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Eliciting beekeepers' preferences for the small hive beetle control policy in Italy: a contingent valuation survey approach

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Abstract

Aethina tumida, commonly known as the small hive beetle (SHB), is a parasite of social bee colonies. In 2014, when the beetle was first detected in the Italian Region of Calabria, the Italian Ministry of Health started an SHB control strategy. Over time, dissatisfaction with the control measures has grown among beekeepers and eroded compliance with the reporting obligations. Our study analyzes Southern Italian beekeepers' preferences toward alternative SHB control policy. We use a contingent valuation survey to elicit beekeepers' preferences for five alternative control strategies. We find the ex-post biosecurity measure in place reflects in the lowest reporting rate. Our results suggest that implementing the destruction of infested hives only (selective destruction) can be a first, effective step toward enhancing compliance with the reporting obligations. Our findings also suggest that training and extension can be a winning strategy to improve beekeepers' collaboration with the passive SHB surveillance system.

Introduction

In this study, we deal with the issue of disease reporting and indemnification, with specific attention to the invasion of *Aethina tumida* in Southern Italy. *Aethina tumida*, commonly known as the small hive beetle (SHB), is a notifiable parasite of social bee colonies originating from sub-Saharan Africa (Neumann and Elzen 2004).

In 2014, when the SHB was first detected in the Italian region of Calabria, the EU mandated Italy to set up an SHB surveillance system and implement appropriate protective measures (European Union 2014). The SHB control strategy developed by the Italian Ministry of Health (MoH) in the years since the first official detection includes mandatory reporting of suspected outbreaks, a surveillance system of sentinel apiaries and private apiary inspections in the whole territory of Italy, the establishment of a protection zone covering all apiaries where the beetle has been detected, a ban on the transport of any bees in and out such zone, and the destruction of apiaries where a single infested colony is found, with indemnity payments to beekeepers for loss of bees and equipment to provide incentives for beekeepers to comply with reporting requirements (Ministry of Health 2014). From September 2019, local veterinary authorities in the protection zone are permitted to enforce the selective destruction of infested hives only. In two years from 2014, more than 6000 hives have been destroyed, that is around 20–25% of hives present in the two provinces of Reggio Calabria and Vibo Valentia. Dissatisfaction with the MoH's eradication measures has grown among beekeepers and eroded compliance with the reporting obligations (Salvioni and Champetier 2022). For example, the statistics reported by the website[1] of the National Reference Center for SHB show that 8 of the 32 affected beekeepers had spontaneously reported the presence of SHB to the local veterinary services in 2014, while from 2015 all occurrences were identified through official surveillance activities (clinical inspections in managed apiaries and sentinel hives). This erosion of compliance is consistent with findings from other studies of disease eradication campaigns, where the loss of stakeholders' support grows as the duration and total cost of eradication efforts increase, while effectiveness decreases (Cameron 2019).

To shed light on the factors influencing beekeepers' reporting and to identify control policy measures that incentivize beekeepers to comply with SHB reporting requirements, we conducted a contingent valuation survey among beekeepers operating in the SHB-infested Italian regions. Our experimental design is aimed at identifying the impact of alternative control strategies on the willingness to accept a compensation payment to report an SHB outbreak. We designed a certainty equivalent (CE) multiple price lists (MPL) payment card (Andersen et al. 2006; Cerroni 2020). The CE is the minimum compensation payment (i.e., willingness to accept) that makes beekeepers indifferent between receiving the compensation and playing the lottery. In other words, the CE is the minimum compensation that beekeepers are willing to accept to report the infestation and pay the costs associated with the government ex-post biosecurity measures. Our experiment consists of five different tasks differing in level of infestation (mass or mild), government ex-post biosecurity action (whole or selective destruction, and management of the infestation), and information about the probability to be inspected by the veterinary authority. In each task, the beekeeper is asked to choose whether to report the infestation to the animal health authority or secretly manage it. The decision is taken by comparing the cost associated with the two alternative actions. Multivariate analysis of survey data allows us to investigate how willingness to report is influenced by beekeeping operation and beekeeper's characteristics, and whether there exists heterogeneity in beekeepers' willingness to report.

Relative to existing studies on animal disease reporting, a major contribution of our work is to provide empirical evidence on the willingness to accept monetary compensation for reporting and suffer the consequences of the government ex-post biosecurity measures. Our findings provide decision-makers with critical information about the effectiveness of alternative livestock disease control measures during an outbreak. Additionally, this study contributes to the still scarce literature on bee health management.

The rest of the paper is organized as follows. In Sect. "The beekeepers' decision-making about reporting", we describe the beekeepers' decision-making about reporting. Sect. "Material and methods" describes the questionnaire used in the contingent valuation survey and analyzes the study population. Specific attention is devoted to explaining

[1] https://www.izsvenezie.it/aethina-tumida-in-italia/.

the MPL method used to ask the respondent to choose between two options, namely to report the SHB in her hives and accept compensation for the loss due to the application of ex-post biosecurity measures or manage the disease privately. In Sect. "Results", we present the results of the statistical analysis. In the final section, we summarize and discuss our main findings.

The beekeepers' decision-making about reporting

The rational beekeeper takes the decision to comply with the mandatory requirement to report a disease outbreak or to secretly manage it by comparing the cost associated with the two alternative decisions. Livestock owners will disclose truthfully the diseased status of their livestock as long as disclosure improves or at least does not decrease the utility of their expected income. Livestock owners usually receive a compensation payment to cover the costs due to mandatory ex-post control measures (depopulation/culling). Under the assumption that livestock owners are rational profit maximizers, if the compensation payment fully covers the economic loss incurred due to the application of the governmental control measure, there is no incentive for risk-neutral animal keepers not to report the disease outbreak. When not adequately compensated, animal owners may choose to secretly manage the disease or dispose of the diseased animals (Hennessy and Marsh 2021).

