COMMENTARY

Did Vulture Decline Increase Death Rates in India?

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Abstract

This commentary critically evaluates the methodology and conclusions of a recent study by Frank and Sudarshan[1] which links the decline of vulture populations in India to an estimated half-million excess human deaths between 2000 and 2005. Utilizing data from India's Civil and Sample Registration Systems, Frank and Sudarshan attributed the claimed rise in human mortality to the ecological consequences of vulture loss, notably increased feral dog populations and associated rabies, waterborne diseases, and other health hazards. By examining the data reliability as well as independent analysis of the same data, we identify significant limitations in data reliability, potential confounding factors, and the robustness of the study's statistical assumptions. Our findings question the strength of the patterns themselves and further the soundness of the causal claims, suggesting that improvements in mortality records and many other factors may potentially explain the observed trends. With the current limitations of data, there is no reliable way to estimate quantitatively the human health consequences of vulture decline.

On 15th July 2024, a piece of health news appeared in Science[2] claiming that the decline of vulture populations in India caused excess human deaths of the order of 5 million during 2000 to 2005. Since a prestigious magazine like Science gave coverage, the news suddenly became a headline globally. This news was based upon a paper accepted in the American Economic Review, subsequently published in the October 2024 issue[3]. However, the report of the work leading to this conclusion was published as a working paper by the Becker Friedman Institute for Economics at the University of Chicago in Jan 2023[1]. The working paper is in the public domain, and the upcoming paper in AER was kindly made available to us by the editors of AER and the authors prior to publication.

A careful reading of both papers reveals several problems, weaknesses, and limitations in the analysis. Since it attracted wide media attention, the paper is likely to create wrong impressions in readers' minds. We had correspondence with the editors as well as the authors about many issues, and although we agreed on some of them, a difference of opinion remained about one major issue. We completely agree about the conservation value of vultures, the alarming decline in vulture populations in India, the association of vulture decline with the use of the commonly used analgesic diclofenac, and the possibility of ecological and public health costs of this loss. Not only do we support vulture conservation efforts, but some of the authors of this commentary are actively involved in an organized attempt towards community conservation of vultures in parts of India. So there are many grounds on which we agree. The difference is mainly about the quantitative estimates of human deaths, which is at the core of the F and S paper. They estimated that the death of about half a million people during 2000 to 2005 could be because of the spread of infectious disease owing to vulture decline. They claimed that the feral dog population increased in India because of vulture decline, leading to an increase in rabies. Vulture decline increased water pollution, leading to an additional threat to human life. To support their claim, they used data in an interesting way. Taking the district as a unit, they classified the country into areas that were suitable or unsuitable for vulture populations prior to the decline. Further, they claim that districts that were suitable for vultures experienced a greater decline in populations and, so, a greater threat to health. Areas that were already unsuitable for vultures presumably did not experience much change. With this assumption, they show that the death rates in vulture-suitable areas increased between 1993 and 2000-2005 as compared to unsuitable areas. Based on the mean difference, they estimated half a million deaths attributable to vulture decline.

We feel that although the thinking behind the analysis is novel, the actual analysis is based on unreliable data and inadequate care in analysis. Since the authors kindly gave us access to their raw data, we analyzed it independently, and our conclusions do not coincide with the authors'. Therefore, it would be appropriate to make both views available to readers. Since the norms of the journal American Economic Review do not allow sound and logical scientific debates, we need to publish our analysis separately. We would also like to invite an open debate on the soundness of the science behind the F and S paper.

The disappearance of any species is bound to trigger a number of ecological changes. Alterations in human ecology and economics should not be surprising. However, estimating the extent of damage is not as simple as treated by Frank and Sudarshan[1][3]. They rightly recognize that establishing cause-effect relationships in complex ecosystems is not easy and have tried to take much care to support their analysis, but many caveats still remain, raising doubts about the robustness of their conclusions. We need to examine more carefully (i) the reliability of the data sources used for the given purpose, (ii) apparent contradictions between alternative sources of data, (iii) alternative causal interpretations of the observed trends, (iv) the heterogeneity of contexts over different parts of the land, and (v) the sensitivity of the statistical results to the specific assumptions and methods used. The paper by F and S is weak on all five grounds, as described below.

