers – who defend wild bee preservation on behalf of society. We could have considered also the cultural ecosystem service related to the value of local beekeeping and associated knowledge and products, but we did not integrate it, since it is less directly related to the issue of competition among bees.

Finally, in line with the idea that ecosystem services are co-produced by both ecosystems and human activities (Bennett et al., 2015; Lavorel et al., 2020; Palomo et al., 2016), our model emphasizes the actors whose activities contribute to the provision of floral resources, and thus indirectly to the provision of the above listed ecosystem services. Since bees use both wild and cultivated floral resources, farmers, foresters and

[2] Some authors have suggested to consider forage provision as an ecosystem service provided to bees by floral resources (de Lange et al., 2013; Melin et al., 2018). Such a service would belong to the category of supporting ecosystem services, i.e. services that are necessary for the production of the three other categories of ecosystem services (provisioning, regulating, and cultural) that more directly contribute to human well-being. While this category of supporting services was proposed in the initial Millennium Ecosystem Assessment (2005), it was discarded later on because it was considered only as an intermediary ecological function, not as an ecosystem service *per se* (Potschin and Haines-Young, 2011). Following other authors (Albrecht et al., 2020; Desaegher et al., 2021), we thus do not consider forage provision for bees as an ecosystem service, but only as an intermediate ecological function.

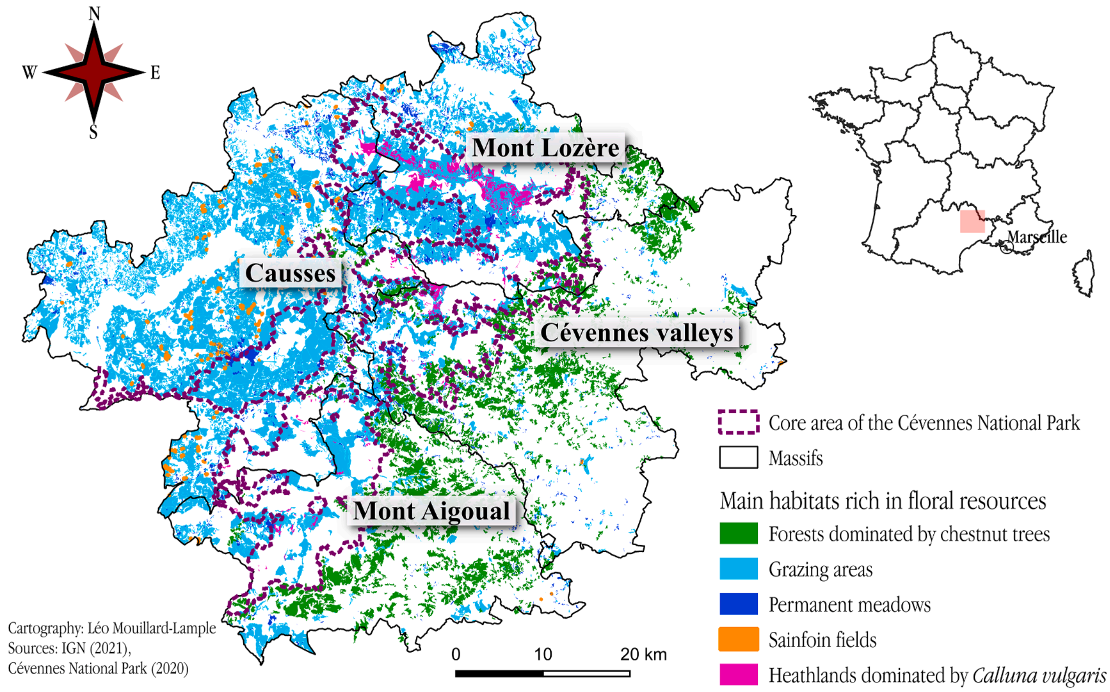

Fig. 2. Map of the case study area with its main massifs and main habitats rich in floral resources. Data were sourced from the Cévennes National Park institution (core area, "massifs" limits, heathland habitats) and the National Institute of Geographic and Forestry Information (Institut National de l'Information Géographique et Forestière – IGN; BD Forêt® used to delineate forest habitats; graphic parcel register used to delineate agricultural habitats).

landscape managers are considered as providers of floral resources, by directly cultivating floral plants or, more indirectly, by maintaining certain types of landscapes – notably open landscapes (Wratten et al., 2012). Some landowners do not influence much the production of floral resources but have a key role in the system by allowing the beekeepers to set up their apiaries on their land (Kouchner et al., 2019).

Those landowners, as well as local policymakers and managers of natural areas are considered "intermediary stakeholders", as they interact with both floral resource providers and beneficiaries and influence decision-making regarding floral resource access and management (Barnaud et al., 2018). They can notably influence farming and forest management practices that underpin the production of floral resources (Durant and Otto, 2019).

2.4. Social interdependencies between stakeholders

Our model highlights three key social interdependencies among stakeholders that are central to the governance of floral resources: (*i*) between beekeepers and wild bee advocates (i.e. between beneficiaries of antagonistic services), (*ii*) among beekeepers (i.e. among beneficiaries of the same service), and (*iii*) between farmers and other beneficiaries (i.e. between service providers and beneficiaries).

Based on Barnaud et al.'s (2018) framework, we analyse these social interdependencies through four factors that are critical for collective action: (*i*) the degree of stakeholders' awareness of their interdependencies; (*ii*) the formal and informal institutions that regulate these interdependencies; (*iii*) the levels of organization at which human and non-human actors operate; and (*iv*) the power relations affecting them.

i. The first factor concerns the cognitive framing of interdependency: do stakeholders perceive themselves as interdependent with each other? This is important because it strongly determines the motivation of stakeholders to engage into collective action. The question of whether or not stakeholders perceive floral resources as a subtractable resource (i.e. whether or not they believe there is a competition among bees over these resources) will be particularly critical in this respect.
ii. The second factor concerns the role of "institutions" *sensu* Ostrom (1990), in our case the formal and informal rules regulating the provision and use of floral resources. When examining the potential for collective action, it is particularly important to analyse the informal rules-in-use among beekeepers as well as the more formal institutions that regulate their access to floral resources.
iii. The third factor concerns the multiple levels of organization involved in the ecological and social processes in the human–bee–flower nexus. Spatial and temporal mismatches can result from these different levels of action and organization (Cumming et al., 2006) and be obstacles to collective action (Ostrom, 2010). It is thus critical to identify potential mismatches between floral resource harvesting and management to determine the right arenas of action to organize coordination at different levels.
iv. The fourth factor is the power relations between stakeholders. Which stakeholders in the system have greater influence on the human–bee–flower nexus, by which means? It is notably important to examine the dominant narratives among stakeholders and how this impacts the governance of floral resources.