In fact, livestock owners often fail to report suspected disease outbreaks to animal health authorities. Many studies have explored the factors of under-reporting (Gates et al. 2021). The economic literature has focused attention on the incentivizing role of compensation paid by animal health authorities. The compensation design is complex since indemnification can provide conflicting incentives between ex-ante biosecurity and reporting efforts (Gramig et al. 2009). This is because indemnification, by reducing the private incentive to take precautions, may create a moral hazard concern (Gramig et al. 2009). A central issue discussed in the literature is whether a single instrument—the compensation payment—can be used to encourage both the ex-ante biosecurity effort and reporting (Gramig et al. 2009; Fraser 2018). In the case under analysis in this study, the problem is simplified because the use of traps is widespread among beekeepers operating in Italian SHB-infested areas. Traps are the only available tool to prevent SHB infestation, while no chemicals have been authorized so far by the European animal health authorities (Sabella et al. 2022). The low cost of traps is not a barrier to adoption. Consequently, the compensation payment offered by Italian animal health authorities to beekeepers reporting SHB outbreaks is only targeted to encourage ex-post reporting by covering the cost of ex-post mandatory biosecurity actions. The current legal requirement in Italy is that the compensation payment is equal to the market value assuming disease-free status (in our case the value of the destroyed hive, colony and already produced honey). Such compensation is expected to indemnify livestock owners against the loss of asset values suffered due to the stamping out policy. As such, it is expected to produce a high level of disease reporting. In fact, over time Italian beekeepers progressively reduced their compliance with the SHB reporting obligation. To shed light on the factors influencing beekeepers' willingness to report, and to identify policy measures that incentivize beekeepers to comply with SHB reporting requirements, we undertook

Table 1 Number of beekeepers and hives by province in Calabria and Sicily region (2021)

	Total beekeepers	% professional operations	Total hives	% hives in professional operations	Average SIZE	Average size of professional operations
Catanzaro	443	49.89	25,469	88.58	57.49	102.09
Cosenza	819	28.57	51,531	84.22	62.92	185.47
Crotone	202	80.20	18,248	95.27	90.34	107.31
Reggio Calabria	368	58.70	35,563	95.24	96.64	156.81
Vibo Valentia	172	66.28	17,562	90.51	102.10	139.43
Calabria	1794	42.81	148,373	89.71	82.71	173.32
Agrigento	291	62.20	10,354	84.31	35.58	48.23
Caltanissetta	280	71.79	7,298	92.46	26.06	33.57
Catania	570	72.81	30,715	95.64	53.89	70.79
Enna	287	83.97	5,682	93.47	19.80	22.04
Messina	448	66.74	15,936	87.29	35.57	46.53
Palermo	643	50.39	21,942	74.45	34.12	50.42
Ragusa	341	53.08	11,876	88.93	34.83	58.35
Siracusa	429	82.75	30,869	97.44	71.96	84.73
Trapani	208	35.58	5,806	60.39	27.91	47.38
Sicilia	2222	48.51	140,478	88.67	63.22	115.54
Italy	68,347	28.30	1,727,468	73.32	25.27	65.49

Source: Italian national beekeeping registry

a contingent valuation survey among the beekeepers operating in the infested Italian regions.

Material and methods

Study population and recruiting strategy

The survey was conducted among the beekeepers operating in both the SHB-infested (Reggio Calabria and Vibo Valentia) and the SHB-free Provinces of the Calabria Region (Catanzaro, Cosenza, and Crotone) and Sicily. According to the data of the Italian national beekeeping registry (Table 1), in 2021 Calabria covered 2.62% of the total number of beekeepers and 8.59% of managed hives in Italy. In Sicily, these percentages are, respectively, 3.25 and 8.13. In both regions, the apicultural sector is characterized by a large percentage of professional beekeepers, double the percentage observed at the national level (28.30). In Calabria, the average size of operations is more than double the national average, ranging from 102.09 hives in the province of Catanzaro to 185,47 in the province of Cosenza.

Unfortunately, individual data from the Italian national beekeeping registry[2] are not available to researchers outside the Italian Health Service. Consequently, we do not have the necessary information to draw a representative sample from the target population. For this reason, we initially used snowball sampling. We piloted the experiment with 4 beekeepers from Calabria in May 2021. In September, at the beginning of the not-busy period for beekeepers, we contacted the beekeepers' associations operating in Calabria

[2] https://www.izsvenezie.it/aethina-tumida-in-italia/.

and Sicily and organized three video meetings, two with 10 beekeepers operating in Calabria and 1 with 3 beekeepers operating in Sicily. These meetings were aimed at presenting the research project and the questionnaire. Furthermore, the participants were asked to fill in the questionnaire. After the meeting, the association Aprocal generously made the contact list of their members available for the survey. This association is very active in the infested provinces and specifically in the province of Vibo Valentia where it represents 68.17 of professional beekeepers.

From October, invites were sent to the beekeepers in the Aprocal contact list. The strategy used to recruit beekeepers included prenotification and reminders. We first pre-notified beekeepers by sending a WhatsApp message asking them to participate in the survey by filling out a web questionnaire. We then sent a follow-up message inviting them to either fill out the web questionnaire or to contact the research group to be assisted by telephone to fill in the questionnaire. Given the scarce number of answers, we finally contacted the beekeepers by telephone.

Survey questionnaire

The survey questionnaire[3] is organized into three sections. The first section contains a set of SHB-related questions intended to assess the type and cost of the ex-ante biosecurity action implemented by the beekeeper, the experience with SHB, and the beekeepers' level of trust in and compliance with the governmental control policy. The second section contains the contingent valuation questions used to measure the willingness to report under five alternative control policy scenarios. Therefore, beekeepers are asked to report their CE (or minimum WTA) in five different CE-MPL tasks. In the final section, the surveys obtained descriptive information on each beekeeping operation (for example, economic and physical size, location, type of management, and products) and socioeconomic information on beekeepers such as age, education, grades, experience in beekeeping, and similar.

