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Electronic Supplementary Material

This supplementary material has not been peer reviewed.

Title: Beekeeper stewardship, colony loss, and *Varroa destructor* management

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ELECTRONIC SUPPLEMENTARY MATERIAL

REFLEXIVITY STATEMENT

Reflexivity refers to consideration of the ways that the research process and prior experiences and perspectives of researchers may shape the way data are collected, analyzed, and reported. There is a diversity of opinion regarding Varroa and Varroa management on this team. The first three authors are new to beekeeping and beekeepers as a topic of inquiry, and approached the research from a position of environmental sociology with an interest in how norms and values can shape perceptions and behaviors. The remaining authors all have years of experience with beekeeping and honeybee research. They are part of the Bee Informed Partnership which has done extensive longitudinal research on honeybee losses and management. Their perspective, based on their research findings, is that Varroa are one of the most significant problems facing beekeeping in the USA. Although these authors range in the determination of the most effective way to address Varroa based on their own studies and regional emphasis, treating colonies with miticides is a management component for most of them. The first three authors come from more diverse social and environmental systems backgrounds and lean toward limited use of pesticides in general. We believe the perspective on Varroa as a major problem is echoed in the literature.

SUPPLEMENTAL EXPLANATION OF CODING OPEN ENDED SURVEY RESPONSES

All the open ended question responses from the survey were imported into an NVivo project (version 11.4.1). NVivo is a software package used to code and analyze qualitative data by creating a set of 'nodes'. A node is a collection of textual references across surveys coded to a specific theme. The lead authors read through a sample of survey responses then discussed ways to code responses. Coding involves looking for recurring themes. For example, "protecting the bees", "give bees a chance", and "helps the bees with one less stress factor" can be thematically grouped into a single category. We

grouped those and thematically similar responses as a belief that “Helps Bees” is an advantage of managing for Varroa mites. We developed preliminary nodes to test and refine using a small sample of survey responses and developed additional nodes. Based on discussions about the pilot coding and content of survey responses, the lead authors then developed and refined a working node structure that the team added to the NVivo project and used for all coding moving forward.

Table S1: Stewardship Concept Codes and Frequencies

Stewardship Concept	Frequency
Keep Bees Healthy and Strong	762
Inspect Hive Regularly	325
Keep Bees Alive	284
FeedWhenNormalSuppliesAreUnavailable	216
Minimize Human-Bee Interaction	216
Educate Others	208
EducatedAboutIssues	192
Help Bees	183
Manage Disease	127
HoneyProduction	118
ManagePestsGeneric	109
Protect Bees	107
Manage Hive Generally	106
Healthy Environment	98
Avoid Chemicals	95
LeaveHoneyForHive	93
DoMyBest	92
Overwinter	87
Forage Provided	81
ManageSplitsAndSwarms	81
MngMitesGeneric	80
As Natural As Possible	76
UseChemicalsOnlyWhenNecessary	76
Pollination	71
GoodNeighborToOtherBeekeepers	65
MngVarroaSpecific	60
Maintain Clean Equipment	59
Work With Other Beekeepers	59
QueenIssues	58
Attitudes and Identity	53
Good Neighbor	52
Water Provided	49
Grow Colony Numbers	41
TreatVarroaSpecific	40
Location of Hive or Space	36
TreatMitesGeneric	34
EnjoyBees	33
Improve Genetic Diversity	33
TreatGenerally	33
Minimize Losses	31

Table S2: Beekeeper Questions

Question No.	Question
36	Last year, did you use a treatment to try to control Varroa mites in your colonies?
123	What were your management goals for beekeeping last year?
134	What were the top three barriers that hindered your management of your honey bee colonies?
135	What do you believe are the advantages of managing for Varroa mites?
136	What do you believe are the disadvantages of managing for Varroa mites?
137	In general, what are the expectations of people whose opinion you value regarding management of Varroa mites?
140	For you, what does it mean to be a good steward of your colonies and beekeeping in general?