Data reliability: First, the main source of data used by F and S, namely the Civil Registration System (CRS) and Sample Registration System (SRS) death records in India, has been seriously questioned for its representativeness, completeness, and consistency with other sources of data, recently in the context of the pandemic deaths in India[4][5][6][7][8]. Data sources with known limitations in one context should be carefully evaluated before extending their reliability to other applications, especially when making causal inferences. The system of birth and death registration in India has many known limitations and has been undergoing gradual changes over decades. Some temporal trends could just be a result of the changing system. An example could be the nomadic communities, which constitute about 7 percent of the population in India, whose cultural norms and practices have been changing rapidly. One of us (SK) has been actively studying livestock and nomadic pastoral communities, and his anecdotes suggest that deaths in these communities are coming on record increasingly frequently. Death rituals and the disposal of dead bodies in these communities have also started getting increasingly compliant with the mainstream systems. Since the distribution of nomadic populations is uneven, this will be reflected in the recorded deaths in some areas more than others. The overlap between pastoral communities and vulture habitats is also not surprising. The death records in different parts of India have different degrees of biases, and area comparisons are therefore prone to multiple confounding factors. In a later section, we will show using a differential prediction approach that it is possible to segregate the apparent increase in mortality rates owing to improved registration systems and those from a genuine increase in mortality.

The second crucial data source for the F and S analysis is about vulture distribution in India prior to the decline. It is based only on overlaps with range maps obtained from BirdLife International[3]. The map data are not a result of consistent sampling efforts with standardized methodology across the country. The records are observational, for which efforts are heterogeneously distributed. Furthermore, there is substantial literature showing the limitations of species distribution models and the possibility of generating misleading conclusions by relying too much on a single source and single method of making distribution maps[9][10][11][12][13][14]. One challenge in generating species distribution maps from observational data is as follows. Figure 1 shows a hypothetical distribution of sightings of a species with either well-designed or convenience sampling. A distribution map has to be constructed by joining the outermost dots, but what can be considered outermost is an unresolved problem. Following some consistent rules, such as making a minimum convex polygon, can lead to consistency across studies, but there is no guarantee that they represent reality. A slight difference in the norms used in mapping can give very different outlines, as seen in figure 1. The edge errors of distribution maps are difficult to estimate. For species such as vultures exhibiting foraging movement over large areas, the errors are expected to be particularly large.

