Journal of Wildlife and Biodiversity 1(2): 69-78 (2017)

by Arak University, Iran (http://jwb.araku.ac.ir/)

DOI: 10.22120/jwb.2017.28260

Research Article

Human-Elephant conflict mitigation methods: A review of effectiveness and sustainability

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Received: 08 September 2017 / Revised: 20 October 2017 / Accepted: 25 October 2017 / Published online: 3 November 2017. Ministry of Sciences, Research and Technology, Arak University, Iran.

Abstract

Human-elephant conflicts (HEC) have resulted in a substantial loss in livelihood and human lives, consequently, the affected communities retaliate by harming or killing the elephants. Thus, measures to mitigate HEC are imperative for the successful conservation of elephants, and to ensure the coexistence of the local population with these animals. Numerous HEC mitigating methods have been implemented. I reviewed 19 different HEC mitigation methods to assess their successes and failures, as well as their sustainability. Methods that required the regular presence of humans for their implementation and functionality tended to be very tedious and unsustainable since the uptake of such methods would be very low. Also, methods that posed no threat to elephants were unsustainable as elephants become used to the methods. Approaches that are affected by weather conditions are unsustainable. Methods that were very expensive to implement are also unsustainable as the method would be abandoned when funding ends. However, electrical fencing was effective and sustainable since it doesn`t depend on the physical presence of humans for it to prevent elephant destruction, especially when a sustainable finance mechanism is assured to ensure monitoring and maintenance of the fence. Beehive fences are also very effective especially when colonization of the hives is assured, and this method is very sustainable as it is cost-effective and honey from the hives could generate income for the population. Also, methods aimed at habitat modification are sustainable since habitat improvement increases the comfort and resources elephants need to live in their habitat.

Keywords: Beehive fences, coexist, elephants, electrical fencing, sustainable.

Introduction

Human-wildlife conflict (HWC) can be characterized as any interaction between humans and wildlife which negatively affects the human, the wildlife or property. Human-elephant conflict (HEC) is a major type of HWC that is considered a major challenge by conservation stakeholders. Today, HEC has become one of the biggest issues facing elephant conservationists (Stephenson 2004). Elephants cause catastrophic damage to farmers (Tchamba 1995, Ekobo 1997, Osei-Owusu and Bakker 2008), and they are considered to be more dangerous than other herbivore species, causing more deaths and injuries to humans (Sitati 2003).

HEC that causes harm to rural farmers and their property constitute a major concern to biodiversity conservation, especially across Africa and Asia (Barnes 1996, Dublin *et al.* 1997, Graham and Ochieng 2008). This conflict mostly occurs in adjacent communities that live

close to the natural habitats where the elephants live.

Considering the rapid increase in the human population that has increased human needs, there has been a resultant expansion of human activities which in many cases have encroached into wildlife areas, especially by local communities living around protected areas. In situations where such areas have a significant population of elephants, HEC is bound to occur. In many cases, as a result of HEC, people lose their crops, livestock, property, and sometimes their lives. HEC has been a big problem to a huge number of people in many parts of the world.

The destruction caused by elephants irritates the affected communities, with the animals often killed, captured, or otherwise harmed in retaliation (Naughton-Treves 1998, Malima *et al.* 2004, Omondi *et al.* 2004) and in some cases, the people decide to turn a blind eye to poaching in reprisal for the damage caused by the elephants (Parker *et al.* 2007, Mwakatobe *et al.* 2014, Karidozo and Osborn 2015).

The implementation of measures to mitigate HEC is imperative to enhance the sustainability of conservation efforts and to improve the coexistence between people and wildlife. The advantages of carrying out HEC mitigating measures will evidently be both on the communities and the elephants. These advantages may include improved attitudes and tolerance of farmers towards wildlife, the decline in crop losses, human death and injury, as well a decline in the mortality of elephants during HEC (Jackson *et al.* 2008).

The aim of this review was to highlight the successes and failures of various HEC mitigating measures that have been carried out in different parts of the world. It was also aimed at assessing the strengths and weaknesses of various HEC mitigating methods.

Material and methods

Sources of Information

The author reviewed the results of different HEC mitigating measures that had been implemented in different parts of the world. The sources of these results were mostly articles that had been published in international peer-reviewed journals. The author focused on articles that reported findings from field research that were carried out.

These articles were gotten by searching on Google Scholar. The appropriate heading on HEC mitigating measures was typed on Google Scholar and many published articles were displayed. The author then downloaded and saved the articles that focused on HEC. Also, some articles were gotten via going through the reference list of already downloaded and saved articles. Numerous articles were gotten. The author now read through each article to select those that reported appropriately on specific HEC mitigating measures, based on practical research that was carried out.