VARROA MANAGEMENT BELIEF SCALE

Supplemental explanation of Table 3. Frequencies show balance of advantages listed by respondents minus disadvantages along with the “none” responses. We grouped all negative numbers (as shown in Fig. 1) into the category of more disadvantages than advantages and all positive numbers into the category of more advantages than disadvantages. There is a significant but weak correlation (Pearson correlation = .286, $p < .001$), between the number of advantages and number of disadvantages listed. It is possible that many respondents simply articulated more complex answers rather than actually believing there are more advantages or more disadvantages. However, a significant group difference when comparing those who did and did not treat for Varroa along the Varroa Management Belief Scale ($Z = -7.024$, $p < .001$, $\text{sig} \leq .05$, 2-tailed) suggests the scale does have meaning. It is important to note that the scale does not account for how respondents may personally weight various disadvantages or advantages. It is possible, for example, that a respondent might list two or even three disadvantages but believe that the one advantage she listed far outweighs those disadvantages. A balance (listing equal numbers of advantages and disadvantages) does not necessarily equate to ambivalence about treating for Varroa.

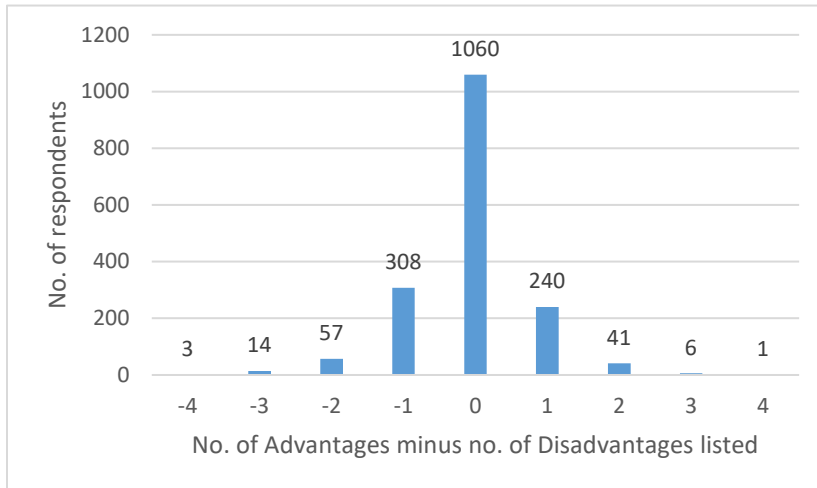


Fig. S1 To get a sense for the relative balance of perceived advantages and disadvantages we subtracted the number of disadvantages from the number of advantages listed by each respondent who listed at least one in each category, excluding the “none” responses (n = 1730). A negative value indicates that a respondent listed more disadvantages than advantages. A zero, as is the case for 30% of respondents, could mean the respondent listed one advantage and one disadvantage or some other equal number of advantages and disadvantages.