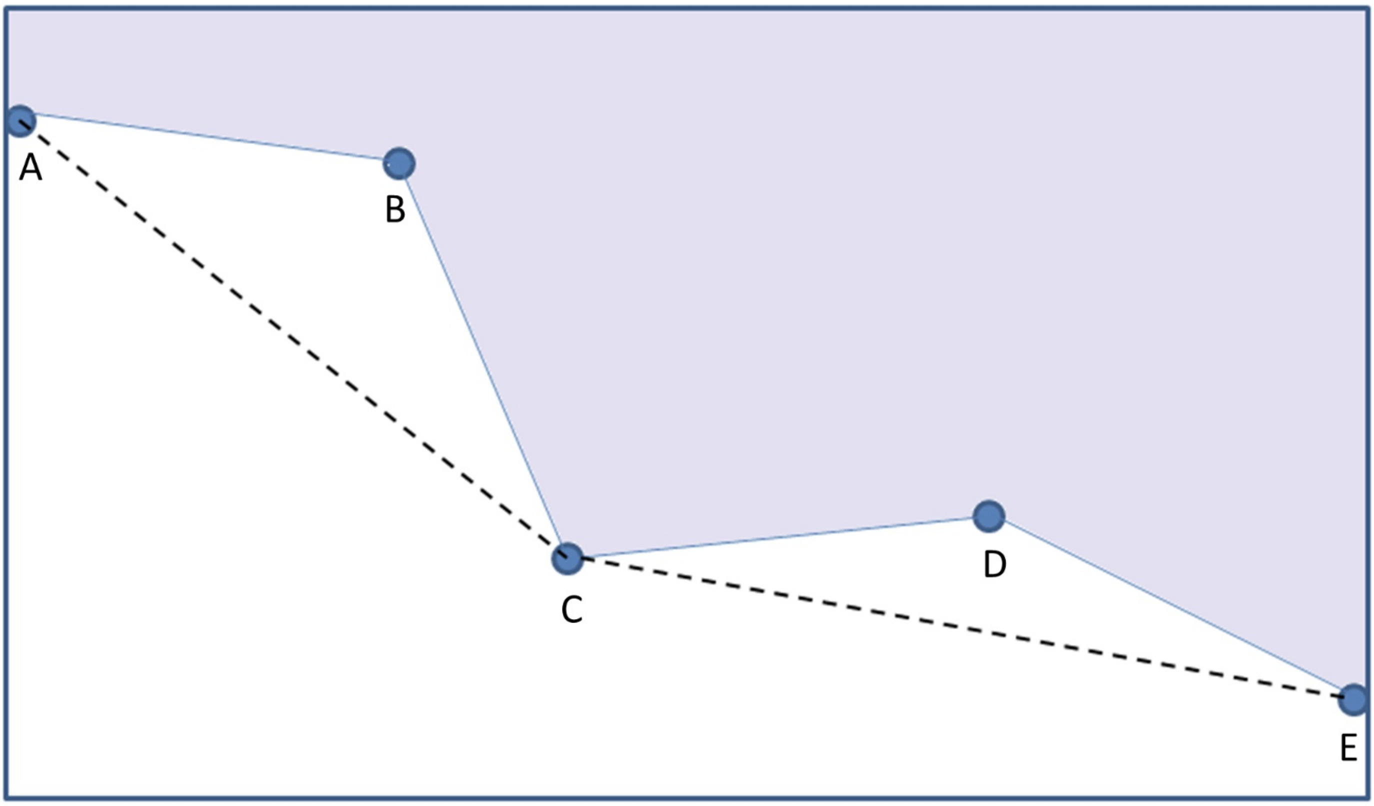

Figure 1. *The edge uncertainties of distribution maps: Edges of distribution maps are difficult to ascertain based on sighting records. In the*

hypothetical map above, the grey area is where the species is present. A, B, C, D, and E are the outermost observation points. The edge can potentially be represented by joining ABCDE, ABCE, ACDE, or ACE. There is no way to ascertain which one correctly represents the edge. Generally, certain norms are followed, such as making a minimum convex polygon. But the convention does not necessarily represent reality. Therefore, the edges of distribution maps are prone to errors that cannot even be estimated.

As a result, although distribution maps constructed from observational data are considered to give a fair amount of reliability about the net distribution area, they are particularly error-prone regarding precise boundaries and the extent of overlaps[15][16][17]. The F and S analysis relies extensively on overlaps and therefore can be substantially error-prone.

F and S also use livestock density data, although somewhat less crucial for the major conclusions. In India, livestock belonging to nomadic pastoral communities has not been quantified, and 2024 will be the first year that there is a plan to survey livestock of nomadic communities[18]. Nomadic communities are unevenly distributed among states and districts and therefore are likely to create substantial confounding. Therefore, this data source also has a big and important gap.

If the data sources are incomplete, biased, or unreliable, no sophistication in analysis can correct it. This is a well-known principle in statistics called GIBO (Garbage in, garbage out)[19][20][21][22]. Complex analyses may not fully address limitations in data quality, as evidenced by ongoing challenges in estimating COVID-19 mortality in India. This controversy is based on the same data source used by F and S, which no analysis has been able to resolve[4][5][6][7][8]. Furthermore, there is another set of problems when data collected for one purpose is used to address another unrelated question[23]. When more than one source of data is used in analysis, the reliability of the least reliable of the sources matters[24], and here the death records data and vulture distribution data compete fiercely with each other for unreliability. Therefore, it needs to be realized that the attempts to quantify human deaths as a result of vulture decline stand on the foundation of highly unreliable data sources.

