

# The Essence of Sustainable Beekeeping

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Worcestershire, organised by the Natural Beekeeping Alliance<sup>2</sup>.*

Firstly, I would like to say a warm thanks to the organisers for putting on this conference, the first on Natural Beekeeping in Britain.

What is more precious than gold? I heard a quiet answer somewhere to the left – it is conversation! And why do we come to conferences other than to meet people and converse? There are many people here with whom I've been in regular contact but have never met, including Heidi Herrmann and Phil Chandler, so I really value this event for making these meetings possible. I would also like to take this opportunity of saying a special thanks to Phil Chandler for helping to put natural beekeeping with the People's Hive of Abbé Émile Warré on the beekeeping map by offering space on his website for the Warré project.<sup>3</sup>

I started experimenting with more natural methods with my National hives in 2005. I looked around for sources of advice in natural beekeeping. I had read Rudolf Steiner's bee lectures<sup>4</sup> long before and returned to them. Bees for Development, headed by Nicola Bradbear had already pioneered sustainable beekeeping and was a good source of guidance. And I came upon Phil's horizontal (Kenyan) top-bar hive pages around that time.

In 2006 when I was considering making a top-bar hive, Johannes Wirz at the Goetheanum in Switzerland drew my attention to the Warré hive. I made some in 2006 and populated them in 2007. I was so enthused by the principles underlying the hive that it seemed worth translating Warré's book *L'apiculture pour tous* into English. Pat and I did that in 2007 and published it free on the Internet.<sup>5</sup> Soon it generated much e-correspondence and phone calls as well as attracting a few visitors from overseas. So with Phil's web space I set up a site for sharing information about the construction and use of the hive. In what seemed a matter of months, it was being tried out in many countries, especially the USA. An international e-group to discuss the use of the hive soon followed.<sup>6</sup>

Phil also helped me in getting involving in natural beekeeping in another way. He asked me to read and comment on some of the draft of his book, *The Barefoot Beekeeper* which was the first wholly devoted to natural beekeeping. Several natural beekeeping books have come out since, including my own *The Bee-friendly Beekeeper*.<sup>7</sup> I had written articles on beekeeping with the Warré hive for several magazines, including *Star and Furrow*,<sup>8</sup> when three different publishers independently suggested that I write a book. Eventually I took the hint and of those to whom I sent the manuscript, it turned out to be Jerry Burbidge of Northern Bee Books who rushed it into print.

I would also like to thank, perhaps a little more tentatively, the Natural Beekeeping Alliance for inviting me to deliver this keynote address. I say 'tentatively', because it is such a big challenge especially with so many experienced beekeepers present. When Heidi originally asked me some months ago to do this talk, the suggested topic was natural beekeeping, but it eventually became sustainable beekeeping, clearly a subject with a much broader scope. So this presentation will be in pretty bold brush strokes. There are thirteen other speakers in the programme and they will be filling in the fine detail.

In thinking about what I could possibly say, I became uncomfortably aware that the term 'natural beekeeping' is an oxymoron, i.e. is self-contradictory. As soon as you put bees in a box you have taken a step on the road to unnaturalness. After that you could go further and further down the road of increasing unnaturalness, depending on your world outlook or desires. Some time ago I drafted what I called the Universal Scale of Increasing Artificiality in beekeeping. As over half of you put your hands up when I asked in the introduction session last night how many considered themselves beginners at beekeeping, I will read all of it out. Maybe some of the manipulations will be a surprise to you.

1. Putting bees in a container (e.g. skep, hollow log)
2. Providing top-bars with comb guides (e.g. Kenyan, Warré & Perone hives)
3. Providing frames
4. Providing frames with foundation
5. Providing plastic foundation
6. Providing a mesh floor
7. Nadiring / Supering
8. Opening the hive
9. Transporting the hive
10. Feeding (e.g. a. planting forage; b. honey.)
11. Removing honey
12. Controlling swarming
13. Drone suppression
14. Practising brood nest spreading
15. Providing a queen excluder
16. Clipping the queen's wing
17. Feeding sugar in emergencies.
18. Artificial queen breeding
19. Regular transportation of hives as in migratory beekeeping (i.e. transhumance)
20. Removing too much honey and feeding back sugar syrup
21. Medicating with so-called organic treatments (e.g. a. powdered sugar; b. organic acids present in the hive; c. essential oils present in the hive)
22. Medicating with synthetics and antibiotics

I drew up this list to send to Dee Lusby's e-group in the USA, which claims to be conducting 'treatment-free beekeeping'.<sup>9</sup> The list could also be called a Universal Scale of Beekeeping Treatments, as everything from putting bees in a container onwards could justifiably be called a treatment. So, obviously the term 'treatment-free beekeeping' is as much an oxymoron as 'natural beekeeping'. Incidentally, in its intentions, the movement that Dee and Ed Lusby started is probably the closest equivalent in the USA to the UK's Natural Beekeeping Alliance.