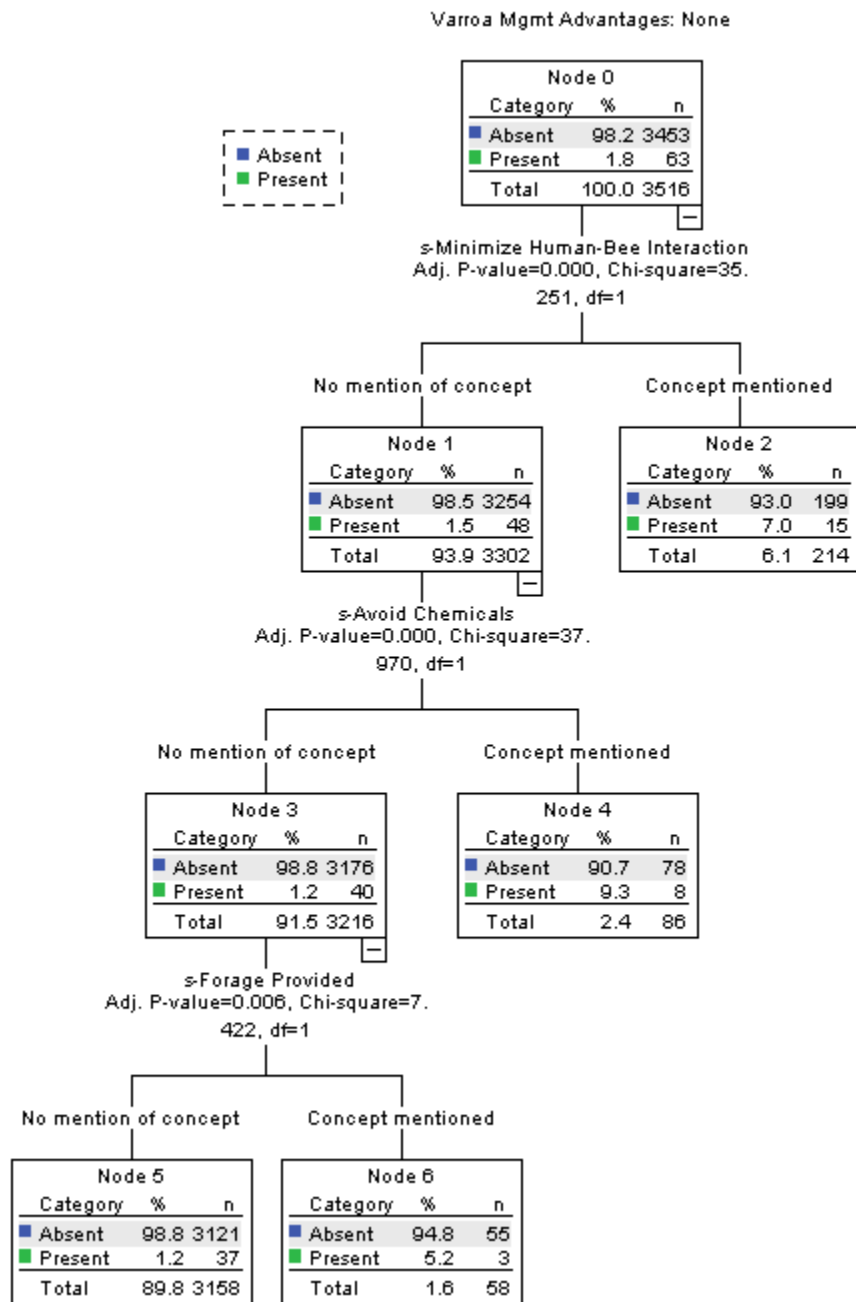


Fig. S2 CART analyses decision tree from SPSS v 24 showing what stewardship concepts predict the belief that there are no advantages to managing for Varroa mites.

