Why wild herbivores raid crops: alternative hypotheses and their differential implications for mitigation of human wildlife conflict

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Abstract: Wild herbivores eating up crops is a major issue in human wildlife conflict. Although there is substantial literature that identifies the conflict, tries to estimate the extent of economic loss, its consequences and also suggests some mitigation measures, many fundamental issues remain unaddressed. A number of speculations about the root causes behind the problem have been made but they haven't been tested as alternative hypotheses. We make a list of alternative hypotheses, collected from a wide variety of sources, evaluate their plausibility and logical integrity, suggest differential testable predictions and their differential implications for mitigation measures. It is important to identify the locale specific causes of the conflict because the efficacy of mitigation measures would crucially depend upon the predominant underlying cause. Measures applied without a good understanding of the causal factors might turn out to be ineffective and even counterproductive. Substantial research needs to be focused on differentially testing the predictions of the alternative hypotheses in order to be able to handle the problem and promote healthy coexistence of wildlife with indigenous people.

Free ranging wild species of herbivores often visit agricultural lands and eat, trample or otherwise damage crops. The severity of this problem is highly variable across landscapes but the problem appears to be widespread globally (Graham et al 2010, Mackenzie and Ahabyona 2012, Karanth et al 2013, Bayani et al 2016, IUCN 2022, Yazezew 2022). A number of mitigation measures have been suggested, often debated and variously implemented with different degrees of success (Sitati and Walpole 2005, King et al 2009, Massei et al 2010, Hoare 2012,2015, Krivek et al 2020, Karanth and Wanamamalai 2020). Compensating the affected farmers has been shown to help maintain a positive attitude towards conservation (Karanth et al 2018, Johnson et al 2018, Joshi et al 2020) but with increasing frequency and extent of damage, this is unlikely to provide a sufficient solution. It is necessary to examine the root causes of the problem. The question why wild herbivores raid crops and the factors that influence the frequency and severity of damage has not been adequately addressed so far. There is a need to examine the different causal hypotheses because they have different and often mutually contradicting implications for mitigation measures. The failure of some of the mitigation measures and the tricky implementation (Hoare 2012, 2015) may be because they were based on a wrong causal assumption.

We state alternative hypotheses, examine them against existing knowledge and anecdotes, state testable predictions and discuss their possible implications for effective management in this paper. The hypotheses are not mutually exclusive. More than one factor might be simultaneously acting in a locale specific manner. But it is important to identify the relative importance of them, in order to design mitigation strategies accordingly.

Since studies addressing causal analysis are scanty, we cannot test those hypotheses with existing data right away. We therefore take an approach of making multiple testable predictions from each of the hypotheses. Testing the predictions is a demanding task and we expect the article would initiate attempts in this direction, which is important for wildlife conservation in near future, if it is to be implemented without profound injustice to indigenous people.

A. Collection of hypotheses

Since there is little serious scientific literature on examining hypotheses for crop raiding collectively, apart from research articles, we listed plausible hypotheses from a variety of sources

including popular articles by wildlife researchers, the opinions of indigenous communities, our own anecdotes, observations and thinking.

Hypothesis 1: Although we did not find any studies establishing causal relationship between habitat loss and crop raiding severity, this is the cause most commonly believed and stated by naturalists and wildlife researchers (Agarwal et al 2016, Mekonen 2020, Yazezew 2022, IUCN 2022). A plausible logic appears to be that animals prefer to remain in their preferred natural habitat but when these are destroyed, fragmented or disturbed they are forced to move out. When they move out they raid crops as an alternative and presumably suboptimal source of food. There are at least four different streams of thinking within this broader hypothesis.

a. The most common perception is that of habitat loss due to deforestation. By this hypothesis wild animals are deprived of the prime habitat they prefer to inhabit. Only because of unavailability or fragmentation of the preferred habitat they are compelled to move out. This hypothesis is mainly propagated by the wild life enthusiasts and appears to be uncritically accepted by most wildlife researchers as well. Although there are no serious research publications supporting this hypothesis, it is often reiterated rhetorically in popular literature propagated by wild life researchers and organizations (for example IUCN 2022). Before being propagated as the cause of human wildlife conflict, it needs to be tested in comparison with alternative hypotheses.
b. Habitat loss due to conservation norms: In our own experience, this possibility was expressed by many individuals from the local communities affected by the conflict. It is thought that because of the policy of complete ban on cutting, extraction and collection from protected areas open patches, grasslands and secondary forests are getting increasingly replaced by tall tree canopy forests. Secondary forests and forest grassland mosaics offer greater feeding opportunities to herbivores (Joshi et al 2018). Local communities think that since the complete ban on forestry operations, canopy forests are taking over the open patches making the habitat less favorable for herbivores.