3. Methodology

3.1. Case study

The study was carried out within the Cévennes National Park in the south of France. Agropastoralism and forestry have both shaped those low mountain landscapes over the centuries. The area is divided into four main geological zones (Fig. 2): (*i*) "Cévennes valleys", schistose valleys, predominantly forested areas, contain most of the floral resources. White heather (*Erica arborea*) and black locust (*Robinia pseudoacacia*) provide resources for the development of bee colonies in March and April. Chestnut trees are the most important resource for honeybees and beekeepers, blooming from the middle of June to the first week of July. During and after the chestnut flowering period, bees are

Table 1
Interviewed beekeepers according to their beekeeping status.

Beekeepers	Number of interviewees	Number of colonies
Professional beekeepers	19	100 – 850
Recently established	*4*	*160 – 200*
Multi-activity beekeepers	4	80 – 130
Recreational beekeepers	10	5 – 60
Retired	1	4
TOTAL	34	

able to forage on mountain flowers such as bramble (*Rubus* sp.) and bell heather (*Erica cinerea*). (*ii*) The "Causses" are large calcareous plateaus shaped by pastoralism. Main floral resources are spontaneous floral species (such as wild lavender and thyme) and melliferous fodder (sainfoin). (*iii*) Mont Lozère is a granite massif partially covered with meadows and *Calluna vulgaris* heathlands. Bees find resources here mainly during summer. The heathlands are critical resources for beekeepers because they constitute the sole mass-flowering resource available in the area in summer. Moreover, the character of heathland honey is sought after, making it an economically profitable resource (Lehébel-Péron et al., 2016). (*iv*) Mont Aigoual is a granite massif with forests of chestnut and pine, moorland and meadows.

Beekeepers move their colonies to different areas to provide the bees with available floral resources. In this way, they benefit from the floral resources at different times and in different areas of the region. Beyond the four zones described above, outside the National Park, the surrounding Mediterranean scrubland offers diverse floral resources such as rosemary, lavender and black locust flowers. The bloom of the garrigue (a shrubland Mediterranean ecosystem with melliferous plants such as *Thymus* and *Rosemary*) early in the season encourages some beekeepers to seasonally move their hives during the winter, relocating them to the Mediterranean plains to avoid the cold mountain temperatures and foster colony development.

To date, 264 species of wild bees have been recorded within the National Park (Genoud and Fonderflick, 2021), although this number is probably underestimated. Some naturalists have raised concern about several endangered bee species, especially some heathland *Bombus* species, which are affected by global warming and the loss of heathland.

The Cévennes area has a long history of beekeeping. From traditional beekeeping in the trunks of chestnut trees to today's migratory beekeeping, this activity is still important and is closely linked with the production of chestnut and heather honey (Lehébel-Péron, 2014). The most recent estimation was a total of 300–320 beekeepers in the area, overall managing about 26,000 colonies (Jobard, 2012).

3.2. Data collection and analysis

Our work is based mainly on interviews with beekeepers, but also on working meetings with researchers in bee ecology and managers of protected areas. To collect the data, we conducted semi-structured interviews with 34 professional and recreational beekeepers in the study area between January 2020 and June 2021 (Table 1). Beekeepers were selected in order to gather a diversity of perspectives on floral resources. We therefore interviewed beekeepers covering a range of types of beekeeping practices, in terms of production systems and forms of organization. Among the interviewed beekeepers, four also have another farming activity. Their perception thus also partly reflects that of the farmers on the question.

We used a snowball sampling strategy. An initial list of interviewees was based on contacts established during local meetings of beekeepers and on some suggestions from National Park agents. Later on, contact details of people with different or important perspectives were asked during the interviews. The interviews were semi-directed, conducted in a conversation mode. Each interview started by asking for a description of the interviewee's current and past activities, and a description of the beekeeping system and practices, including the migratory circuit of beehives. The interviewees were then asked about their perception of floral resources, their use of these resources, the main changes affecting the availability of resources, and the evolution of their beekeeping practices. They were also asked about the social interactions and rules-in-use among beekeepers and other stakeholders, notably regarding access to apiary locations, number of colonies per apiary, and distance among apiaries.[3] Some interviews were supplemented with a participatory observation of beekeeping activities (e.g. hive migrations, apiary visits). The interviews lasted from 1 to 4 h. They were fully recorded and partially transcribed.[4] We undertook a thematic analysis of the whole interviews through the lens of the conceptual model of the human-bee-flower social-ecological system described in the previous section. We thus analysed the beekeepers' perceptions of floral resources, their practices, and social interactions with other stakeholders in the system so as to characterize the human–bee–flower system and its key social interdependencies (see the guide of interview's analysis in Appendix Table A1). Throughout the study, additional meetings were held with National Park agents and others with ecologists and bee naturalists, allowing to gain knowledge on their perceptions through participatory observations.

4. Results

The first result section below presents our findings regarding the main components of the human-bee-floral social-ecological system (section 4.1, Appendix Table A2), and the second section analyses the key social interdependencies between beekeepers and other stakeholders in the Cévennes (section 4.2, Table 2).

4.1. Main components of the social-ecological system in Cévennes area

We identified the key components and characteristics of the studied social-ecological system, i.e. the floral resources, the key ecosystem services derived from these, the providers and beneficiaries of these services, as well as the intermediary stakeholders (Appendix Table A2).