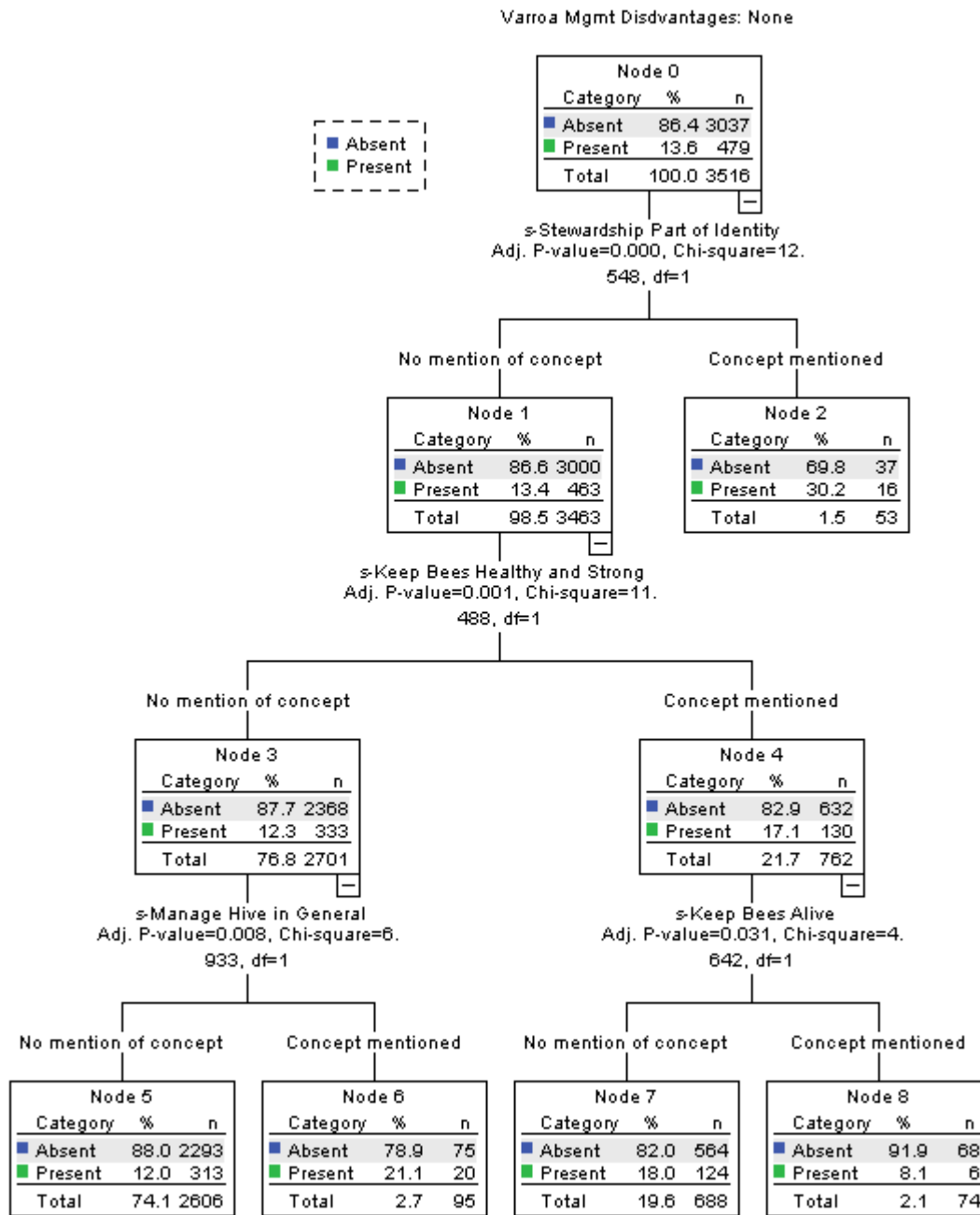


Fig. S3 CART analysis decision tree from SPSS v 24 showing what concepts of stewardship predict the belief that there are no disadvantages to managing for Varroa mites.