As an aside, I would like to say that the list of treatments I read to you should really be presented as a matrix or a table with several columns because it has branches depending on what hive you start with. John Haverson, who is here, has made a start in drawing up such a matrix. But it gets complicated because there are further branch points. We end up with a multidimensional matrix that is hard to picture.

There exists the view that mankind is part of nature and thus everything mankind does is natural. Polixenes represents this view in his conversation with Perdita in Shakespeare's *A Winter's Tale*. Perdita takes the opposite view and I expect that most of us here go along with her. This means that all beekeeping is more or less unnatural.

Faced with this conundrum, what is it that unites us all in coming to this conference? I suggest that it is our effort to put the species-specific needs of the bee at the centre of our beekeeping. In German, they call it '*wesensgemäß Bienenhaltung*', which could be translated as 'bee-appropriate beekeeping'. As that seems a bit of a mouthful, I favoured the term 'bee-friendly beekeeping'. But that sounds too much like the title of a book by one particular beekeeper! So I have coined the term 'apicentric beekeeping' which I would like to launch at this conference.

On 25 July I searched for the term in Google. There were no entries, so I added it to my home page at bee-friendly.co.uk. On 30 July there was one entry, and that was my home page. However, I claim no ownership of the term. Maybe the organisers would like to call the next conference in this series 'Apicentric Beekeeping'?

Now, after that little semantic discussion, I come back to my theme: sustainable beekeeping. For anything we do to be sustainable it should meet the needs of the present without compromising the ability of people elsewhere on the planet, or future generations, to meet their own needs. Living sustainably falls under three broad criteria: economic, social and environmental. These criteria are sometimes referred to as the three legged stool of sustainability. If one leg is missing the stool falls over. All three criteria need to be considered.

Firstly let's look at the environmental aspect: this venue here at *Green and Away* visibly and tangibly expresses it. You may wish to explore the site and study the ingenious ways that the venue and the way it works reduces the environmental footprint of the conferences held here – right down to the compost loos! And I cannot escape the fact that I undermined that reduction by driving here from North Wales, albeit with a car load of hive equipment. The simplicity of apicentric, natural beekeeping can help keep consumption to a minimum. We do not need to be lured by those equipment catalogues into buying more and more stuff. The lower intervention involved helps us cut fossil fuel use in travel to out-apiaries. My beekeeping travel is largely by bicycle, if necessary with a trailer attached.

We may also wish to consider the effect of our beekeeping on native pollinators. Too many hives in one place might make it hard for other bee species to survive. Tomorrow, we shall hear more on wild bees from Brigit Strawbridge.

Now to the social aspect: to make beekeeping socially sustainable it must not adversely impact the lives of others. That means care in siting apiaries coupled with public education about swarming and its health benefit for bees. Heidi will cover this tomorrow. Hive products can have health benefits for society, and should of course be fairly traded. And there is the beneficial effect on the wellbeing of individuals or groups engaging in this open air activity. I don't go as far as accepting the claim that human life on the planet is dependent on the honey bee, but she certainly enhances our life.

What about the economics of beekeeping? I suspect that many here are less interested in the economic sustainability of beekeeping. I'm guessing that we are predominantly hobbyists who would settle for the enjoyment of watching bees and taking a modest crop of honey for family and friends. Many beekeepers fund their beekeeping from other activities. But there may be a few sideliners among us for whom beekeeping is an important supplement to their income. And in developing countries this is especially important. People would be less likely to keep bees if it was not economically sustainable for them. Incidentally, are there any commercial beekeepers, bee farmers amongst us? [One hand went up.]

So that very briefly covers environmental, social and economic sustainability. But in beekeeping, like in any form of husbandry, there is a fourth criterion, one that cannot be subsumed under the three that form the 'three legged stool', and that is the species-specific needs of the animal, in our case the bee. And I am sure it is looking after the 'beeness' of the bee that motivates most of those who have come to this conference.