Floral resources are the central component of the studied social-ecological system. In the Cévennes, these are mainly perceived as vulnerable and declining resources. The periods of honey production are getting shorter, and floral resources are getting more uncertain. In the spring, floral resources allow colony development, but the production of white heather and black locust honey remains unpredictable. Chestnut tree nectar is the most important resource and also the most reliable one. However, global warming and summer droughts exert an ever-increasing impact on nectar production, and the future of this resource is uncertain. Moreover, chestnut trees, which were formerly massively cultivated, are now mostly wild trees and with lower nectar production, according to beekeepers. Likewise, the availability of heathland floral resources in August has strongly declined since the 1990s, on top of its shrinking spatial cover. Still, heathland remains the only mass-flowering resource at the end of summer in the area. Floral resources provided by farmers' crops such as sainfoin are also uncertain and declining. Droughts and increasingly early harvests decrease the availability of these resources.

Two key ecosystem services are derived from the nexus floral resource – bee in the study area: a provisioning service (honey production) and a cultural service (intrinsic existence of wild bees).

In the Cévennes, honey is the main beekeeping product. The sale of swarms occurs but is less frequent. Among professional beekeepers,

[3] An apiary is the place where managed colonies are placed to produce honey. Colonies live in beehives that are loaded onto trucks for migration. The truck load is the maximum number of hives carried in the truck.

[4] Only the most relevant parts for the themes analysed are transcribed, the rest of the text being synthesised.

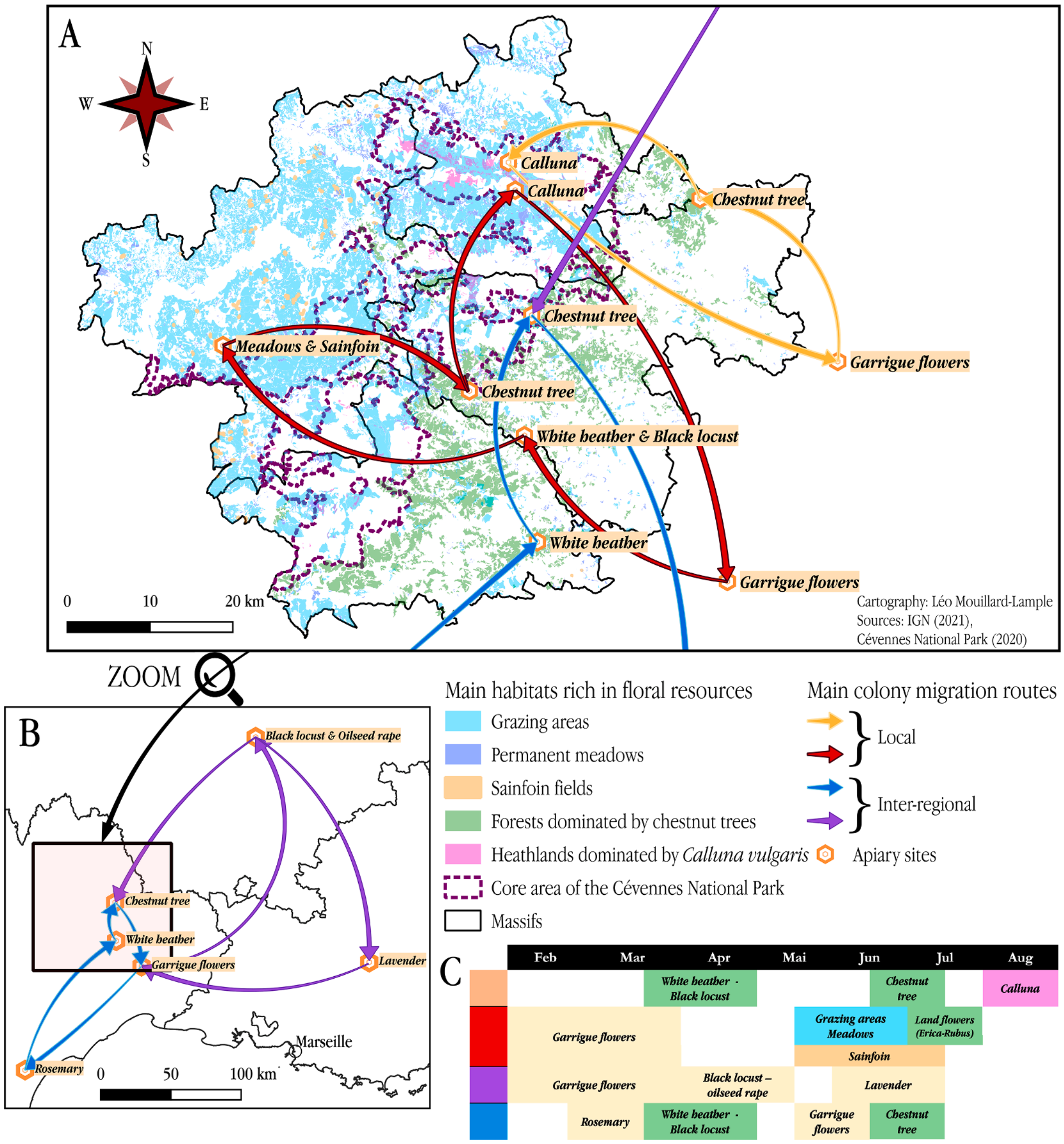

Fig. 3. Main beekeeping migratory systems in the Cévennes area. In addition to sedentary beekeepers, there are two systems of colony migration: (A) a local transhumance system whereby colonies are moved locally within the Cévennes area and surrounding garrigue, and (B) an inter-regional transhumance system. Colony migration follows the phenology of mass-flowering resources (C). See Fig. 2 for geographic information sources. Apiary sites and colony migration routes are schematic examples of typical routes obtained from interviews.

there are three main types of production system (Fig. 3). The first is a *local migratory system* in which most resources come from the area, and the colonies remain within a limited geographical area. These beekeepers move their colonies between the scrubland surrounding the area, the Cévennes valleys of white heather, black locust and chestnut trees, the meadows and pastures of the Causses, and the meadows and heathlands of Mont Lozère. Some go to the north of the area to locate their colonies near fir trees. The second is an *inter-regional migratory system*, in which beekeepers move their colonies over a wider area. They often benefit from the earlier development of colonies, moving them to follow the rosemary blooming in the southwest of France, black locust and oilseed rape in the east, and lavender in the southeast (Fig. 3B). In the Cévennes area, they concentrate on the resources of the first zone described above, the Cévennes valleys (white heather, black locust, chestnut trees, mountain flowers). The third is a *sedentary system* with low production costs and high added-value products such as soap or wax. This system is less common among professional beekeepers. In addition, there are many non-professionals who sometimes move their colonies locally, in particular to produce heathland honey.