c. Invasive species are rapidly replacing local palatable species leading to change in land use by herbivores (Rozen-Rechels 2017) that may lead to raiding crops (Krivek et al 2020).
d. Water availability in certain seasons is perceived to be a main cause why animals move to the vicinity of human settlement, where water is more likely to be available throughout the year. Once they move close to human habitation for water, they also consume the food sources available in the vicinity.
e. Seasonal pinch period: Forests in India are highly seasonal and there are periods in the seasonal cycle where forage in the wild is almost depleted. If crops are standing during this pinch period, animals are attracted to it as the only source of food during the pinch period.

Hypothesis 2: As profound success of the conservation strategies the populations of many wild species have increased substantially during recent decades. Expanding the range and migrating out are natural instinctive responses to overcrowding. So the phenomenon of animals moving out from protected areas is an inevitable effect of increasing populations (Matthysen 2005).

Hypothesis 3: The advent of agriculture in human history changed human ecology substantially. The plants selected as crop species were particularly rich in nutritive value and poor in secondary metabolites. Over several generations there has been selective breeding for better nutritional quality and reduced secondary metabolites. Therefore crops, in general, have greater palatability than wild forage (Hill 2018, Plotnik et al 2023). Therefore, wherever herbivores have a choice of wild forage against crops, other things being equal, they will prefer crops over wild forage (Delger *et al*., 2011, Chiyo et al 2011). By this hypothesis, in contrast with hypothesis 1, animals are pulled by better nourishment prospects and not pushed out by dearth of fodder in preferred habitats.

Hypothesis 4: According to this hypothesis, animals have a fear of humans since humans have been a hunting species from an early ancestral stage. The hunting practice became more efficient and thereby destructive with development of technology. Therefore by natural selection, learning and cultural inheritance a tendency to avoid humans developed in the wild animals. If animals prefer forests to human settlements as assumed by hypothesis 1, it is because of the fear of humans than because of preferred food and other aspects of the habitat. Since the ban on hunting,

this process is reversing rapidly. The habitat preference also may change because of the altered behaviour in response to ban on hunting.

An interesting possibility is generated by poaching. Since the ban on hunting, poaching has dwindled but still prevalent in remote parts where law and order is weak. Since poachers and presumably natural predators prefer areas away from human settlements, animals may learn to perceive the vicinity of settlements a safer habitat then remote forests (Price et al 2014). Wherever the poaching pressure is sufficiently intense, it is possible that animals prefer human habitation over forests, particularly at night. Thus area specific success or failure of the ban on hunting is expected to affect human animal conflict in unintended ways.

B. Logical integrity, limitations and possible flaws in the hypotheses in the light of existing knowledge and anecdotes:

The assumption of the habitat loss family of hypotheses that animals prefer to stay in their natural habitats and avoid human dominated landscapes raises multiple questions. The distinction of land as natural habitats versus human settlements is recent in the evolutionary and ecological history. In some areas human settlement is new. The demarcation of protected areas is very recent and quite artificial. The assumption that animals intuitively avoid human habitation and prefer natural habitats is questionable (Shrivastava et al 2020). They have coevolved and coexisted with human species sharing the habitats. Segregation of habitats is not a phenomenon of long duration. Agricultural lands are difficult to distinguish from grasslands which are their natural habitats. So the assumption that animals avoid human occupied landscapes unless the habitat is lost or fragmented remains unsubstantiated.

The loss of habitat hypothesis also suffers from the short term versus long term effects and logical inconsistencies associated with it. In the short run, if the animal population is assumed constant and if their habitat shrinks, they will be forced to move out of the presumed preferred habitats. However, if the habitat is crucial for their breeding, loss of habitat will also reduce the breeding rate and the population will dwindle. Therefore in the long run, habitat loss is unlikely to cause sustained conflict. In contrast, if we assume that they can breed even after loss of habitat, then the assumption that the habitat is crucial for their survival is under question.

The assumption that many species of primates and small herbivores inhabit and breed in their "natural habitats" i.e. mostly protected areas in recent times and only come out to raid crops in certain seasons and certain times gets challenged by the recent observations that they often stay and breed within agricultural or horticultural areas. They often do not need natural forests, in some parts of India many generations of them have not seen natural forests and they successfully breed within the cultivated habitats. However since almost all wild life research is restricted to protected areas, there is little data on populations outside the presumed natural habitats. It is possible that preference to the presumed natural habitat was induced by the fear of man, largely owing to hunting. After hunting has been banned, this distinction is expected to vanish in subsequent generations. Therefore there is no need to consider animal movements outside their presumed natural habitats as anything unnatural.