In each of the five MPL tasks, we consider a hypothetical situation in which the beekeeper has detected the presence of the SHB in her apiary and can either report it to the veterinary authorities or manage the disease privately. Notification leads to government actions intended to prevent the spread of the SHB. Beekeepers who notify the authorities of suspected SHB infestation are eligible to receive compensation payments to make up for economic losses associated with the control measures. Beekeepers may choose not to report the disease suspicion and privately manage the disease. When a beekeeper does not report an infestation, then detection is still possible via government surveillance activities. Detection leads to government control measures.

The five scenarios prospected in the questionnaire differ in the extent of (i) infestation level, from heavy[4] to light,[5] (ii) government action in case of detection (whole destruction, selective destruction, or management of the infestation), and (iii) information about the probability to be inspected by the veterinary authority. In each scenario, the MPL

[3] The questionnaire is available on request from the authors.

[4] The SHB Infestation is defined as heavy when it results in severe damage to the bee colony, hence in the need to replace it.

[5] The SHB Infestation is defined as light when it does not severely damage the bee colony.

Table 2 Scenarios, response options menu

Scenarios	Level of infestation	Government action after reporting	Probability to be inspected by the veterinary authority
1	Heavy	Whole apiary destroyed	Unknown
2	Light	Whole apiary destroyed	Unknown
3	Light	SHB infested hives destroyed	Unknown
4	Light	SHB management procedure	Unknown
5	Light	SHB management procedure	Known

task asks the respondent to choose whether she would prefer to accept a compensation payment and report or not to accept any offer and manage the disease privately. Table 2 provides key characteristics of the five scenarios. Consequently, we define an SHB infestation as light when it does not severely damage the bee colony while we define it as heavy when it results in severe damage to the bee colony with the need to replace it.

The SHB does not directly attack adult bees but feeds and reproduces in the combs of hives. In large and healthy colonies, the bees are often able to control small populations of SHB and limit their reproduction (Zawislak 2010; Tarver et al. 2016). Heavily infested by SHB colonies might die or leave the hive and any honey and wax harvest destroyed (Delaplane 1998).

The status quo policy is described by the first two scenarios. In scenario 1 (S1), SHB infestation is assumed to have severely damaged the bee family, which needs to be replaced. In scenario 2 (S2), it is assumed the infestation is mild and the family is not damaged. In scenarios from 2 to 5, the SHB infestation is constantly maintained at a light level.

The control measure assumed in the first three scenarios consists of the depopulation of the infested apiary. In S1 and S2, we assume the mandatory ex-post biosecurity measure consists of the destruction of all hives in the apiary. In S3, we assume the destruction only of the infested hives (selective destruction). In the last two scenarios, the mandatory ex-post biosecurity measure consists of the adoption of disease management procedures, such as sanitation of the apiary, defined by animal health authorities. In S5, we additionally assume that beekeepers know in advance they will be inspected by public veterinarians with a 10% probability.

We assume the replacement cost of a destroyed hive is 600 euros. This amount includes the cost of the hive, bee colonies, and already-produced honey. This estimate is based on anecdotical evidence gathered through personal conversations with beekeeping extension specialists operating in the areas where the SHB is present. The cost to privately manage the disease when the infestation is heavy, that is when the beekeeper suffers the cost of both the sanitation of the apiary and replacement of weak colonies, is assumed to be 300 euros. While in the case of light infestation, the disease management cost is assumed to be 15 euros, because the colony is not damaged and does not need to be replaced. We also assume that the cost incurred by beekeepers to adopt the control measures defined by the official veterinarians is 50 euros.

The level of per hive compensation payment paid by the animal health authority to beekeepers depends on the nature of the ex-post biosecurity action. In scenarios 1 to

Table 3 Payment card for scenarios 1–3

Option A: Notify the infestation			**Option B: Do not notify the infestation**	
Compensation payment	**Cost of the compulsory biosecurity measure**	**Net cost suffered by the reporting beekeeper**	**If not inspected**	**If inspected**
			Cost to manage the disease privately	**Cost of the compulsory biosecurity measure**
100	600	500	300	600
125	600	475	300	600
150	600	450	300	600
…	…	…	…	…
575	600	25	300	600
600	600	0	300	600

All cost are expressed in Euro per hive

3, that is when infested hives are destroyed, the compensation ranges from 100 to the maximum level of 600 euros. In scenarios 5 to 6, when the mandatory control action consists of the application of disease management procedures, the compensation payment ranges between 20 and 34 euros.

In each of the five choice tasks, respondents first read instructions explaining the decision scenario. Beekeepers are then presented with the outcome of two options: (1) to report, suffer the consequences of the biosecurity action, and receive a compensation payment and (2) not to report and suffer the cost to manage the disease privately (Table 3). Respondents were asked to indicate whether they were willing to report at each of the prospected compensation levels.

The questionnaire is written in Italian. Attributes and their levels, as well as the vocabulary and language used in the survey, were identified in consultation with beekeeping extension specialists.

Data analysis

We use both univariate and multivariate statistics to analyze survey data. We first use univariate statistics to characterize the survey respondents. Specific attention is devoted to describing the stated willingness to report an outbreak of SHB in their apiaries and their willingness to accept a compensation payment under the five alternative control strategies.

To better understand the influence of beekeepers' characteristics on the choice of whether to accept a compensation payment and report, we perform multivariate regression analysis.

More in detail, we first estimate the reporting choice probability using a probit model for each scenario. Subsequently, to better understand the preferences of beekeepers for the different policy scenarios and alleviate the problem of the small sample size we exploit the pseudo-panel nature of repeated choice observations (Revelt and Train 1998; Train 2009). The survey data provided multiple responses from each individual respondent. Namely we have repeated measurements (one for each scenario) of both the willingness to report and to accept for each beekeeper. Asking respondents to answer more than one choice task is an economical way of gathering more information, though the extra observations from the same respondent do not represent independent information. It means that willingness to report/accept is nested (clustered) within beekeepers. Clustered data violate the assumption of independence of observations that we typically make in regression models. Not accounting for the presence of clustered data may result in standard errors smaller than they should be, leading to incorrect inference. To avoid this problem, we make use of multilevel models with random effects that allow for random taste variation across respondents, but with constant tastes across replications for the same respondent.