In the region, pollination is not mentioned as a key ecosystem service by the people who potentially benefit from it. This perception can be explained by the fact that pollination is not yet perceived as endangered in this area. In addition, most farmers in the area raise livestock and do not perceive their activity as critically dependent on pollination. Vegetable growers and chestnut growers are more obviously dependent on pollination, but pollination contracts between farmers and beekeepers, which exist for orchards in other regions, are absent in the study area. In the case of the seldom managed chestnut groves, beekeepers seem to be more dependent on the large quantities of honey and pollen supplied by chestnut trees than chestnut growers are on managed pollination. Beekeepers therefore do not receive any rent for pollination, but growers give them easy access to their land to set up apiaries. Also, some professional beekeepers receive a grant from the European Common Agricultural Policy for their contribution to pollination in semi-natural habitats.

In contrast, the cultural service of the intrinsic existence of bee diversity is a strong concern for some stakeholders. In this study, we focused on those who advocate and work for the conservation of wild

Table 2
Key characteristics of social interdependencies.

Factors of social interdependency	Social interdependency	
Cognitive framing of interdependency	*Among beekeepers*	Intraspecific competition diversely but increasingly perceived, leading to usage conflicts between beekeepers. Underlying notion of common-pool resource through thresholds in number of colonies.
	Between beekeepers – wild bee advocates	Interspecific competition little perceived. Subtractability of floral resources difficult to assess (uncertainty and unknown withdrawal rate).
	Between beneficiaries - providers	Resources are provided by nature, but agricultural depletion and change of practices are responsible for resource decline.
Institutions	*Among beekeepers*	Formal rules: agro-environmental measure for pollination service imposes a minimum of colonies per apiary. Informal rules: courtesy rules of distance. Apiary management: individual (livestock management, truck loading, working comfort, resource availability) and interindividual (site loans).
	Among beneficiaries	Charter: regulation on maximum number of colonies and minimal distance (under development). No effective collective management.
Scales and levels of organization	*Among beekeepers*	Apiary load decisions are taken at local or individual level. Temporal mismatches: blooming period, drought period, colony development. Spatial-temporal mismatches: migratory beekeeping.
	Between beekeepers – wild bee advocates	Ecological level: foraging area, difference between honey and wild bees. Wild bee advocates can have an impact on access policies for managed colonies taken at the national or protected area level.
	Between beneficiaries – providers	Spatial mismatches: floral resource production scale vs. beekeeper management vs. foraging scale of bees.
Power relations	*Among beneficiaries*	Large migratory beekeepers have more developed colonies with higher resource foraging potential. Hobbyists and wild bee advocates have less power over the number of colonies, but more political influence in the area. Hobbyists and wild bee advocates have less power over the number of colonies, but more political influence in the area.
	Between beneficiaries – providers	Floral resource providers: – Decide on land-use: bee-keepers have only harvesting rights – Depend on agricultural policies (higher impact than beekeeping sector)
	Among intermediaries	Landowners (private and institutional): apiary property rights, influence hive position decisions. External market influences land-use decisions, selling prices of honey, etc.

bees and thus may get into conflict with beekeepers due to interspecific competition. These include National Park agents, as well as ecologists, naturalists and researchers who work on wild bees. However, National Park agents have a dual role, as they aim to act in favour of all pollinators, managed or not, and also to support sustainable local beekeeping.

In terms of providers of floral resources, the National Park plays a limited direct role – for instance, through a project promoting melliferous hedges. Conversely, it is mainly farmers and foresters who maintain or destroy floral resources through their practices and are the main providers of ecosystem services in our system (Appendix Table A2). Several of their practices can have a negative impact on the production of floral resources: the transition from permanent to temporary meadows that are non-bee-friendly, the transition from sheep to cattle grazing, mowing during the flowering period, and the planting of coniferous trees (Gonella et al., 2022). In contrast, if they maintain an open landscape of grassland and cultivate chestnut groves, for example, livestock farmers and chestnut producers maintain the availability of floral resources.

The National Park and institutional organizations such as the French Biodiversity Agency and the National Forest Agency can also act indirectly on the production of resources through political decisions on land-use policies – they are considered intermediary stakeholders along with farmers and foresters. All these stakeholders are the main landowners in the area. By formally or informally giving beekeepers permission to place colonies on their land and thus to harvest floral resources, they influence colonies distribution in the area. In the Cévennes, contractual agreements are made with institutional organizations in exchange for a monetary contribution based on the number of colonies. With private owners, the agreements are most often informal, in exchange for honey and depending on the rough size of the apiary.

4.2. Analysis of social interdependencies

In this section, we analyse the key social interdependencies mentioned above: (*i*) between beekeepers and wild bee advocates (i.e. between beneficiaries of antagonistic services), (*ii*) among beekeepers (i.e. among beneficiaries of the same service), and (*iii*) between farmers and other beneficiaries (i.e. between service providers and beneficiaries). They are analysed through four factors identified as critical for collective action, as mentioned in the conceptual framework section (section 2b).

4.2.1. Cognitive framing of interdependency

Our analysis revealed ambiguous and complex perceptions among beekeepers regarding intra- as well as interspecific competition, i.e. the subtractability of floral resources. Thus, they have different cognitive framing of the related social interdependencies – among beekeepers and between beekeepers and wild bee advocates (Table 2). Nectar and pollen provision are often perceived as non-subtractable, i.e. unlimited resources, especially during major blooming periods, which provide enough for all beekeepers regardless of the number of colonies.