The natural attraction of crops owing to their greater nutritive value is quite likely since crop raiding elephants are observed to be larger and fattier (Chiyo et al 2011). Preference to crops along with gradual loss of human fear are less popular hypotheses among wildlife researchers, but owing to the multiple deficits and flaws in the more popular hypotheses, there is a need to examine all possible alternative hypotheses with quantitative testing of their differential predictions.

C. Differential testable predictions

The set of possible hypotheses are not mutually exclusive. However, assessing their relative role is important for designing appropriate mitigation strategies. Also the relative importance of different causal factors can vary contextually and therefore the predictions also need to be tested in context specific manner. For testing the differential predictions it is crucial to have access to reliable data. Testing the suggested predictions with dubious data sources is likely to be misleading. Currently although qualitatively the problem is known to exist, there are no reliable quantitative measures of the extent of loss in different areas. Therefore although on ground testing may not be possible as of today, we state the testable predictions with the hope that sufficient research inputs will be made in near future to collect reliable and comparable data.

Correlation between forest cover and habitat quality is expected according to the sub-hypotheses of the habitat degradation group. If deforestation, habitat fragmentation, invasive species or net

loss of preferred habitats is the major cause of conflict, we expect a negative correlation between forest cover and crop damage across area units such as district, taluks, beats or circles. The correlation needs to be robust to corrections for area cultivated, the extent of forest agriculture interface and other relevant factors. If the loss of open patches and secondary forests are critical, a finer level classification using appropriate tools should reveal a positive correlation with canopy forest or negative correlation with non-agricultural open patches within the habitats. If invasive species are mainly responsible for the habitat loss, the extent of area covered by the invasive species should be correlated with the extent of crop damage. Also weeding out should demonstrably reduce the frequency and extent of damage (Krivek et al 2020). If water constraints drive animals close to human habitats, provision of water resources within PAs will reduce crop damage quickly. This is being done in most wildlife parks today. However, no systematic data appears to be maintained to test whether better water availability throughout the year in PAs reduces the conflict.

In certain areas habitats have been evidently restored over large areas that can help in testing certain predictions. For example in certain patches along the wastern ghats and costal Maharashtra there was large scale deforestation by the middle of the 20^{th} century because of charcoal making (Sathe 1988). After charcoal was substituted by kerosene and then by LPG gas as domenstic fuel, charcoal making ceased in most areas and secondary forests grew back substantially. In these areas the problem of crop damage should have reduced after the restoration. It is difficult to get data about the amount of crop damage in the past for any quantitative analysis. The perception of old people is on the contrary. The perceived crop damages have increased after the restoration. Since retrospective analysis is difficult due to lack of crop damage data, prospective studies need to be undertaken. Wherever ecological restoration is attempted over sufficiently large area crop damage should decrease significantly. Management of many protected areas includes regeneration, grassland management, provision of water and weeding off invasive species. These protected areas offer us opportunities to test many of the predictions. By the habitat loss family of hypotheses, crop damage in and around such areas should decrease with good management.

If increase in population is a necessary and sufficient cause, correlations across area units between population estimates and crop damage should be observed after correcting for

confounding variables. While a positive correlation is most likely, the critical question is how much variance in crop damage is explained by population density.

Whether animals prefer wild forage or crop species is relatively easy to test by two lines of investigation. A very promising testable prediction can come through nutritional analysis of wild forage compared with locally grown common crops at appropriate stages of development. Alternatively using captive animals, choice experiments can be performed between common wild forage and locally grown crops at the appropriate stage of development. This is very likely to clearly differentiate between whether animals prefer natural forage and come out only when it is inadequate, or whether they prefer crop species, other things being equal. If they appear to prefer crop species under otherwise identical conditions, the question changes to what prevents them from eating crops almost all the time. This is very likely to be fear and avoidance of humans. If that is true, it follows that loss of this fear will increase the conflict.

Another testable prediction of this line of thinking is that wherever traditional hunting practices by communities are still prevalent, crop damage should be less serious because the fear of humans is reinforced. This is testable if reliable data on traditional hunting/poaching is available, which is the tricky part of the prediction testing. The corollary is easier to test. It is possible to quantify human avoidance behaviour. The ease of sighting wild animals, absence of any response to tourists or flight distance in response to approach on foot in a wild life sanctuary should be correlated with crop damage in surrounding villages and this correlation should stand after correcting for population density.