Phil Chandler has elaborated three basic principles of natural beekeeping:<sup>10</sup>

1. Interference in the natural lives of the bees is kept to a minimum.
2. Nothing is put into the hive that is known to be, or likely to be harmful either to the bees, to us or to the wider environment, and nothing is taken out that the bees cannot afford to lose.
3. The bees know what they are doing: our job is to listen to them and provide the optimum conditions for their well-being, both inside and outside the hive.

Although those principles appear under the heading 'natural beekeeping', they could just as aptly be the principles of apicentric beekeeping.

Now Phil cautions against elaborating these principles into a book of rules. I can go along with that. Even within the apicentric beekeeping movement there is an extraordinary diversity of views and approaches.

There needs to be some flexibility to accommodate that diversity. OK, we know that organic and biodynamic standards have a legal aspect because the products are traded and the customer wants to be sure of what they are paying for. But most natural beekeepers are not organic or biodynamic certified. However, they do want to be part of a community that is working to the same goals to develop an understanding of the life and needs of the bee.

Furthermore, beginners might be glad of some clear guidelines as there are some aspects they might not think about until they are more experienced, but wished they had thought about earlier. The most embarrassing thing I did as a beginner still makes me blush. My mentor said I needed paradichlorobenzene to stop the wax moths from destroying the comb in my supers. I duly bought a pack of paradichlorobenzene. It smelt vaguely of moth balls. I soon realised that I did not need it and I never used it. When I went to look for it a couple of years ago with a view to arranging for its safe disposal, all I could find was the pack, still sealed inside another bag. Though crystalline, it had evaporated through the plastic bags and is now somewhere up there doing its bit to wreck the ozone layer.

I mentioned that we take our cue from the needs of the bee. Where can we find out what the bee's needs are? Observation of bees is in first place, seeing, hearing and smelling as much as you can from outside the hive. Heinrich Storch's book *At the Hive Entrance* can help you with this. Our bees are our teachers.

The best teachers would no doubt be feral honey bees. Feral honey bee colonies seem to be bouncing back after the first ravages of the Varroa mite. Indeed, a person in this room knows the whereabouts of at least forty ferals. Can we learn their secret?

Apart from observing the bees, read as much bee biology as you can. A very good start for the beginner is Jürgen Tautz's *Buzz About Bees – The biology of a Superorganism*. It is a fine synthesis of an holistic approach backed by all the resources of analytical science. Mark Winston's *Biology of the Honey Bee* is a valuable resource. And if you have time, read as much bee science as you can in the apiological journals, or at least the digests of it in the beekeeping magazines. Although we should keep in mind that a lot of bee research is done on colonies in frame hives and may not reflect the biology and behaviour of the bee at its most natural.

Let us look at how some of Phil's three principles could translate into practice. What I present now is how I would interpret them for myself. There is nothing here that is intended to be prescriptive.

Firstly the choice of hive: honey bees can adapt to any sort of cavity. The strangest cavity I've seen a honey bee nest in is a water company valve chamber in the ground.<sup>11</sup> Bees can even survive the winter high amongst the branches of trees. But these are hardly the optimum conditions mentioned in Phil's third principle. So we put our bees in containers. In the UK, a log hive or a skep is probably the most bee-friendly hive. British Beekeepers' Association co-founder Frank Cheshire called the skep a 'hive for bees' in contrast to his 'hives for beekeepers'.<sup>12</sup> In the next conference in this series I hope skep beekeeping will be represented. [Phil Chandler: we do have a skep here.] But skeps or wooden hives made from planks are not necessarily the most sustainable choice everywhere. That means that local conditions need to be taken very much into account when deciding what is the most sustainable, most appropriate technology.

Could we do natural beekeeping in a common or garden frame hive, a National or a Langstroth for example? I think the answer is 'yes'. All natural beekeeping is on a scale of naturalness and even a National could be included. You might want to dispense with foundation, a queen excluder, swarm control, routine sugar feeding etc. There were frame beekeepers doing without these before an apicentric beekeeping movement started to take on a distinct identity. And, incidentally, there is even a frame version of Warré's 'People's Hive' in the early editions of his book.