> *"From 30 to 100 colonies per apiary, it wouldn't make any difference […]. It works or it doesn't work."*[5]

[5] « De 30 à 100 [ruches par rucher] ça changerait rien […] ça marche ou ça marche pas. ».

a professional beekeeper, January 2020

However, during periods of depleted food supply, some beekeepers evoke the subtractability of floral resources.

"When flowers produce a lot of honey, they do produce, there's no competition, we can set up a lot of colonies. On the other hand, when there are less flowers, well, obviously, the competition becomes noticeable."[6]

a professional beekeeper, January 2020

The subtractability of floral resources remains difficult to assess due to the complexity of their structural properties, the variability and unpredictability of floral resource dynamics, and the lack of knowledge on the harvesting rate by all beekeepers. Moreover, due to beekeeping practices (colonies migration at night, hidden apiaries), the number of colonies in a vicinity sharing floral resources is difficult to determine. So is the impact of intraspecific competition on production. Yet while competition is not easy for beekeepers to estimate, the notion of floral resources as a common good is present in their discourse. These are often compared to common-pool resources such as pastoral resources (common grazing). Beyond a certain threshold of colonies per apiary – which depends on the beekeeper – some acknowledge the existence of competition.

"We put up to 120 or 130 colonies in certain locations. Above that, there is a lot of competition between the bees, between the colonies, so we don't install anymore."[7]

a professional beekeeper, January 2020

The arrival of large numbers of beehives during the blooming period has thus led to conflicts in the area and changed the perception of resources. Some beekeepers even expressed a form of denial regarding competition, illustrating the ambiguity of beekeepers' representations of this:

"We don't notice any competition – or we don't want to notice it."[8]

a professional beekeeper, May 2021

Interspecific competition is even less acknowledged. Beekeepers lack indicators to assess the effects of their practices on wild bees. They also question the non-excludability of floral resources. Several considered that managed and wild bees feed on different floral resources. They challenged the idea that honeybee competition has an impact on the availability of resources. Beekeepers often point out the problem of resource availability rather than resource distribution – in other words, they see the problem as not the increasing number of apiaries, but climate and land-use changes that are decreasing the availability of resources.

Concerning the interdependency between providers and beneficiaries of floral resources, beekeepers' perception of providers is ambiguous. On the one hand, floral resources are seen as natural resources. On the other, the transformation of agricultural practices is perceived as responsible for the lack of resources. Agricultural decline in the area was highlighted for its negative impact on floral resources.

All in all, the idea of competition between bees over floral resources appears to be an important paradigm shift for beekeepers. Since they have long perceived these resources as unlimited, it is a significant change for beekeepers to acknowledge these interdependencies.

4.3. Institutions

The use of floral resources by beekeepers is managed mainly through colony locations. This is a critical element in beekeeping practices, which involves a constant search for potential sites. The choice of a site for an apiary is made individually, based on environmental quality (floral resources, sun exposure, wind shelter, etc.), health, safety, and logistics. Apart from its biophysical properties, colonies site choice is seldom directly constrained by regulatory rules, except local legislation imposing minimum distances to houses and roads. Some professional beekeepers receive a grant for pollination through European Common Agricultural Policy agro-environmental measures. This grant is subject to the installation of a minimum of 24 colonies per apiary, with a 2-km distance between apiaries of the same beekeeper.

Generally, the rules regarding distances between apiaries are informal. Beekeepers present these as "common sense" or "courtesy" rules that involve respecting a certain distance between apiaries. However, there is no collectively decided threshold.

"A 500-m distance as the crow flies is recommended…"
"Between two apiaries? Is this more or less respected?"
"No, no…"[9]

a non-professional beekeeper, January 2020

Our analysis revealed the absence of an arena to collectively discuss these rules. Colony load per apiary and apiary distance are individual choices based on the evaluation of floral resources, the amount of hives beekeeper's truck can load, working comfort, and colonies management logistics. Inter-individual cooperation between beekeepers exists (e.g. lending of apiaries, close distances), but there is no collective arrangement at a local or regional scale.

Facing conflicts due to massive colony migration, some beekeeper organizations have recently decided to set a threshold within a good practices charter. They recommend separating apiaries by a minimum of 300 m, and allowing no more than 70 colonies per apiary. However, the professional beekeepers interviewed questioned the relevance of these rules and deplored the lack of consultation of professional beekeepers in the development of the charter. The wild bee advocates surveyed also questioned the charter, considering the threshold as insufficient to limit interspecific competition. Nor were farmers involved in the development process of the charter, although it recommends good practices for farmers (e.g. favouring permanent grasslands, avoiding or preventing the use of pesticides). Nonetheless, although this charter is controversial and has no legacy power (as it just makes recommendations rather than requirements), it is an interesting attempt to regulate the social interdependency related to competition over floral resources. This indicates that floral resources are increasingly perceived as a common-pool resource, and that stakeholders understand that they need to collectively organize to regulate their use.

4.4. Scales and levels of organization

There are multiple spatial and temporal scales in the ecological processes surrounding bee foraging, hive migration, resource use, and floral resource production, as well as in management and political decisions. First, bee foraging occurs at the scale of their foraging range, whereas beekeepers' decisions regarding access to floral resources are taken at the scale of apiary sites. While beekeepers are present throughout the territories, where they have the opportunity to give their opinion on local policies, wild bee advocates have an impact on colony access policies at the national level or more specifically in protected areas.

Second, hive migration extends the range of floral resource

[6] « Quand ça mielle ça mielle vraiment, il n'y a pas de concurrence, on peut mettre beaucoup de ruches. Par contre quand ça mielle moins, ben évidemment ça peut peut-être se ressentir. ».

[7] « On monte jusqu'à 120 ou 130 ruches sur certains emplacements. Puis après ça fait beaucoup de concurrence donc de toute manière on n'en met pas plus. Beaucoup de concurrence entre les abeilles, entre les ruches. ».

[8] « [La compétition] on ne la sent pas ou on ne veut pas la sentir. ».

[9] « – Il se préconise comme distance 500 m à vol d'oiseau– Entre deux ruchers? Et c'est à peu près respecté?– Non, Non… ».

beneficiaries that need to be considered in the system and reinforces social distances between beekeepers and other stakeholders. It also results in temporal mismatches between migratory and sedentary beekeepers: in the case of mountain beekeeping, where the season begins late, migratory beekeepers whose colonies are active earlier given the warmer climate may be able to exploit different floral resources than sedentary beekeepers.