HEC mitigating measures

Numerous researches have been carried out on different measures to mitigate HEC. Thus, the author reviewed findings on these different measures following reported field experiments carried out by different scholars. The mitigating measures reviewed by the author include traditional, biological and physical measures. The methods include:

1) Beehive fences

2) Chilli pepper methods

- Spraying and/or shooting prepared capsicum
- Chilli fences where the chilli extract is mixed with tobacco or oil and applied on the fence.
- Chilli smoke involving the burning of chilli, tobacco and straw, dung mixture or chilli bricks creating a pungent smell.

3) Fences

- Fence with bells or trip alarms. Polythene cord or thatching twin attached to poles used to surround farms, with cowbells or trip alarms attached to it at given distances.
- Electrical fencing

4) Spotlight. Guards stand on watchtowers with bright torchlights and point in the elephant`s eyes.
5) Elephant drives. Trained domestic elephants (kunkies) used to drive wild elephants.
6) Fire. Bush fires are set which while burning, scare elephants away.
7) Noise or sound
- Noise from playing the drums, shouting, vehicle, tractor, loudspeakers etc
- Playing Elephant Warning Calls close to elephant herd (humankind sound)
- Playing noise of bees
- Use of firecrackers (explosives)

8) Habitat improvement
- Building manmade salt ponds
- Establish wildlife corridors between parks (increases habitat)

9) Digging trenches
10) Culling (Killing) of problem elephants
11) Contraception
12) Translocation of elephants to other areas

More experiments were reviewed on electrical fencing and chilli fences than the other HEC mitigating measures (Fig. 1), since following the extensive search that was carried out more information was available and obtained on these two methods.

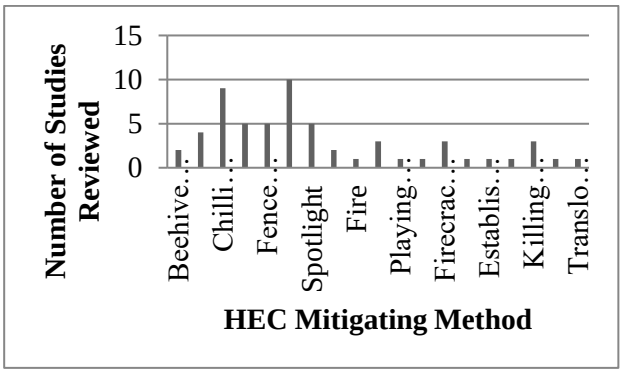

Figure 1. The number of studies reviewed for each Human-Elephant Conflict (HEC) mitigating method. The studies that were reviewed represent experiments that have been conducted and published in peer review journals.

Results

Beehive fence

Beehive fences effectively reduced HEC (Fig. 3) as crop destruction was minimized in experimental plots compared to the control plots with no fence (Lucy *et al*. 2009, Lucy *et al.* 2017). Elephants usually get scared of bees as they can easily attack them when elephants disturb or shake the fence on which beehives have been attached. This method has an advantage in that in addition to minimizing HEC, the beehives serve as income-generating activities (IGA) as honey can easily be collected and used for subsistence or sold. This method is also cheaper and easily affordable. The method was therefore highly desired by the communities.

Community members would be highly motivated to invest in this method, thus contributing to beehive fence being a sustainable approach in mitigating HEC. However, it would be very important for the users to have adequate training on the management of beehives so as to ensure adequate colonization of the hives by bees, without which, the method would be relatively ineffective. Also, the beehives should be suspended on a tightly secured fencing wire so that the beehives can swing freely (Fig. 2) especially when an elephant touches the fence, thus disturbing and releasing the bees to irritate or sting the elephant. It should as well be noted that the closer the beehives, the more effective the method would be.

Chilli pepper methods

Spraying and/or shooting prepared capsicum

Capsicum prepared as a spray or as pellets when sprayed or shot at the elephants usually using dispensers, effectively deterred and scared away elephants (Fig. 3), since many elephants could easily run away when the substance hit the elephant and capsicum spread on them (Osborn and Rasmussen 1995, Ferrel 2002, Sébastien *et al*. 2010). This repellent effect of capsicum on elephants could be as a result of the substance

causing effects on the animal such as burning sensation in the mucosa of the trunk, watering eyes, and trigeminal pain. However, this method could be very challenging thus limiting uptake by the community since spraying and shooting requires physical presence which is tedious and labour intensive. Also, it entails a high cost to prepare this substance, thus communities would not easily invest in it.