If you are trying to be sustainable you will use renewables to make your hives. That means mostly plant derived materials. If you are concerned about interference from magnetic fields, you will minimise or eliminate the use of steel in your hives. In any case, steel has a high ecological footprint, i.e. it takes up a

disproportionate amount of the global hectareage to produce it and dispose of waste compared with, say, wood.

But we do not want to leave the beekeeper's needs entirely out of the equation. To husband bees the container used needs to have a certain degree of manageability. That takes us to top-bar hives such as the vertical top-bar hive, examples of which are Oscar Perone's hive and the People's Hive of Émile Warré, to the Kenyan horizontal top-bar hive, and even to the frame hive called the *Einraumbeute* (one box hive). All four hives will be presented after coffee in four parallel sessions: the Warré by myself, the Kenyan by Phil, the *Einraumbeute* by Heidi and the Perone by Andy Pearce and Hazel. Each presentation will be repeated three times at half-hourly intervals.

I believe that beekeepers of whatever persuasion should be free to choose the hive that suits them. I like to see plurality in hive type. Indeed, some wag has stated that it is the duty of every beekeeper to invent a new hive before they die. And, looking at the history of beekeeping, something approaching that seems to have been going on. I urge the officials of the National Bee Unit and the beekeeping associations to respect that plurality and to inform themselves, even to the extent of getting some appropriate training in how the more apicentric hives are constructed and managed.

The linking feature of all four hives is near-natural comb. It is not 100% natural because the comb spacing is predetermined by the beekeeper. Significantly narrower spacing occurs in the wild. I recently removed a feral colony from a chimney. Its comb spacing averaged 29 mm; 30-31 mm is common.<sup>13</sup>

Another feature of natural comb is that the bees fix it to the sides and top of the cavities, leaving peripheral galleries, usually at the sides. All three top-bar hives allow the bees to do that. Johannes Thür hypothesises that closing the comb to the hive walls is important for what he calls *Nestduftwärmehindung*, the retention of nest scent and heat.<sup>14</sup> But framed comb used in modern hives is designed to prevent the nest from fixing to the side of the cavity. I think the integrity of the bee colony superorganism is something that we are only just at the very beginning of understanding. It is worth keeping an eye on unfolding research about this.

Natural comb allows the bees to decide for themselves what cell size they want, in particular how many drone cells to build into the comb. A healthy colony in high season has about a thousand drones. Drones are more important to colonies than for just mating with queens. A drone has a higher heat output than a worker and can free up workers for tasks other than keeping the hive warm.

Not only does comb cell size vary according to whether drone cells are produced but also natural worker cells vary in size too.<sup>15</sup> If you are using near-natural comb you do not have to worry about this. The bees will decide. But if you use sheets of embossed wax foundation you are forcing bees onto a uniform cell size.

One might be excused for thinking that the absence of frames in these top-bar hives I mentioned makes them uninspectable. On the contrary, just a little more care is needed for inspection, and a couple of extra tools.<sup>16</sup>

Where should you install your hive? Ideally it should be where there is a good diversity of pollen and nectar forage over the entire season. This is often easily attained in a city, less so in some of the green deserts that our agricultural landscapes have become. I'm lucky in living in a florally diverse area with lots of marginal land and woodland. Beekeepers rarely command enough acreage to make a significant difference to the forage of their bees. But it is nevertheless a good plan to fill the garden with bee plants. If nothing else, it is a pleasure to watch the bees foraging.

What bees should you put in your hive? Try to use locally adapted bees if you can. I hardly think it sustainable to use bees that have been air-freighted from the antipodes. There is often a good trade in bees in local beekeeping associations at prices well below commercial rates. Beginners are often given swarms. You can attract local bees by setting up bait hives with swarm lures. I have a 35% success rate doing this.<sup>17</sup>

It follows from the first principle of natural beekeeping that you will open your hives only if there is very good reason and you have the possibility of taking some remedial action. For example, in a horizontal top-

bar hive you may need to adjust the comb a little as the colony grows. Each opening of a colony disrupts for a while the integrity of the nest, violates the retention of heat and the nest atmosphere, which includes its humidity and bouquet of volatile compounds which have yet to be fully identified and assigned a role. This disruption creates remedial work for the bees, and that is an energy cost to the colony.