Competition between bees is also different over the year depending on both floral resource availability and hive density, leading to temporal mismatches.

Finally, there are mismatches between the scale of floral resource production (e.g. farming practices at field scale) and floral resource appropriation by bees (the approximate foraging range of honeybees is 10 km^2; Steffan-Dewenter and Kuhn, 2003). Although negotiation with a landowner occurs at the scale of an apiary site, floral resource production by a farmer in the area (or a farmer's effect on these through the use of pesticides, for example) may influence the production of honey and wild bee-mediated pollination services to surrounding beneficiaries who are not involved in the negotiation process.

4.5. Power relations

Beekeepers can influence competition through the development of their colonies and through hive migration, which impact both intra- and interspecific competition. Colonies supplemented by syrup or previous blooming outside the area are perceived as more competitive than colonies developed on floral resources alone within one area:

> *"My colonies are smaller and are fragile. They should not be together with Formula 1 bees that have three honey supers*[10]*, which will* decimate *them."*[11] a multi-active beekeeper who raises local bee subspecies, May 2021

These asymmetries involve a form of power relations; however, this power is relative and constrained by the resilience of a particular beekeeping system. Two other kinds of stakeholders seem to be most influential at a local scale in this human–bee–flower system: farmers as floral resource providers and landowners. Farmers own and/or manage flower-producing landscapes and benefit from supportive agricultural policies. In contrast, at both a national and transnational scale, the beekeeping sector is less supported – and relatively powerless in the face of the interests of agribusiness. Beekeepers are "landless farmers": they have only usage rights and thus depend on landowners. Landowners, whether or not they farm the land, have the right to exclude beekeepers and may influence the locations of apiaries.

> *"We are landless farmers. We are marginalized and have no influence over the landowners, who have hundreds of hectares."*[12]
>
> a professional beekeeper, May 2021

Conflict between beekeepers over access to floral resources (for example, caused by the arrival of new beekeepers close to an existing apiary) are thus mediated by landowners. While apiary site rentals are usually paid in honey, some landowners accept a high density of hives in exchange for money. This can result in an increase in rent and in the arrival of a massive number of colonies, leading to competition between beekeepers in the area.

> *"The beekeeper who came to install his huge number of hives paid €4.50 per hive. [...] So multiplied by 300 hives, the landowner made money by allowing the deal."*[13]
>
> a professional beekeeper, January 2020

In this context in which beekeepers have little power over their interdependencies, debates with wild bee advocates on the exclusion of beehives from certain protected areas are seen as threatening for their activity. And both beekeeping and naturalist organizations struggle to impose their views on political decisions at national and local levels.

Overall, our analysis reveals a diversity of perceptions regarding bees' competition over floral resources, and the complexity of the issue, with multiple nested levels of organization. We also show that there are some informal rules-in-use related to the use of floral resources, but no coordination or action arena where to discuss these rules. In terms of perceived interdependencies, the beekeepers in our case study felt dependent on nature and environmental conditions rather than on human activities and providers of floral resources. However, global changes and the arrival of new beekeepers who come to mountains to flee lowlands intensive agriculture are changing the beekeepers' perceptions and social organisation. The decrease in floral resources increases competition among bees and therefore reinforces the dependency of beekeepers on providers and strengthens the mutual interdependency between beekeepers. Finally, the different levels of interdependency and power relationship suggest that collective action to overcome bees' competition should not be limited to an issue of sharing resources among beekeepers and wild bee advocates, but also include higher levels factors and actors that influence the availability of floral resources.

5. Discussion

In this discussion, we first highlight the contributions of this work to the scientific debate on both interspecific and intraspecific bee competition. Second, we emphasize that beyond competition, it is critical to take into account the global changes affecting the availability of floral resources, notably land-use changes and climate change.

5.1. New insights on bee competition and governance of floral resources

A key originality of our work is to consider floral resources as common-pool resources and to examine how these resources are perceived and managed by stakeholders. Some previous studies used, like us, the conceptual lens of ecosystem services and social-ecological systems to study human-bees interactions, notably (*i*) wild bees-humans systems (Matias et al., 2017) and (*ii*) the migratory beekeeping system in Australia (Patel et al., 2020). Matias et al. (2017) have analysed the different ecosystem services related to "wild bees" – actually mostly unmanaged honeybees – around the world. They highlighted the importance of interdisciplinary studies integrating the various services in order to examine trade-offs between provisioning and cultural services. As for Patel et al (2020), they developed a model of a migratory beekeeping system drawing on Ostrom's socio-ecological system framework (Ostrom, 2009). They highlight the importance of access to apiary sites and the existence of multiple pressures on floral resource availability, which is consistent with our findings. However, in these studies, floral resources were either not considered (Matias et al., 2017) or considered only as habitats for managed honeybee colonies, the colonies being the main resource units of the system described by Patel et al. (2020). Floral resources are not studied as resource units *per*

[10] In common commercial hives, honey super is a box added to the beehive and used to collect honey. When honey flow is important, beekeepers stacked the honey supers on the hive to add more space for honey storage. Three honey supers on a hive means that the colony is highly productive and that the harvest is plentiful.

[11] « Mes colonies sont plus petites, elles sont fragiles. Il ne faut pas qu'elles soient avec des bombasses qui ont trois hausses, qui vont les déniaper. ».

[12] « Nous on est agriculteurs sans terres. On est marginalisé. Et donc tu n'as aucun poids par rapport à tous les propriétaires terriens qui ont des centaines d'hectares. ».

[13] « En fait l'apiculteur qui est venu poser ses quantités de ruches phénoménales il a payé 4,50€ par ruches. [...] Donc 4,50€ fois 300 ruches, il s'est laissé faire le propriétaire. ».

se. Their characteristics (excludability and subtractability) have not been examined, nor have the stakeholder's perceptions of these resources. And yet, a crucial point in our system lies in the fact that both floral resources and bees could be considered as common-pool resources. This has also been highlighted by Durant: "*What makes the bee forage case unique is that both bee forage and honey bees can act as CPRs, in that they are both subtractable/depletable, and it is difficult to exclude certain resource users from accessing the resource.*" (Durant, 2021). Considering floral resources as resources from which ecosystem services mediated by bees are derived allowed us to capture the importance of a paradigm shift regarding the nature of floral resources (from unlimited public good to subtractable common-pool resources), and its implications in terms of social interdependencies, conflicts and governance.