Hence, we first estimate the reporting choice probability by fitting a two-level mixed effects probit model, where for a series of M independent clusters (beekeepers), and conditional on a set of fixed effects x_{ij} and a set of random effects u_j,

$$\Pr\left(y_{ij} = 1 | x_{ij}, u_j\right) = H\left(x_{ij}\beta + z_{ij}u_j\right)$$

for $j = 1, \ldots, M$ clusters, with cluster j consisting of $i = 1, \ldots, 5$ observations. The responses are the binary-valued y_{ij}. Random effects (u_j) indicate the deviation of the cluster from the regression line.

Second, we estimate the linear relationship between the elicited WTA and a set of beekeepers' characteristics. To avoid the potential problem due to intra-cluster correlation, we fit a two-level random intercept linear model

$$\mathrm{WTA}_{ij} = \beta_0 + \beta_k x_{kij} + u_j + {}_{ij}$$

where the random effect at the beekeeper level u_j serves to shift the intercept of the regression line (β_0) up or down according to each beekeeper.

Results

After checking the validity of the returned questionnaires, 32 were deemed complete and usable, resulting in a valid response rate of 12% based on total contacts. This is a good result in consideration of how difficult recruiting farmers and livestock owners can be (Weigel et al. 2021). The result is even more remarkable if we consider that people living in the southern regions of Italy are traditionally characterized by non-cooperation with authorities and low levels of social trust (Putnam 1992). Again, in these regions, there is a traditional code of conduct that places importance on silence in the face of questioning by authorities or outsiders.

In the province of Vibo Valentia, the 12 respondents cover 10.53% of registered professional beekeepers and 15.02% of registered hives. The 7 respondents from the province of Reggio Calabria cover 7% of professional operations and 1.79% of hives in this province. Finally, respondents from the free-from-SHB provinces in Calabria and Sicily cover only a very limited fraction of the beekeepers' population. Checking the representativeness of the surveyed sample is problematic because the individual data of the beekeeping registry are not available to researchers outside the Italian Health Service.

Univariate analysis

Characteristics of respondents

The average age in the sample is 52 years. 83.87% of respondents are male. As for the educational level, respondent beekeepers hold a secondary (high) school diploma (60%) or above. 25% of respondents claimed to have a specific agriculture education and one holds a university degree in veterinary. On average, respondents claimed to have 20 years of experience in beekeeping.

On average, respondents have 168 hives divided into 15 apiaries. The distribution of the number of hives is skewed to left with a median size of 60 hives. Sixteen out of 32 respondents practice nomadism. Most of the apiaries in the sample are conventionally managed (68.75%), while the remaining 31.25% are organically managed.

Nearly half (46.88%) of the participant operations declared having total revenues below 12,000 euros a year. Another 21.88% declared revenues between 12,000 and 28,000 euros. Only nearly a quarter of participants declared revenues above 38,000 euros. Beekeeping is the major source of revenues for most of the participant operations (78.13%), with 40.63% of participants exclusively specializing in beekeeping. It is worth noting that the specialization in apiculture is not synonymous with small size. The operations specialized in beekeeping are nearly uniformly distributed in the two tails of the economic size distribution with no operations in the middle size class interval (28,000–38,000 euro). Sales from honey are the most important, when not the only source of revenues from apiculture in 56.25% of operations in the sample. Sales of queens and bees (bee, packages, and nucleus colonies) rank second in the list of revenues from apiculture, followed by sales of wax, pollen, royal jelly, and propolis. Pollination services are the least important source of revenues for participants, with only 4 operations declaring they cover between 25 and 50% of their revenues from apiculture.

Most of the participants (68.75%) have other sources of revenue in addition to apiculture, which includes agricultural products, agritourism, and processing of farm products. Finally, 40.65% of participants declared that beekeeping covers more than 75% of their income, while in 31.25% of cases beekeeping is less than 25% of their income.

SHB-related questions[6]

71.88% of respondents claim to use traps to detect the presence of SHB in their apiaries. This percentage rise to nearly 100% in the infested portion of the surveyed territory. As for the costs related to SHB control, nearly 35% of respondents claim no costs for SHB control. The beekeepers who claim costs state to spend very little money, mainly for purchasing traps, with only 2 respondents claiming to spend above 10 euros per hive. Nearly 35% of respondents state that up to 5 additional hours of work beyond their normal weekly hours are needed for SHB monitoring and control, 23% of respondents claimed between 10 and 32 additional hours, and only two respondents above 50 additional hours.

[6] Response was not mandatory for this set of questions. Descriptive statistics were calculated out of the whole sample (N = 32) unless stated otherwise.

Table 4 Percentage of beekeepers accepting and non-accepting any of the proposed levels of compensation payments by scenario ($n = 32$)

	S1	S2	S3	S4	S5
Not accepting any bid values	40.63	50.00	40.63	15.63	12.50
Accepting a bid value	59.38	50.00	59.38	84.38	87.50

As for the SHB impact on the participant operations, no respondents claim SHB to be the cause of winter mortality. Only one affirms that SHB was the cause of death of her bees, while the other two that it caused a reduction in their honey production.

Another group of questions explores the beekeepers' beliefs and attitudes toward the control policy carried out by the MoH. We first asked what level of probability they attach to the event of an operation being inspected by the public veterinarians in the past producing season. 31.25% of the 16 respondents attribute zero probability to such an event, and another 35.25% of beekeepers think there is a very low probability (up to 50%) while only one attributes 100% probability to the event. The same question was then asked but referred to inspections in the future production season. The response rate is very low (64% no response), 20% of respondents attribute zero probability to the event of being inspected by public veterinarians in future producing seasons.