At a finer seasonal scale, one can distinguish between a push hypothesis which states that animals tend to move out during the pinch periods of food availability within the forest; versus the pull hypothesis which states that animals are attracted by the more nutritious crops. A careful look at the phenology of food availability within forests and maximum nutritive stages of crop vis a vis animal movements and season specific extent of crop damage can resolve between the push and pull hypotheses. Crop raiding should be restricted to seasons when food availability within the forests is low independent of crop availability if the push hypothesis is correct. On the other hand, crop raiding incidents should increase when the crops are at their peak nutritious stage, independent of wild forage availability. This distinction is easier to test and interpret as well as has important implications for mitigation.

D. Implications for mitigating conflict

If habitat loss is the cause, mitigation is inherently difficult. Habitat loss needs to be prevented and restoration attempted in any case, independent of its relation with crop damage. But it is highly unlikely that habitat restoration will be effective in preventing crop damage. The expected time required for restoration is large; in the meanwhile the populations may adapt to suboptimal habitats and keep breeding outside the so called preferred habitat. With increase in populations the restored habitat is likely to turn inadequate. Therefore although restoration needs to be done for multiple other reasons, we cannot expect it to resolve the crop damage problem.

If hypothesis 1b is correct, the classical India policy of wildlife management consisting of ban on all human activities needs to give way to a well managed resource use. Periodic and carefully calculated extraction of timber and other forest produce might be desirable. There are multiple unknown variables important for management and that needs huge research inputs in a new direction.

If increasing population is the necessary and sufficient cause, population control is the possible solution. This can be achieved by carefully calculated and controlled culling or permitted hunting; or alternatively by castration/contraception. Culling is safest from ecological point of view whereas male castration has greater risk of local extinction, large population fluctuations and loss of genetic diversity (Watve and Dandekar, MS under preparation). These risks are much smaller in calculated culling.

If the nutritive value and thereby attractiveness of crops is proved to be greater than wild forage at least in some seasons, then crop raiding needs to be assumed as inevitable. If the hypothesis that the fear of humans is the factor minimizing crop raiding in spite of its attractiveness then attempts to restore the fear of humans is the most promising solution. Here hunting can be used only as a tool. The objective of hunting by this and the previous hypothesis is different. Research inputs to design appropriate hunting/culling practices that would reinstate necessary level of human avoidance behaviour will be able to mitigate the problem substantially with minimum required killings. If culling is systematically designed to facilitate human avoidance behaviour, then the effect would be disproportionately greater than the proportion actually killed. Here the

method of hunting/culling needs to be selected appropriately to effectively change behaviour of the species.

On the other hand, if killing or castration only reduces the population but the attractiveness of crops and reduced fear of humans persists, then the effect will be less than the proportion culled. It is likely that dominant and larger individuals/groups take to crop raiding owing to its greater nourishing content. Weaker individuals/groups keep away from the stronger groups. But if the crop raiding animals are removed the subordinate ones take their place very soon (Plotnik et al 2023). If this is true, reduction in conflict by culling or removing animals would be disproportionately ineffective. Such factors might be responsible for the observed ineffective culling (Hoare 2012). The subtleties of animal behaviour are important in designing mitigation measures but studies considering behavioural factors related to farmer herbivore conflict are still largely inadequate (Watve et al 2016, Bayani and Watve 2016, Plotnik et al 2023).

Independent of the cause of conflict and the appropriateness of alternative mitigation measures, it is necessary to have an appropriate and realistic compensation strategy giving relief to affected farmers. If realistically assessed, the reduction in compensation needed can also serve as an appropriate marker of the success of the measures. Such data can be collected with minimum efforts and maximum reliability if appropriate protocols are applied (Joshi et al 2021). Monitoring changes in populations, their spatial distribution and behaviour demands much greater and continued research inputs. Therefore a minimum hassle and realistic damage compensation protocol is extremely critical under any circumstances. Innovative protocols based on the principles of game theory are demonstrated to work on pilot scale (Joshi et al 2021).

Substantial research inputs are nevertheless needed on the multiple other dimensions of the problem in order to make the mitigation measures effective with minimum damage to the populations. So far wildlife research and management in India has largely focused on giving protection and allowing populations to grow. This was a relatively easy challenge. The challenge of the future to monitor populations outside PAs, keeping the conflict to a minimum and ensuring population viability of the species is orders of magnitude difficult challenge and would require research inputs proportionately. This needs a paradigm change in wildlife research and scientists in this field need to be prepared for a major change in their mindset.

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