Through our case study, we provide an original contribution to the scientific debates on competition among bees by examining in particular the perceptions of beekeepers. Previous studies have attempted to evaluate the foraging rate of floral resources by bees (Torné-Noguera et al., 2016; Wright et al., 2018) and to measure nectar and pollen availability (Baude et al., 2016). However, the spatial structure of competition and the land carrying capacity for honeybee colonies remain unclear. Henry and Rodet (2020) have put forward the concept of apiary influence range, based on a study showing that interspecific competition seems to occur mainly within a proximal area around apiaries. However, this view has often been debated by interviewed beekeepers and considered irrelevant in their production area. Although certain informal practices and conflicts suggest that beekeepers in the Cévennes do acknowledge some forms of competition and subtractability in some circumstances, they do not believe that the presence of their apiaries can threaten wild bees. It could be argued that this reflects their lack of concern for wild bee conservation, but our observations show rather the opposite. A previous study in US context – where honeybees are non-native – has also shown that beekeepers are generally more concerned about wild bee conservation than the overall population (Penn et al., 2019). According to beekeepers in our case study, the overall resource availability depends first and foremost on the types of resource and on weather conditions, rather than on the harvesting rate. All in all, it is quite difficult for beekeepers to assess interspecific competition on the ground, and this is an obstacle to finding new forms of organizing access to floral resources – whether it is for interspecific and intraspecific competition.

Beyond interspecific competition leading to tensions between wild bee preservation and beekeeping, our study also addresses the question of intraspecific competition among managed colonies. Here again, viewing floral resources as subtractable common-pool resources is a paradigm shift paving the way to collective arrangements between beekeepers. However, this intraspecific competition is itself debated and seldom studied. Some studies reported that overpopulation of managed colonies beyond the carrying capacity of actual forage resources decreases honey production (Al-Ghamdi et al., 2016). Mathematical models have been proposed to determine the optimum number of colonies per apiary and distance between apiaries in order not to exceed ecosystem carrying capacity (Atanasov and Georgiev, 2021; Esteves et al., 2010). On the social side, some studies report that the recent boom in manuka honey in New Zealand led to sharp increase in colony densities and conflicts regarding the size and location of apiaries (Lloyd et al., 2017). In France, a study has shown that divergence between beekeepers who consider resources as limited – and shared between colonies – and those who consider resources as unlimited is a source of tension when it comes to choose apiary locations (Dupré, 2020). Furthermore, the fact that beekeeping activities are not always visible and that apiaries are openly accessible to anyone make it difficult for beekeepers to assess intraspecific competition, and it prevents coordination from taking place (Gill, 1996). All these studies underline the need to do more research on the processes underpinning collective action among beekeepers, and our study contributes to this line of research. We highlight in particular that the paradigm shift that leads to view floral resources as subtractable resources and thus as common-pool resources is critical to enlighten and enrich the debates on competition.

Illustrating such a shift of paradigm, our case study turns out to be an interesting case to investigate the emergence of new commons – a topic which gains traction in the literature on commons. While all stakeholders do not currently define floral resources as a common good, this idea is currently emerging. Representations, institutions and rules regarding floral resources are evolving, as shown by the on the ground discussions surrounding a new beekeeping charter. Durant (2021) uses the concept of "commoning" to examine the emergence of new social arrangements to access floral resources. However, in her study floral resources were considered from the start as common-pool resources – their subtractability was not questioned. Our case study suggests that "commoning" should also pay attention to the perceptions of the resource. The emergence of new commons requires not only the emergence of new rules and arrangements, but also first and foremost the changing perception of a resource, i.e. the cognitive process through which a resource becomes a common good in the eyes of its users. Few studies have investigated these issues (Berthet, 2013; Fontaine, 2016). And yet, our findings show that it is critical to study these cognitive processes, especially in the case of floral resources governance.

5.2. The need to consider the impacts of land-user practices and global changes

Our results suggest that floral resources should not be looked at only through the lens of competition among bees – a framing that would make beekeepers the main culprits in the decline of pollinators –, and that it is critical to consider also other factors affecting floral resources, notably land-use practices and global changes. In our study, the concept of ecosystem services pointed out essential stakeholders of the social-ecological system that should be further examined and interviewed: the providers of floral resources, such as farmers and foresters whose land-use practices heavily influence the availability of floral resources (Durant and Otto, 2019; Malkamäki et al., 2016). In France, a substantial amount of honey productions relies on cultivated plants (rapeseed, sunflower, lavender, alfalfa, chestnut etc.), or semi-natural elements such as grasslands and hedgerows, that are maintained by farmers. However, if agricultural and forestry practices can enhance floral resource supply, they also can degrade it (Billaud et al., 2021; Decourtye et al., 2010; Grab et al., 2019). Farmers, growers or foresters often promote floral resources in an unintentional way, since their primary objective is to harvest wood, fruits or seeds, for example. These providers may be concerned with the yield and quality of their harvest, but not with the associated nectar and pollen resources. As a result, they may be less reluctant to resort to pesticides to achieve their goals, at the expense of bee health and nectar and pollen quality (Gierer et al., 2019; Zioga et al., 2020). Although it can be in the interest of some farmers to provide favourable habitats for all bees if they rely on pollination (Veldtman, 2018), the social interdependencies between farmers and beekeepers appear quite asymmetrical. First, many farmers do not feel that their system depends on pollination, such as livestock farmers in our study. In the case of fruit growers who highly depend on pollination services, such as almond grower in the US or canola grower in South Africa, the case studies described in the literature has shown that farmers can end up controlling the access of honeybees to floral resources (Durant, 2021; Masehela et al., 2020). In addition, the intensification of agricultural practices increases the decline of wild pollinators and the dependence of entomophilous crops to managed pollinators (Ellis et al., 2020). While promoting managed pollinators can empower beekeepers, the asymmetry of power between farmers and beekeepers results mainly in the intensification of beekeeping practices without changes in the agricultural system as documented in the US context (Cilia, 2019). This allows the pollination service to be preserved without consideration for wild bees, thus maintaining an agricultural system that is deleterious to all bees. In the context of almond pollination, this asymmetric relationship between beekeepers and farmers curtails the agroecological transition (Durant, 2021). More generally, this asymmetry appears as an obstacle to collective action for sustainable governance of floral resources, and it should be further examined.