Now to the controversial issue of colony reproduction. We humans find our own reproduction inconvenient for most of the time and so try to keep the lid on it. We extend this to the natural reproduction of bee colonies which is by swarming. Most beekeepers try to stop this or at least bring it under their own control. In doing so they are interfering at the most crucial point in the maintenance of the future fitness of the bee population. A whole array of complex behaviours subject to natural selection are circumvented by preventing reproduction by swarming. If you want a vivid description of these, Tom Seeley's book *Honeybee Democracy* is a good place to start. Removing the influence of natural selection can progressively reduce the fitness of the bees.

Probably the most powerful argument in favour of natural swarming is to do with the control of disease in the bee population. Swarming is associated with only vertical transmission of disease, which theory predicts will select for low pathogen virulence, milder pathogens, if you like.<sup>18</sup> This means that if the pathogen kills the host that is the end of the line for both host *and* pathogen. On the other hand, multiplying colonies by splitting them, as is common beekeeping practice, increases horizontal disease transmission which evolves high pathogen virulence. This is because the main reservoir for disease is usually the brood combs and the brood in them. If the pathogen kills off one part of a split there is still a chance for another part to survive and propagate the pathogen. It is not the end of the line for the pathogen. And even if all parts of a split fail there is still infected comb and equipment present to spread disease, e.g. through robbing. Helped by common beekeeping practices, pathogens can freely develop their virulence. For example, their reproductive fitness can increase, as there is less incentive to curb it sufficiently to allow the infected colony to swarm and thus secure the pathogen's survival by vertical transmission. The result is selection for increased lethality of pathogens.

Another clue to the value of swarming is that a swarm generally tries to move a few hundred metres from the parent colony. This can reduce colony density at a particular site. This behaviour could reduce not only disease transmission risk but also competition for forage. It should be kept in mind when deciding on how many hives to an apiary. Tom Seeley found that wild honey bees surviving Varroa had an average of a kilometre between colonies. As the saying goes: the worst enemy of a bee colony is another bee colony. My own hive density is 2.5 hives per apiary. Out of curiosity, I worked out my average hive separation. My average hive separation is 1.3 km. However, the range is 1 metre to 3.5 km, and I have not factored in known feral colonies or a neighbouring beekeeper's hives.

By speaking in favour of reproduction by swarming, some accuse me of being irresponsible. Swarms can be inconvenient to neighbours. Of course, not every beekeeper has the luxury of simply letting their bees swarm. Some adaptation to local circumstances is often needed, especially in urban areas. Although we could equally say that if the public want honey bees, then they should be prepared to tolerate them when they swarm and know exactly who to call if the swarm sets up home in their chimney. Heidi will be addressing the swarm issue in her talk tomorrow. Beekeepers working with reproduction by swarming can reduce its impact on the locality by learning all the ways of taking swarms, and by strategic placement of bait hives. Bait hives are not only collectors of swarms but also, through their entrance activity, *indicators* of imminent or recent swarm emergence. Incidentally, I believe that at least half the colonies I have removed from buildings in the past few years are from conventional, dare I say unnatural, beekeepers.

Having spoken in favour of natural reproduction, it follows that queen breeding is something that is best left to the bees. There are all sorts of goals in artificial queen breeding. Suppression of defensiveness and swarminess are two common ones. As scientists have found a correlation between defensiveness on the one hand and productivity and winter survival on the other,<sup>19</sup> it is doubtful if such selection is sustainable. Furthermore, there may be other more subtle correlations to do with fitness and survival that we do not yet know about. So let us leave reproduction to the bee. In my view, that also goes for the efforts to restore the indigenous British bee *Apis mellifera mellifera* to parts of Britain. It seems to me that it is only sustainable if

all beekeepers sign up to it, and even then a good deal of artificiality is involved in reaching that goal. The difference between breeding bees, and say, pigs, is that in the latter case we can have its reproduction entirely under our control.

Another feature of breeding bees is to sideline the commons, namely the bees that just happen to be in your locality. There are famous breeders who have managed to spread their idealised bee's genes round the world. I am sure you have heard of the 'Fastbuck' breed of bee.

What is the sustainable approach to pests and disease? The simple answer is to keep only healthy colonies. But there is one pest that is still causing great economic damage to beekeeping in the UK, and that is Varroa. How should we deal with Varroa in a sustainable way?