We then investigate the beekeepers' level of trust, compliance, and reciprocity. We first asked respondents to give their opinion about the efficacy of the eradication policy carried out by the MoH so far. Most of the participants have a very negative opinion. 72% of the 25 respondents claim that the control measures in use are not effective. The remaining beekeepers claim that these control measures have just little (10–50%) effects. As for compliance with reporting obligations, we asked to assess the percentage of notifications of suspect findings of SHB. 52% of the 25 respondents claim that SHB larvae findings are notified, while the percentage increases to 60% in case adult beetles are found. To investigate reciprocity, we asked respondents how much they desire that their neighbor be notified of the finding of SHB in her apiary, at a different level of infestation. At low levels of infestation (up to 10 adults), notification is surely or at some extent desirable for nearly 60% of the 25 respondents. This percentage increases to, respectively, 73.08% and 76.92% when the infestation increases.

We also asked about the attitude toward the use of chemicals (insecticides) in case they became available in Italy. 40% of the 25 respondents claim that they will surely adopt it, while 36% (mostly beekeepers using organic management) are not keen to adopt it.

Finally, 21.88 of the respondents are very (100%) worried about the enlargement of the protection zone, while another 20% expressed a level of threat above the indifference level (50%). Another 21.88% of beekeepers consider enlargement as not a threat.

Acceptance and willingness to accept

Between 40 and 50% of beekeepers state not to accept any of the proposed levels of compensation payments when reporting is followed by the total (S1 and S2) or selective (S3) destruction of the infested hives in their apiary (Table 4). The percentage of beekeepers that state not to accept any of the proposed levels of compensation payments lowers to 15.63 and 12.50 when reporting is not followed by the destruction of the infested hives,

Table 5 WTA by scenarios (mean and median)

	S1	S2	S3	S4	S5
Accepting beekeepers	19	16	19	27	28
Mean WTA	455.00	448.13	397.37	30.17	30.36
Median WTA	585.00	550.00	400.00	33.50	33.50

Table 6 Beekeepers accepting to report by WTA and scenarios (1–3)

	No. of beekeepers			Percentages		
WTA	S1	S2	S3	S1	S2	S3
100	4	3	4	21.05	18.75	21.05
200	1	1	1	5.26	6.25	5.26
350	0	0	3	0.00	0.00	15.79
400	0	1	3	0.00	6.25	15.79
500	3	2	1	15.79	12.50	5.26
550	0	2	0	0.00	12.50	0.00
575	1	0	0	5.26	0.00	0.00
585	2	2	0	10.53	12.50	0.00
600	8	5	7	42.11	31.25	36.84
Total	19	16	19	100.00	100.00	100.00

but rather by the obligation to follow the disease management recommendations provided by the governmental veterinary services (S4 and S5).

Only one out of the total 32 respondents choose not to report in all five choice tasks. She is not willing to make trade-offs between reporting and privately managing the disease. This respondent probably protests against some aspect of the constructed market scenario (Meyerhoff and Liebe 2006). Additionally, 2 beekeepers accept only in the first scenario, while 9 respondents do not accept the first 3 scenarios. Moreover, 5 respondents do not accept in 2 scenarios, 3 of them do not accept the first 2 scenarios, 1 the second and third scenario, and another 1 the last two scenarios. Unfortunately, we did not pose questions to check the reason for not accepting any of the compensation offers. Nevertheless, during the interviews, most of the beekeepers who chose not to accept in scenarios 1 and 2 commented on their choice by their negative attitude toward eradication with the destruction of infested bees. Many of them also added that the destruction is a nuisance and not effective in terms of eradication.

Table 4 shows that the scenarios which record the largest number of beekeepers accepting to report are S4 and S5, i.e., the scenarios in which reporting is not followed by the destruction of the infested hives. Namely, 27 beekeepers out of 32 (84.38%) accepted to report in scenario 4 and 28 beekeepers in scenario 5. In other words, only in one case does the choice switch from not to reporting when the probability to be controlled is known.

The median level of accepted compensation (Table 5) steadily decreases passing from S1, to S2 and S3, while it is stable at 33.50 euros passing from S4 to S5. A Kruskal Wallis test is run to test for the equality of the median WTA distribution across the scenarios.[7]

[7] The Kruskal–Wallis test is used when you have one independent variable with two or more levels and an ordinal dependent variable. It is the non-parametric version of ANOVA and a generalized form of the Mann–Whitney test method since it permits 2 or more groups.

Table 7 Beekeepers accepting to report by WTA and scenario (4–5)

	No. of beekeepers		Percentage	
WTA	**S4**	**S5**	**S4**	**S5**
20	4	4	14.81	14.29
25	3	2	11.11	7.14
30	4	6	14.81	21.43
31	1	1	3.70	3.57
33	1	1	3.70	3.57
33.5	1		3.70	0.00
34	13	14	48.15	50.00
Total	27	28	100.00	100.00

Table 8 Definitions, means, and standard deviation for the explanatory variables

Variable	Definition	Mean	SD
LNHIVES	Size of the operation in terms of hives (logs)	4.282	1.190
TRAP	Denotes whether the operation makes use of traps for SHB control	0.710	0.461
APIC_REVENUE	Percentage of revenues from the apicultural activity over the total revenue	4.581	1.669
HONEY	Percentage of revenues from honey over the total apicultural revenue	4.065	1.315
QUEEN	Indicates whether the operator rears queens for sale	0.581	0.502
FARM REVENUES	Farm revenues from apiculture and other activities	2.258	1.483
DIPLOMA	Indicates whether the operator holds a diploma or less	0.613	0.495
EXPERIENCE	Indicated the years of experience of the operator in beekeeping	20.000	13.005
AG_VET_ED	Indicates whether the operator has a specific education in agricultural or veterinary	0.290	0.461
APIC_INCO ~ 75	Revenues from apiculture more than 75% of household income	2.645	1.330
Reggio Calabria	Indicates whether the operation is located in the province of Reggio Calabria	0.226	0.425
Vibo Valentia	Indicates whether the operation is located in the province of Vibo Valentia	0.355	0.486

Given the compensation ranges in the three first scenario is very different from the range proposed in the last two scenarios, we run two separate tests. The results of the first test (Pearson χ^2 (2) 0.72, $P=0.68$) show that the medians of the first three scenarios are equal. The second test (Pearson χ^2 (1) 0.10, $P=0.91$) shows that even the medians of the last two scenarios are equal.