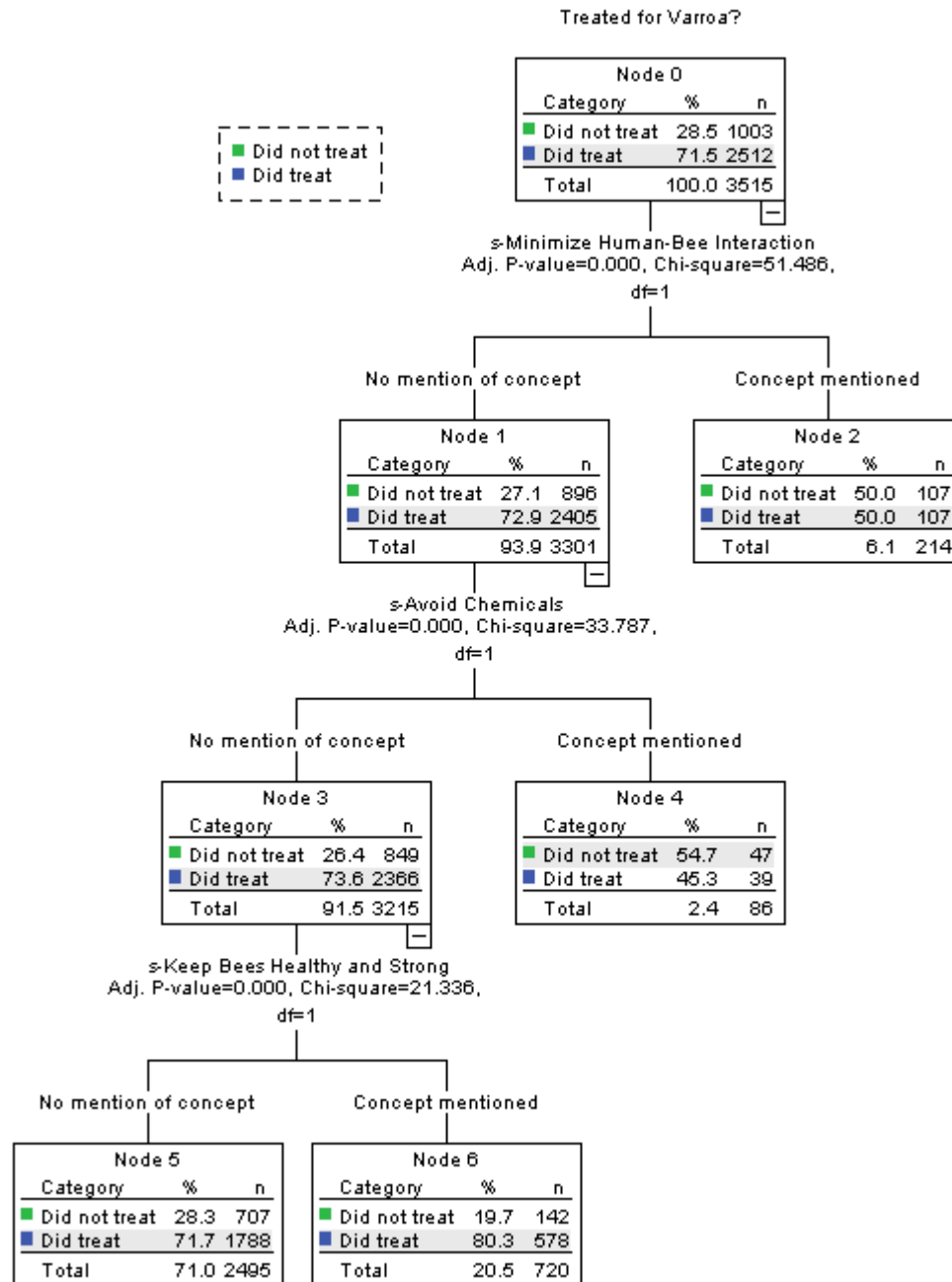


Fig. S4 CART analysis decision tree from SPSS v 24 showing relationship between beekeeper stewardship concepts and self-reported treatment (yes or no) for Varroa mites.

LIMITATIONS AND FUTURE RESEARCH

As early, basic research on beekeepers there are several limitations to this study. We do not know and have no way of knowing whether ours is a representative sample. Given recruitment through BIP, an entity that actively promotes treatment for *Varroa*, our sample may have a pro-treatment bias. Further, because the focus of the National Colony Loss and Management survey to date has been loss rates and management practices rather than beekeepers, we have no demographic data on our beekeeper respondents. We do know, however, that the make-up of our respondents is largely hobby or backyard beekeepers with a few sideliners and few commercial beekeepers. Finally, the management beliefs and stewardship concepts tested in this analysis are terms broadly defined by diverse individuals. More work is need to figure out more precisely what beekeepers mean by stewardship, *Varroa* management, and even treatment.

These limitations and the implications of our discussion above suggest several areas for further investigation. At a basic level, further research is needed to understand who beekeepers are, additional beekeeper types, and what motivates them. In terms of supporting *Varroa* management outreach, additional research is needed to examine the possible effects of norms and expectations held by respected social referents on beekeeper beliefs and practices. In addition, the range of who and what sources of information beekeepers trust in discussions of honeybee management needs to be better understood. To better tailor outreach to different types of beekeepers there is also need for continued research to more fully understand the range of advantages and disadvantages of treating for *Varroa*. Fuller, more complex descriptions of those advantages and disadvantages from trusted sources may be key to improving beekeepers' management of *Varroa* and adoption of best management practices.