Compatibility versus contradiction with alternative sources of data: If a given source of data has some weaknesses, a good approach is to check whether alternative sources of data converge on similar inferences. Unfortunately, that is not the case here. F and S give rabies as one of the possible infectious diseases that could have increased as a result of vulture decline. The trend in rabies incidence in India[25][26] has shown a consistent decline in the decades accompanying vulture decline. Rabies incidence has certainly not increased as claimed by F and S. Waterborne diseases, other infectious diseases, and overall death rates in India also have a declining trend during these decades[27][28]. The F and S analysis depends upon the relative trends in vulture-suitable and unsuitable districts, but here too, other sources of data are contradictory. For example, Rubeshkumar et al[26] give state-wise incidence of rabies, and we can see that states with minimum districts suitable for vultures according to F and S analysis, such as Kerala and Tamil Nadu, have much higher incidence than states with almost all suitable districts, including (prior) Bihar. Anthrax is another infectious disease possibly implicated, as mentioned by the authors. Anthrax generally takes the form of sporadic outbreaks, and therefore the time trends are chaotic. But the geographic locations of the outbreaks in the past three decades[29] reveal that over two-thirds of them were not located in the high-risk districts as depicted in figure 2 of the F and S paper.

The classification of districts according to suitability for vultures is also incompatible with other bird distribution data sources available. The suitability maps shown in figure 2 of the paper do not agree quite well with other sources of vulture distribution data such as Bird Count India[30] and the State of India's Birds[31]. Interestingly, many of the districts in which the residual populations of vultures are still breeding naturally are labelled as unsuitable for vultures by F and S. Anecdotally, where we (MW and PM) have seen abundant nesting of vultures prior to the decline has been labelled unsuitable for vultures by F and S. When there is inconsistency between different sources of data, it reflects the poor reliability of data, and sweeping claims should not be made based on such data. Thus, many of the claims made in the paper by F and S do not converge with alternative data sources.

Alternative causal interpretations: Some of the causal links speculated in the paper have alternative plausible causal factors. For example, an increase in sales of the rabies vaccine can simply be due to increased awareness and availability of health services in rural India. The policy of handling feral dogs has undergone a major change in India over the last three decades. In response to animal welfare activism and a series of court petitions, capture or culling of feral dogs was largely replaced by vaccination and castration, but the castration drive has not been efficient enough to control the feral dog population[32][33][34][35]. So if feral dogs have increased, factors other than vulture decline could also be responsible. The above studies examining feral dog populations in India haven't found vulture decline as the primary cause of the increase in the dog population. In the absence of recognizing and comparatively weighing alternative causal hypotheses, jumping to a single causal inference makes the case very weak.

When the population-weighted death rate of a district increases, there are two distinct alternative classes of causes. One is that the true mortality rate has increased, and the other is that the system of death registration has improved, bringing a greater proportion of deaths on record. The efficiency and accuracy of the death registration system have been widely different across areas, and therefore the apparent rise due to improvement will have wide variance across districts. Unless the two alternative causal interpretations of increased apparent mortality are not comparatively weighed, the area-specific cause of the rise in mortality cannot be inferred. We attempt to do this with data in a later section.

Heterogeneity of contexts across the land: Given the cultural, ecological, and economic heterogeneity of India, dividing the entire land by a single criterion based on a single data source and comparing an error-prone parameter between the two classes is likely to invite many known-unknown confounding factors. In our analysis described in a later section, we try to take care of the spatial heterogeneity effect in the best possible way we could think of.

The practice of disposing of carcasses differs substantially in different parts of India. One of the authors of this paper (PM) has been connected with a community-driven in situ conservation movement for vultures in coastal Maharashtra State for over 25 years. This effort has resulted in remarkable success in restoring natural vulture breeding. In this experience, the limiting factor in breeding success has been the availability of carcasses[36]. In the state of Maharashtra, a village cleanliness drive undertaken by the state government changed carcass disposal practices substantially. The vulture conservation movement had to undertake a special drive to make carcasses available to vultures in the form of "vulture restaurants." So, the impression that excess carcasses remained unconsumed after the vulture decline is not equally true for all parts of India.