In S1 and S2, when reporting is followed by the destruction of the entire apiary, most beekeepers accept to report the SHB infestation only at high levels of compensation (Table 6). In S3, when reporting is followed by selective destruction of the infested hive, there is again a large group of beekeepers (36.84%) that is willing to report only when the compensation payment fully covers the cost connected to the destruction of the hive, but most of the beekeepers (63.13%) is willing to accept an indemnity lower than 500 euro. In scenarios 4 and 5, the acceptance rate (85%) is much higher than in previous scenarios 1–3 (Table 7). Half of the beekeepers accept to report only when compensation fully covers the costs, while 40% of respondents are willing to accept very low levels of compensation payments.

Table 9 Separate Probit models–dependent Norefund (0 accepts, 1 does not accept)

	S1			S2			S3		
	Coefficient	***P*>*z***	**dy/dx**	**Coefficient**	***P*>*z***	**dy/dx**	**Coefficient**	***P*>*z***	**dy/dx**
LNHIVES	0.211	0.52	0.078	−0.729	0.082	−0.29	0.065	0.854	0.023
ORGANIC	2.039	0.048	0.692	0.736	0.413	0.287	−0.805	0.342	−0.254
TRAP	−0.722	0.563	−0.275	1.695	0.129	0.56	1.645	0.136	0.437
APIC_REVENUE	0.12	0.747	0.045	−0.186	0.574	−0.074	0.32	0.397	0.112
HONEY	0.074	0.797	0.028	0.09	0.733	0.036	−0.302	0.399	−0.105
QUEEN	−1.042	0.168	−0.382	−0.375	0.614	−0.148	−0.802	0.238	−0.282
FARM REVENUES	0.538	0.21	0.2	0.107	0.724	0.042	−0.754	0.055	−0.263
DIPLOMA	0.475	0.64	0.171	−0.581	0.594	−0.229	−0.16	0.867	−0.056
EXPERIENCE	−0.035	0.434	−0.013	−0.009	0.839	−0.003	−0.007	0.864	−0.002
AG_VET_ED	−1.236	0.264	−0.388	−2.136	0.071	−0.65	−0.952	0.305	−0.288
APIC_INCOME_OV75	−0.526	0.296	−0.195	0.228	0.588	0.09	0.178	0.662	0.062
Reggio Calabria	1.626	0.227	0.583	−2.095	0.072	−0.609	−0.714	0.54	−0.218
Vibo Valentia	2.153	0.137	0.717	−2.081	0.039	−0.668	0.312	0.747	0.111
_cons	−1.867	0.29		3.824	0.051		0.319	0.842	

dy/dx refers to the marginal effect of an independent variable, that is the derivative (slope) of the prediction function. They indicate the probability of success (does not accept in our case) following probit

Multivariate regression analysis

In this section, we present the results of the multivariate regression models employed to investigate the determinant of the reporting decision under and identify the determinants of the willingness to accept a compensation for disease reporting.

Given protest responses may lead to inconsistent welfare estimation (Meyerhoff and Liebe 2010; Villanueva et al. 2017), we exclude the observation found to be affected by the problem of serial non-participation.

The definitions, means and standard deviation for the explanatory variables used in the multivariate models are presented in Table 8.

Willingness to report model

The willingness to report is a dichotomous variable (NO REFUND) that takes value 0 when the beekeeper accepts to report, and 1 when she does not report. We analyze the probability that a beekeeper with specific characteristics does not report by estimating probit models.

We first analyze the decision by using separate Probit models, one for each survey scenario. We find that no model can be estimated for the last two scenarios because several variables perfectly predict failure, that is acceptance of the compensation. In scenario 4, such variables are organic management, education in agriculture, and operating in the province of Reggio Calabria. The latter two variables also predict failure perfectly in scenario 5. In Table 9 we report the estimated coefficients and marginal effects of the probit models for the first three scenarios.

In scenario 1, organic management is the only variable having a statistically significant positive influence on the probability of not reporting. This is probably due to the fact that organic beekeepers are strongly against killing animals to control disease and are the least convinced of the effectiveness of stamping out. In scenario 2, having an education

Table 10 Average predicted probability of not reporting by scenarios

Scenario	Average predicted probability
1	0.372
2	0.480
3	0.380
4	0.124
5	0.090

Table 11 Multilevel Mixed probit with crossed individual random effects—dependent Norefund (0 accepts, 1 does not accept)

	Coefficient	Std. err	*P* > *z*
s2	0.459	0.414	0.267
s3	0.036	0.406	0.930
s4	− 1.231	0.451	0.006
s5	− 1.485	0.483	0.002
LNHIVES	0.468	0.237	0.049
ORGANIC	0.709	0.541	0.190
TRAP	− 0.715	0.639	0.264
APIC_REVENUE	0.054	0.195	0.782
HONEY	− 0.209	0.200	0.295
QUEEN	− 1.999	0.561	0.000
FARM REVENUES	0.366	0.267	0.170
DIPLOMA	− 0.018	0.541	0.973
EXPERIENCE	0.005	0.029	0.862
AG_VET_ED	− 1.555	0.690	0.024
APIC_INCOME_OV75	− 0.545	0.245	0.026
Reggio Calabria	1.898	0.835	0.023
Vibo Valentia	1.773	0.662	0.007
_cons	− 0.685	1.135	0.546
var(_cons) .3957119	0.3401681	0.3401681	

in agriculture and operating in the provinces of Reggio Calabria or Vibo Valentia, i.e., in the infested areas, have a large statistically significant, negative impact on the probability of not accepting. Additionally, the larger the size of the operation, the higher the probability to report. Finally, in scenario 3 the larger the farm revenues, the lower the probability of failure to report. These results suggest the existence of behavioral differences among beekeepers. Given the small size of the samples under study may limit the generalizability of our findings, we do not offer an interpretation of these first results. To alleviate the sample size problem, we exploit the pseudo panel nature of our data and estimate a mixed probit model with crossed individual effects. The likelihood-ratio test (chibar2(01) = 3.16; Prob > = 0.038) of the model shows that there is enough variability between beekeepers to favor a mixed-effects probit regression over an ordinary probit regression. Beekeepers are found to differ in their response patterns over policy alternatives. After controlling for all the covariates, the average predicted probability of not reporting, based on the contribution of both fixed and random effects, by scenarios is reported in Table 10. The random effect measured at the beekeeper level ranges between − 0.53 and 0.78. The estimated probability of reporting (Table 11) significantly increases when a disease management policy (S4 and S5) is considered with respect to the base category S1 (high infestation and whole destruction). No statistically significant difference is found between the effects of the first three scenarios.