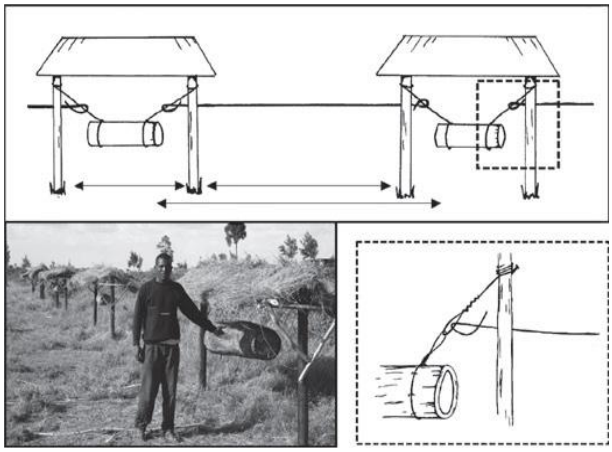

Figure 2. Beehive fence for the mitigation of HEC. The fence is constructed with log beehives hung under small thatched roofs (adopted from Lucy *et al*. 2009)

Chilli fences

89% of experiments on chilli fences effectively deterred elephants (Fig. 3), since many elephants ran away when they approached and came in contact with the fences on which chilli paste was applied (AERP HEC project 2006, John 2006, Graham and Ochieng 2008, Chelliah *et al.* 2010, Tammy *et al.* 2011, Hiten *et al.* 2012, Karidozo and Osborn 2015, Alex *et al.* 2016) compared to the control.

However, Simon and Donny (2009) reported that chilli fences had no deterrent effects on elephants, as crop-raiding by elephants was similar both in the experimental and control plots. Generally, the loss of pungency of chilli when exposed to rain or sun reduces its effectiveness and thus becomes a poor deterrent for elephants. Also, community members cannot easily adopt this method or invest in it since the cost of chilli paste is usually very expensive, and the method is labour intensive as it requires regular reapplication of chilli grease or paste on the fence. The method would only maintain its effectiveness if conservation stakeholders provide regular funding, without which it becomes unsustainable.

Chilli smoke

80% of experiments on chilli smoke effectively deterred elephants (Fig. 3), since the pungent smell that was created caused elephants to run away (Ferrel and Guy 2002, John 2006, Graham and Ochieng 2008; Karidozo and Osborn 2015), thus protecting farms and minimizing crop destruction compared to the control. Nevertheless, Tammy *et al*. (2011) reported that chilli smoke had no significant deterrent effects on elephants, as crop-raiding by elephants was similar both in the experimental and control plots. This method can be very successful if many of such materials are burned around the farm since the more the smoke produced the more the effectiveness of the method. This will in effect increase cost which may make the method to become very expensive for local farmers to invest in. Also, this method is highly dependent on wind, thus if the wind doesn`t blow the smoke towards the elephants, it becomes unsuccessful.

Effects of Fences

Electrical fencing

The electrical fence effectively minimized HEC (Fig. 3) as the fence acts as a barrier that prevents elephants from crossing (Thouless and Sakwa 1995, Charles 1996, Caitlin *et al.* 2000, Gunaratne and Premarathne 2005, John *et al.* 2008, Colin *et al.* 2009; Graham *et al.* 2009, Tammy *et al.* 2011, Wumuyu 2012, Ahmad and Magintan 2016). Electrical fences have the capacity of not only protecting individual farms but also protecting the entire community depending on the extent of the fence. To increase its efficiency, the electrical fence needs to be

well solid and maintained regularly. The construction, maintenance and enforcement cost of electrical fences is high and thus this method may only be feasible in conservation areas with adequate financial resources. Such finances would be able to create, train and ensure the functionality of a committee charged with the responsibility of regular monitoring and maintenance. A sustainable finance mechanism has, therefore, to be put in place to guarantee the sustainability of the method. For instance, Kenyan Wildlife Service (KWS) has constructed and maintained a total of 1,225kms of electrical fences nationally with 888 km within protected areas, and the cost of constructing 1km of electrical fences is about US$15,000 (Chiemelu 2004).