Global changes are a critical factor to take into account when considering the availability of floral resources. Our study highlights how global changes increase the vulnerability of floral resources and how in turn this leads to changes in beekeepers' perceptions and practices. The period of blooming in the study area is becoming shorter and less predictable due to climate change and agricultural practices, aggravating conflicts between beekeepers and giving rise to new arrangements, such as the beekeeping charter. Other studies have shown that if competition between honeybees and wild bees has increased during the past decades, this is likely due to the joint effects of a global decrease of floral resources (Herbertsson et al., 2016; Rodríguez et al., 2021) and exclusions of beehives from agrosystems (Durant, 2019). *Volatile exclusions* (due to the destruction of bee foraging land) or *toxic exclusions* (due to pesticide use) combined with global changes are reducing floral resources and concentrating honeybee colonies in remnants of natural habitats. Conservation practices could thus result in a third, *ambient*, exclusion of beekeepers from floral resources, increasing beekeepers' vulnerability.

All in all, this makes it urgent to build a dialogue between wild bee advocates, beekeepers and farmers so as to co-construct solutions to conciliate conservation of wild bees, sustainable beekeeping and sustainable farming.

6. Conclusion

Our findings about beekeepers' perceptions and use of floral resources in the Cévennes support the idea of considering floral resources as a common-pool resource. While floral resources are not considered as a common-pool resource by many actors, we plead for adopting a constructivist view. We analyse the cognitive processes through which some actors are progressively viewing floral resources as a common-pool resource, and the implications of this change for the rules and arrangements for floral resources governance. To do so, we draw on a model combining theories on collective action, common-pool resources and ecosystem services to characterize the human–bee–flower social-ecological system and the social interdependencies among its key actors.

We found that while competition for floral resources, i.e. their subtractability, is differently perceived by beekeepers, the idea of floral resources being a common good underlies a range of discourse and practices. For example, informal "courtesy" rules on distance among apiaries and individual initiatives to define colony density thresholds are already in use. Yet there is currently no arena to discuss these different perceptions and the potential approaches for floral resource governance. And while collective action seems a promising avenue for better governing floral resources, not all conditions are in place to achieve its successful implementation. Power asymmetries among actors could hinder the equitable management of floral resources. Governance of floral resources thus raises several questions that need to be further explored in order to avoid the implementation of unsustainable or unfair solutions. Faced with environmental problems, commons governance can appear as an emancipatory alternative. However, it can also be coopted to maintain a *business-as-usual* system by fixing the social and environmental problems arising from the crisis of capitalist production (De Angelis, 2013). In the context of Californian almond orchards, "pseudo-commoning" practices driven through top-down processes (Durant, 2021) have led to the persistence of power asymmetries and a situation in which practices are not widely adopted on the ground. Durant (2021) argues that this "pseudo-common" solution fixes the problem of pollination in the short term but discourages change towards beneficial practices by maintaining industrial agriculture, forcing beekeepers to adapt. Rather than pitting wild bee advocates against beekeepers, competition issues should challenge new ways of organizing both the sharing and the production of floral resources, which must necessarily be based on genuine commons approach. It is thus urgent that scientists and policymakers integrate stakeholders' perceptions and knowledge to co-construct bottom-up governance alternatives and catalyse social change.

Table A1
Key themes analysed in the interviews.

Life story	
Farming system	Amount of colonies Sedentary or migratory system Colony replacement, eventual queen breeding activity Genetic of colonies Land Capital: *truck, honey factory* Work: *Number of people working on the farm* Inputs: *Sugar, petrol, mite treatments* Production: *Tons of honey per year, diversity of honey, honey sales channel, pollen sales, swarm sales* Main floral resources in the system
Floral resources	Perceptions Dynamics and issues Beekeeping strategies
Apiary location	Choice of location issues, criteria
Bee competition	Perceptions of competition, subtractability Indicators: Number of colonies per apiary, distance between apiaries Perception of existing rules and possible existing cooperation
Relationship with other beekeepers	Cooperation (apiary loans, mutual aid…), conflicts
Relationship with institutions	National Park Protected geographical information Beekeeping unions, beekeeping development associations association for the defence of the black bee subspecies
Providers of floral resources	Perceptions of social interdependencies

Table A2
Components of the human–bee–flower system in the Cévennes.

Component	Characteristics
Floral resources	Decline of floral resources and increasing uncertainty: – Chestnut trees: main resource for honey production, but impacted by global warming, with an uncertain future. – *Calluna vulgaris* heathlands: the only resource for bees in the area in late summer, but in decline. – White heather and black locust: unpredictable resources for honey production. – Agricultural fodder (e.g. sainfoin): mowed increasingly early.
Ecosystem services	Honey production Wild bee biodiversity
Stakeholders	
Beneficiaries – *Beekeepers*	Professional beekeepers: – Local migratory beekeepers – Large-scale migratory beekeepers – Sedentary beekeepers Hobbyist beekeepers
Beneficiaries – *Wild bee advocates*	National Park managers, scientists, interested citizens
Beneficiaries – *Farmers*	Chestnut growers and a few fruit/vegetable growers
Providers	Livestock farmers maintaining open landscapes Foresters and chestnut growers National Park: landscape management
Intermediaries	National Park: land-use management policies and landowner National Forest Agency: landowner Private landowners: – Farmers – Local / secondary residents

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Co-author is managing guest editor of the special issue but has been excluded from the entire review process of the article. – C. Barnaud.

Data availability

The data that has been used is confidential.

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Appendix

Tables A1 and A2

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