The positive coefficient of the operation size suggests that the larger the size the lower the probability to report. Larger, capital-intensive farms have greater fixed costs which cannot avoid paying in case of business interruption. This may cause a lower propensity to report.

On the contrary, the production of queen bees, the high incidence of apicultural revenues over income, and specific education in agriculture and veterinary are found to significantly increase the probability to accept the compensation and report. The education in agriculture and veterinary probably helps beekeepers to properly formulate expectations about the benefits of reporting. Similar considerations may apply in the case of specialization in beekeeping and queen rearing.[8] These findings provide empirical support to the existence of behavioral differences in reporting decisions (e.g., across farm types and sizes) argued in literature (Wang and Hennessy 2014; Barnes et al. 2015; Fraser 2018; Osseni et al. 2022). Finally, it is worth noting that after adjusting for the random-effects structure, organic management and farm revenues are no longer found to be statistically significant.

Willingness to accept models

To explore what factors influence the willingness to accept a compensation payment, we make use of multilevel random intercept linear mixed-effects models.

In consideration of the difference in compensation ranges offered in the first three scenarios compared to the last two, we fitted two separate models. One model for scenarios 1–3 ($n = 54$) and another for scenarios 4 and 5 ($n = 47$).

The likelihood-ratio test comparing the mixed model for scenarios 1–3 with one-level ordinary linear regression is significant (chibar2(01) = 7.49, Prob > = 0.003), hence the mixed model is favored. The estimated coefficients are reported in Table 11. The use of traps, all things being equal, is found to be the only characteristic that significantly increases the willingness to accept the compensation offers in scenarios 1–3. The cause of such increases cannot be found in the need to cover the cost incurred for the ex-ante control actions because, as shown by the survey, they are very small. The higher WTA may rather be caused by a difference in perception of the likelihood and consequences of an SHB infestation. This is because the decision of whether to adopt preventive biosecurity actions is usually driven by the perceived likelihood and consequences of the infestation. The higher the perceived likelihood and consequences of an SHB incursion, the higher the probability the beekeeper takes the decision to use traps. The observed increase in the WTA of beekeepers using traps may then be explained by the negative beliefs about the potential economic impact of an SHB incursion in the adopter's group. On the other hand, the negative coefficient of farmers located in the two provinces at

[8] Queen production requires high level of skill and beekeeping experience.

Table 12 Two-level random intercept linear mixed-effects model for WTA (S.s 1–3)

	Coefficient	*P* > *z*
s2	− 8.022	0.797
s3	− 64.744	0.038
LNHIVES	10.724	0.780
ORGANIC	− 26.817	0.775
TRAP	498.206	0.000
APIC_REVENUE	− 78.368	0.058
HONEY	56.310	0.158
FATT6	171.002	0.172
QUEEN	− 12.663	0.831
FARM REVENUES	− 28.293	0.586
DIPLOMA	− 269.956	0.001
EXPERIENCE	1.777	0.573
AG_VET_ED	26.599	0.749
APIC_INCOME_OV75	58.941	*0.117*
T_REVENUESMORE2	− 47.109	0.715
Reggio Calabria	− 179.073	0.130
Vibo Valentia	− 296.554	0.012
_cons	328.789	0.124

risk (Vibo Valentia and Reggio Calabria) may be related to a better knowledge of the potential real economic impact of SHB in the Calabrian context. The experience gained by operating in areas where the SHB is known to be present is that the impact is often lower than what was anticipated based on prior experience in different geographical contexts (Salvioni and Champetier 2022). Our findings also suggest that education plays a role in the definition of the minimum amount needed to report. More in detail, we find that a low level of education commands significantly lower compensation amounts. Finally, we find that the larger the apiary, the larger the WTA. To explain this effect, we can first consider that when production ceases due to the stamping out ordered by the veterinary authorities on premises with an SHB outbreak, fixed costs—including interest on investment, depreciation, etc-cannot be avoided. Consequently, capital-intensive, large operations may require larger compensation amounts to cover their fixed costs.

As for the relative effect of the three scenarios, we find that scenario 3—characterized by mild level of infestation and selective destruction-lowers the WTA by 65 euros with respect to scenario S1—severe infestation and whole destruction-used as a base category, while S2 is not found to have a significant effect. Finally, the coefficient of the constant term informs us of the overall (across beekeepers) average WTA which is found to be 328.79 euros. The shift of the intercept at the beekeeper level ranges between − 96.40 and 121.16 so the average intercept at the beekeeper level is found to be 331.42.

The results of the mixed model fitted for the last two scenarios are reported in Table 12. The likelihood-ratio test (chibar2(01) = 10.31; Prob. = 0.001) favors the use of the mixed model to the one-level ordinary linear regression. Even in this model, the variable with the largest positive influence on the minimum amount required to report is the use of traps, followed by organic beekeeping management. The larger claims of

Table 13 Two-level random intercept linear mixed-effects model for WTA (S.s 3–4)

	Coefficient	*P* > *z*
s5	0.2401406	0.487
LNHIVES	0.636155	0.236
ORGANIC	2.300087	0.027
TRAP	3.062589	0.091
APIC_REVENUE	0.7845463	0.169
HONEY	0.0256156	0.961
FATT6	− 0.1265494	0.939
QUEEN	− 1.452676	0.082
FARM REVENUES	0.8246926	0.366
DIPLOMA	2.711161	0.039
EXPERIENCE	− 0.0632883	0.267
AG_VET_ED	− 2.365717	0.028
APIC_INCOME_OV75	− 0.5382768	0.250
T_REVENUESMORE2	− 2.556106	0.385
Reggio Calabria	− 2.088446	0.247
Vibo Valentia	1.060693	0.364
_cons	24.29734	0

organic beekeepers are probably the result of larger net income streams, hence operation values,[9] of organic versus conventional apiculture. Unfortunately, the economic literature on organic beekeeping is still very scant, making the verification of this hypothesis problematic. Differently from the previous model, here the coefficient of low education is positive. Hence, holding a diploma or below increases the compensation amount required to report. On the contrary, specific education in agriculture or veterinary reduces the compensation to accept reporting. Finally, operators specialized in queen rearing have smaller claims all other things being equal. These latter findings suggest that education and experience are likely to play a role in the quantification of the economic losses consequent upon the reporting decision. Similarly to the willingness to report model, we find that heterogeneity in willingness to accept (Table 13).