Some of you may know that I am not a no-treatment fanatic, even though I do not treat my own colonies. If a beekeeper has only one or two colonies and wants to increase the certainty that they will have them next year, maybe they would want to treat. However, unfortunately, the more organic of the chemical options are really not particularly organic at all. Indeed they are quite poisonous for the bees. And even conventional apiologists writing in Norman Carreck's recent review of the Varroa problem agree that the sustainable option in the long term does not involve putting chemicals in the hive.<sup>20</sup> A lot of beekeepers that I know, including some conventional beekeepers in my locality, do not treat for Varroa and seem to be able to sustain the higher losses that are usually involved. Many in the USA who practise small-cell beekeeping seem eventually to find that their losses return to those of pre-Varroa days. Unfortunately, it is not possible to find peer-reviewed data on this.

Now we come to the honey harvest. If you are lucky, the bees will store surplus honey in your hive. By surplus honey, I mean honey that is over and above their needs for even the worst winter in your particular locality. I see no reason why you could not take this surplus. Indeed, in a stacked hive such as the People's Hive, it could represent a significant heat sink during the winter and may therefore be better out of the way.

If you are unlucky, the bees may not have stored enough honey for winter. Then the question arises of whether to feed or not. If you are adhering to natural selection, maybe not feeding is worth considering. I had a Warré colony winter on only eight and a half pounds of stores and build up to swarm strength the following spring. But if your colonies are particularly precious, you will consider feeding them. You may be able to feed back honey from your own apiary. Failing that, honey from a trusted disease free local source would be a possibility. If no relatively safe honey is to hand then sugar is an option, but only just enough to get the bees through a crisis. I have not tried the biodynamic option of adding chamomile and thyme teas and a little salt to sugar syrup, but it is widely practised and it could mitigate the effects of feeding pure sucrose.

Once you have the honey out of your hive there comes the job of extracting it for serving at the table. The hives I have mentioned lend themselves to low cost extraction by allowing the honey to drain. This only requires utensils found in any kitchen. It involves the least processing of the honey. However, it is relatively easy to make a hygienic press for free out of recycled materials and use it to speed up the extraction process. Making a centrifugal extractor is quite another matter.

Ladies and gentlemen: that was a mere sketch of the essence of sustainable beekeeping. I hope you enjoy the rest of the conference. We are now open to questions.

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<sup>1</sup> [www.greenandaway.org](http://www.greenandaway.org)

<sup>2</sup> [www.naturalbeekeepingalliance.com](http://www.naturalbeekeepingalliance.com)

<sup>3</sup> [warre.biobees.com](http://warre.biobees.com)

<sup>4</sup> Steiner, R. (1923) *Bees*. Anthroposophic Press, NY.

<sup>5</sup> [warre.biobees.com/bfa.htm](http://warre.biobees.com/bfa.htm)

<sup>6</sup> <http://uk.groups.yahoo.com/group/warrebeekeeping>

<sup>7</sup> [www.bee-friendly.co.uk](http://www.bee-friendly.co.uk)

<sup>8</sup> Heaf, D. J. (2008) Sustainable & bee-friendly beekeeping. *Star & Farrow* **109**, Summer, 28-31.

<sup>9</sup> [www.beesource.com/point-of-view/ed-dee-lusby/](http://www.beesource.com/point-of-view/ed-dee-lusby/) and <http://groups.yahoo.com/group/Organicbeekeepers/>

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- <sup>11</sup> [www.dheaf.plus.com/beeremovals/valvechamber\\_cutout.htm](http://www.dheaf.plus.com/beeremovals/valvechamber_cutout.htm)
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- <sup>15</sup> [www.dheaf.plus.com/warrebeekeeping/cell\\_size\\_measurements.htm](http://www.dheaf.plus.com/warrebeekeeping/cell_size_measurements.htm)
- <sup>16</sup> <http://warre.biobeas.com/cutter.htm>
- <sup>17</sup> [www.dheaf.plus.com/warrebeekeeping/bait\\_hives.htm](http://www.dheaf.plus.com/warrebeekeeping/bait_hives.htm)
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- <sup>19</sup> Wray, M.K., Mattila, H.R. & Seeley, T. D. (2011) Collective personalities in honeybee colonies are linked to colony fitness. *Animal Behaviour* **81**(3) 559-568.
- <sup>20</sup> Carreck, N.L. (Ed.) (2011) *Varroa – still a problem in the 21st Century?* International Bee Research Association, Cardiff.