Our analysis of raw data made available by F and S:

For the time being, let us forget about the data reliability issue and see whether, by independent analysis, we get results that support the conclusion of F and S about excess human deaths caused by the vulture decline. At our request, F and S kindly made their raw data available to us, which we could analyze independently. Our objective was not to repeat the analysis exactly the same way but to test the robustness of the conclusion under a slightly different set of assumptions and different but equally logical and careful statistical approaches. It is possible to adopt different and equally valid statistical approaches for a given problem. If the statistical inference varies substantially with alternative approaches, the inferences should be considered fragile. Strong and robust patterns should turn out to be significant by all valid alternative statistical approaches.

We do not intend to present a conclusive picture of what emerges from our analysis. Since the data sources themselves are unreliable, we do not make an attempt to infer anything. Our intention is only to examine if we analyze the same data with alternative approaches, whether the inferences remain the same. We only present here some illustrative examples of how alternative approaches lead to different patterns.

We examine the following alternatives:

i. Instead of dividing the districts into suitable and unsuitable for vultures, we take the index of vulture distribution overlap with districts as a continuous variable and see whether it correlates with the difference in population-weighted mortality. Making two or more categories from continuous data amounts to a partial loss of data. Correlations use the entire data more elaborately. Correlation has the advantage that it is less sensitive to outliers than the comparison of two group means. Further, non-parametric correlations are substantially robust to outliers.
ii. F and S take the average of distribution overlaps of three species. We did not understand the logic of taking the average. Even if one species of vultures is present in an area, the ecological service of scavenging is available. Therefore, for any district, taking the one with maximum overlap would be ecologically more meaningful. Nevertheless, we use both average and maximum overlap indices to see whether the inferences are different by either consideration.
iii. To reduce variability at the baseline itself, we calculated three-year average death rates as a baseline, in addition to using 1993 data alone, to assess the impact of averaging on results. Averaging out is expected to reduce stochastic noise, if any.
iv. The most important component of our analysis is the attempt to differentiate between the two causes of the apparent change in the population-weighted death rates with time. It is possible that the change is because of gradual improvement/alterations in the system of death registration. Owing to increased communication infrastructure and protocols for the digitization of data gradually reaching remote areas, the death registration system has been improving over the years, although still not error-free everywhere. Deaths on record may increase simply because of improvements in the system. The other possibility is that of a genuine increase in death rates in some districts as per the vulture decline hypothesis. Both causal factors operate on the background of a decline in mortality and increased life expectancy all over India[28].

We take a differential testable prediction approach to differentiate between the two causal hypotheses. If there was a difference in the death registration efficiency across districts and there is a gradual improvement, then greater improvement is expected in districts with lower efficiency. Areas already having a good system are less prone to change. If this is true, the coefficient of variation (CV) in population-weighted death rates is expected to decrease with time. On the other hand, by the vulture decline hypothesis, if the death record for the baseline year is independent of vulture abundance and after the decline the death rates in certain districts are increasing but not in others, the CV is expected to increase. The second testable prediction is that the former hypothesis expects a negative correlation between population-weighted death rates at the baseline time and the difference in them with time. On the other hand, if death rates are genuinely increasing in multiple districts, more of the excess deaths are likely to be reported in areas with a better system and less in areas with poorer systems. This is expected to give rise to a positive correlation between baseline death rates and the difference over time. The mutually contradicting testable predictions not only allow us to distinguish between the two causal hypotheses but, if both are simultaneously present, then data can be corrected for the former in order to test the latter hypothesis.

Results of our analysis:

We observe that the CV in population-weighted death rates decreases with time, independent of whether we take 1993 as the baseline or take a three-year average of 1993-1995 or of 1996-1998. We also note that the population-weighted death rates have a positively skewed distribution with many outliers. Further, across districts, the correlation between baseline population-weighted death rates and the difference with time is consistently and strongly negative (Figure 2). This indicates that the increase in the accuracy of death records explains a substantial part of the apparent increase in mortality. We take the residuals of the best-fit regression and treat them as death rates corrected for the increased efficiency of death registration. We use these residuals for further observing the relationship with vulture suitability.