The overall average WTA is 24.30 euros with a shift at the beekeeper level that ranges between −2.75 and 2.66 euros. Finally, as for the relative effect of the two scenarios, it is worth noting that knowing the probability to be inspected does not impact the WTA.

Conclusions

Notwithstanding limitations due to the small sample size, our findings are a first attempt to fill the knowledge gap on the impact of the SHB in the Mediterranean environment. More in detail, the survey has produced the first empirical evidence of the economic effects of the SHB on beekeeping in Southern Italy as well as unique information on beekeepers' preferences for the SHB control policy.

First, the survey reveals that in the SHB-infested areas, there is the widespread use of traps, i.e., the only ex-ante biosecurity measure allowed in the EU so far. The survey data also reveal that most beekeepers perceive SHB as a threat but also that they are not keen to adopt any possible biosecurity means made available by the research sector.

[9] The operation value is given by the discounted sum of the expected value of all future income the beekeeping activity can generate.

Second, the SHB increases the production cost mainly due to the additional hours of work needed for SHB monitoring and control. Apart from this, no respondents claim SHB to be the cause of winter mortality. Only one affirms that the SHB was the cause of the death of her bees, while the other two stated that it caused a reduction in their honey production. In other words, differently from what happened in other countries, the SHB does not appear to be posing a threat to the survival of the beekeeping sector in Calabria and Sicily.

Third, another group of questions explores the beekeepers' level of trust and reciprocity. Most of the participants have a very negative opinion about the efficacy of the control measures used so far. As for reciprocity, most beekeepers perceive reporting as desirable. At the same time, the survey reveals that there is a high percentage of beekeepers who are not willing to contribute to the surveillance if the control measure adopted after their notification is based on the destruction, either total or selective, of their bees.

Fourth, nearly half of beekeepers stated not to accept any of the compensation offers when reporting is followed by total (S1 and S2) or selective (S3) destruction of the infested hives. The probability of reporting rate increases when reporting is not followed by the destruction of the infested hives, but rather by the obligation to follow the disease management recommendations provided by the governmental veterinary services (S4 and S5). The estimated probabilities to report confirm that in terms of beekeepers' preferences, management approaches rank highly, whereas destruction and particularly destruction of the whole apiary ranks lowly. The very high values of probability recorded in the last two scenarios suggest beekeepers strongly prefer control policy measures based on disease management compared to depopulation policies. Moreover, disease management is found to reflect the highest compliance with reporting obligations. As for the first three scenarios, when reporting is followed by the destruction of the infested hives, it is interesting to note that the lowest compliance rate is recorded in S2, which is when the infestation is light, and the whole apiary is destroyed. This scenario is the closest to the status quo both in terms of control policy and degree of infestation. Given selective destruction is expected to improve compliance with reporting requirements, efforts should be made to eliminate the barriers to the implementation of such a depopulation approach.

Fifth, our results show that either the willingness to report or the willingness to accept vary across different socioeconomic groups of beekeepers. Such a finding provides empirical support to the existence of behavioral differences in the reporting decisions argued in the literature. A major policy implication of this result is that the indemnity design should account for the heterogeneity in behavioral response across livestock owners. A second policy implication results from the finding that specific education in agriculture or veterinary reduces the probability of failure to report. This result suggests that training and extension can be a winning strategy to improve beekeepers' collaboration with the passive SHB surveillance system. All in all, further research is needed to explore what factors drive the different responses of beekeepers and inform the policy design.

Though more research using a larger sample is needed to confirm our findings, the evidence provided by the survey helps draw a new, more detailed picture of the SHB invasion in Italy. The most important evidence is that the SHB is producing lower damages and economic losses in Southern Italy than what was anticipated based on prior experience in different geographical contexts. This is probably partly due to the Southern Italian climatic and environmental conditions, but also partly to the widespread use of traps and good beekeeping practices among beekeepers operating in the Italian SHB-affected zones. The evidence gained in the fortunately small, Italian areas where the SHB is present is relevant for all beekeepers operating in Europe, primarily for those operating in areas that are contiguous to the areas where the SHB is present.

Nevertheless, new research is needed to better understand the epidemiological model of the beetle and other traits that may help find effective biosecurity measures and tailor the SHB control strategy to specific environmental conditions. New, knowledge on the behavior and impact of SHB will also help enhance the beekeepers' ability to properly formulate expectations about the benefits of reporting, in this way contributing to improving their collaboration with the SHB surveillance system. Finally, it will help to assess the risk associated with the SHB incursion and, in turn, the design and development of risk management tools to protect beekeepers from losses due to SHB.

Abbreviations

CE	Certainty equivalent
EU	European Union
MoH	Italian Ministry of Health
MPL	Multiple price list
SHB	Small hive beetle
S1	Scenario 1
S2	Scenario 2
S3	Scenario 3
S4	Scenario 4
S5	Scenario 5
WTA	Willingness to accept

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Author contributions
CS and SC contributed to study conception and design. CS contributed to data collection, analysis and interpretation of results, and draft manuscript preparation. All authors reviewed the results and approved the final version of the manuscript.

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Availability of data and materials
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Declarations

Competing interests
The authors declare no conflict of interest.

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