Fence with bells or trip alarms

Fence with bells and trip alarms were generally ineffective to mitigate HEC with just 40% of the experiments successfully reducing conflicts compared to the control (AERP HEC project 2006, Wahed *et al*. 2016), and 60% of the experiments unsuccessful (Caitlin *et al.* 2000 Ferrel and Guy 2002, Graham and Ochieng 2008). Generally, bells in themselves do not scare away elephants, but may only alert farmers when elephants come to their fields. Also, elephants learn and habituate to bells as they don`t face any threat or physical harm resulting from bells. However, the noise from the alarm alerts people and irritates elephants scaring them away (Wahed *et al.* 2016). This method is a cost-effective early warning approach which even though it requires regular maintenance, it does not necessarily need frequent replacements. Uptake of this method by communities would be good, especially when community members have adequate training on its maintenance.

Spotlight

Spotlights effectively minimized HEC by preventing crop damage by elephants (Fig. 3) since the bright rays of the torchlight is directed into the eyes of the elephant, thus scaring them away (Charles 1996, AERP HEC project 2006, Graham and Ochieng 2008, Simon and Donny 2009, Tammy *et al.* 2011). The effectiveness of this method is guaranteed only when the guards chase the elephants away while directing the light into the eyes of the elephant. The torch lights must therefore be very bright and the elephants have to be close enough. This method has an advantage in that it is cost-effective, and thus the communities can easily bear the cost. However, the method is labour intensive, and thus many people would not be motivated to go through the intense stress associated with this approach. Also, the elephants may tend to come back to the farms in periods when there is no light.

Elephant drives

50% of the experiments carried out showed that elephant drive is effective for HEC mitigation (Fig. 3), as well trained domestic elephants (kunkies) successfully drive wild elephants away (Charles 1996). However, inadequately trained domestic elephants cause wild animals to panic and run randomly, thus destroying crops the more (Tammy *et al.* 2011). Thus, for this method to be successful, the domestic animals need to be given adequate training such that they can drive wild elephants in an orderly manner, without which their actions will instead increase HEC. This method is generally not sustainable because it can only be implemented by trained wildlife experts, and it may only provide a temporal solution since the wild elephants would return to the farms when the trained domestic animals are not there.

Fire

The only experiment conducted on fire showed that it is an effective method in mitigating HEC (Fig. 3) as elephants tend to run away from huge fires (Tammy *et al.* 2011). This method is labour intensive as it requires regular control of the fire to prevent it from extending into the nearby

environment. Without control, fire may extend and destroy crops and surrounding vegetation.

Noise or Sound

Noise from human activities

Only about 33% of the experiments showed that noise from human activities could mitigate HEC (Fig. 3) since elephants would be scared and thus run away from such unpleasant sounds (Charles 1996). Generally, playback of a tape containing a jumble of noises, through loudspeakers was more effective than a single noise of an animal. However, noise may cause elephants to run (escape) uncontrollably thus destroying more crops and creating more conflicts (Ferrel and Guy 2002, Tammy *et al*. 2011). Also, elephants may get used to the sound knowing it is empty threat and not escape.

Playing Elephant Warning Calls close to elephant herd

This method was ineffective in mitigating HEC (Fig. 3) since the elephants came back when the calls ended (Caitlin *et al.* 2000). The method requires repeated playing of the warning calls (humankind of sounds) close to the elephant herd till the elephant leaves the area.

Playing noise of bees

The sound of disturbed bees playing close to elephants effectively mitigated HEC (Fig. 3) as the sound scared the animals away (Lucy *et al*. 2007). However, this method can only provide a temporary solution as elephants tend to return to the area when there is no noise.

Use of firecrackers or explosives

This method effectively mitigated HEC (Fig. 3) as elephants become scared and run away after hearing the sound of these explosives (Charles 1996, Ferrel and Guy 2002, Graham and Ochieng 2008) especially when it occurs close to the animals. However, the method does not eradicate elephant raid as elephants may become use to the noise, or come back to the area when there is no noise.

Habitat Improvement

Building manmade salt ponds

This method effectively mitigated HEC (Fig. 3), especially in areas where elephants frequently moved to communities in search of salt (Li and Ning 2003, Wahed *et al.* 2016). This indicates that habitat improvement could be a reliable way to reduce conflicts since the resources needed by the elephants would be made available to them. Conflicts mostly arise when these animals do not have the resources they need within their habitats, thus they are forced to go and search for it elsewhere. Manipulating wildlife habitat by improving or providing food, water, adequate space as well as improved habitat health could be considered by stakeholders as vital approaches to mitigate HEC.

Establish wildlife corridors between parks (increases habitat)

The establishment of corridors effectively mitigated HEC (Fig. 3) as elephants would easily move via corridors to other areas where they will have better habitat conditions such as food and/or water at a given period or season (Alfred *et al.* 2010). For corridors to be effective, the habitat conditions of the corridor should be similar to the preferred habitat condition in the original site where the elephants live. If the habitat conditions of corridors are not suitable for the elephants, they will always move out of the corridors to the adjacent land to obtain the resources and comfort that they need, hence creating conflicts. Also, sufficient habitat conditions should exist in the areas where the elephants are using the corridor to move to, without which the carrying capacity of the site could be exceeded (as the elephants would add to the already existing population in the new site), resulting to deterioration of the new site as well as increase conflicts.

Digging Trenches

Dug trenches were ineffective for HEC mitigation (Fig. 3) as elephants could easily collapse the walls of trenches with their massive body weight especially in humid areas, thus crossing over them (Li and Ning 2003). Blair and Noor (1981) reported that Malaysian elephants have been known to cross over trenches of up to 2.3m wide. Trenches also have a disadvantage in that they are very expensive to construct and maintain.

Culling (Killing) of problem elephants

Culling of selected elephants was ineffective for HEC mitigation (Fig. 3) since the remaining herd came back to the area after some time, the population increased via reproduction, and others migrate to the area, thus creating conflicts (Whyte 1993, Tchamba 1995, Hoare 2001). The killing of problem elephants by wildlife officials is a common practice in many countries, especially as the local populations affected by HEC perceive this measure as a positive step by the government to retaliate against the destruction caused by these animals. Such methods may only scare away elephants for a short time, and thus does not provide a long-term solution to HEC. Hoare (2001) reported that after killing one elephant in a herd of crop-raiding bull elephants, by the fourth night after, its radio-collared companions had returned to raid fields within one kilometre of the shooting incident. Thus culling may only improve the relation and trust between conservationists and the local communities, but it`s an ineffective approach for HEC mitigation. Instead, killing may reduce the gene pool of elephants in an area.

Contraception

Contraception is ineffective in mitigating HEC (Fig. 3), as the approach may be damaging to the individual female and those around her, while it would require that a very huge percentage of the female elephants should be on contraceptives in order to achieve a zero population growth (Ian *et al.* 1998). This approach would therefore entail a very huge cost, thus making it not to be practically feasible and unsustainable. However, Stuart and Rudi (2001) reported that immunocontraception (inhibition of the fertilisation process) using the porcine zona pellucida (pZP) vaccine could slow down the reproductive rate of elephants. But again, for this approach to be effective, contraception should be repeated after some time when the contraceptives may have weakened and become ineffective. This is therefore a very tedious and costly process.

Translocation of elephants to other areas

Translocation was ineffective in mitigating HEC (Fig. 3) since some of the males and females with calves left the release site and either returned home or roamed into nearby human settlements (creating conflicts) and were then poached by the local community or shot by Problem Animal Control (Noa 2009).

Noa (2009) reported higher mortality rates of translocated animals in the release site than the local population. Also, some elephants die during the translocation process, probably due to the stress they are subjected to. Thus translocation is not a sustainable approach as the elephants that return home from the release site create conflicts, whereas the translocated animals may increase HEC in the release site. Translocation also has a challenge in that it is a tedious and expensive process.

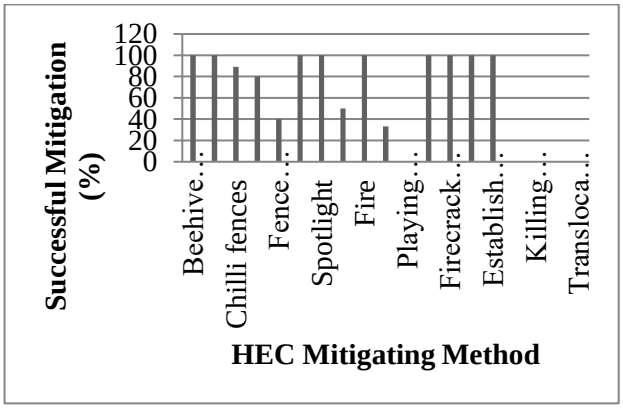

Figure 3. The number of studies reviewed that reported successful mitigation of Human Elephant

Conflict (HEC) for each mitigating method. An experiment is considered to have successful mitigation if it effectively scared or deterred elephants compared to the control.

The mitigation of HEC remains a major unresolved challenge for wildlife managers and stakeholders. Extensive field experiments have been carried out using different approaches to mitigate HEC. However, many of these approaches provide only temporal solutions and therefore become ineffective and unsustainable. Beehive fencing, electrical fencing, habitat manipulation and improvement could be considered the most effective and sustainable measures to mitigate HEC especially when well implemented, with adequate monitoring and maintenance carried out as the need arises.

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