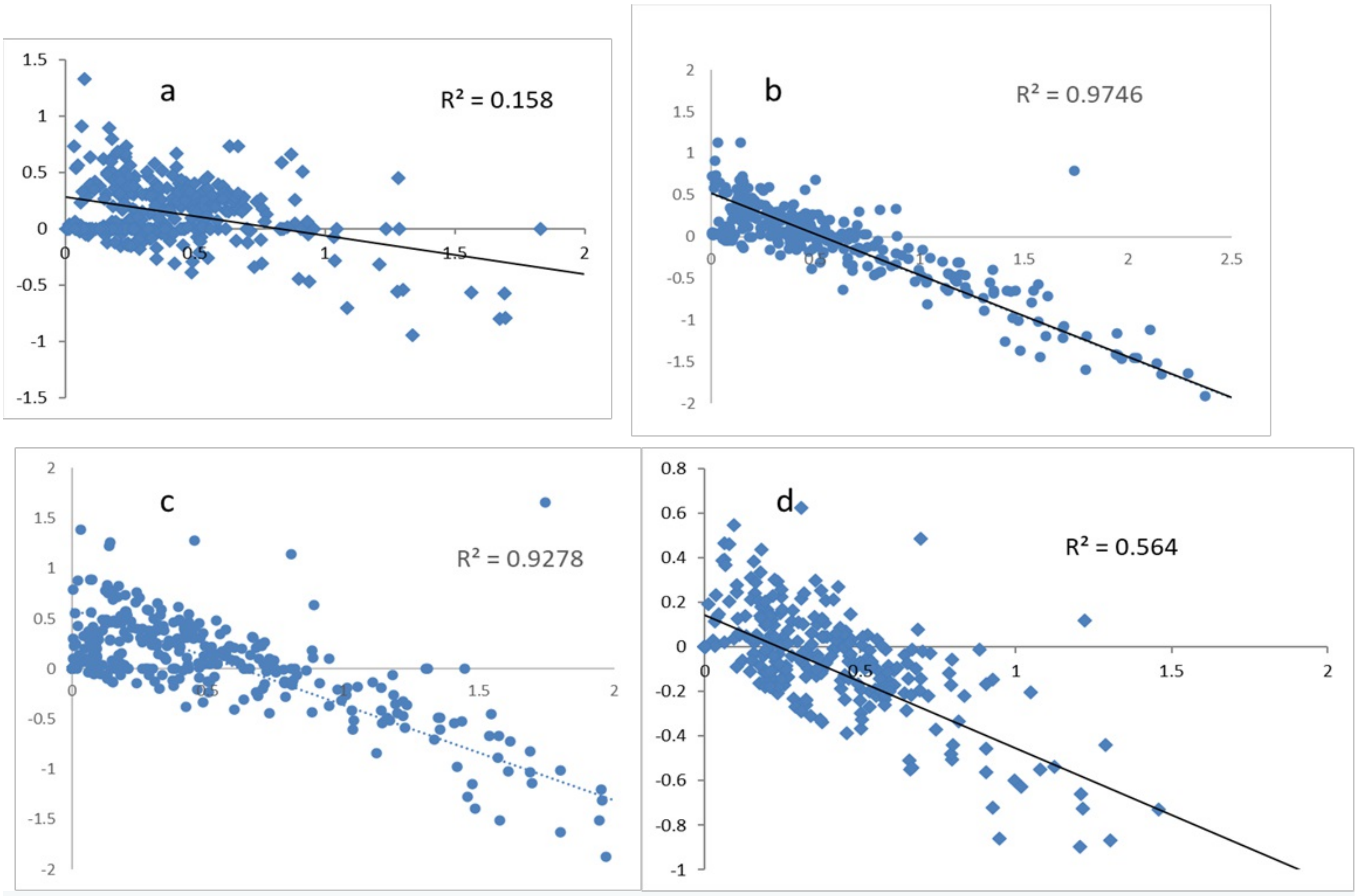

Figure 2. *Examples of the correlation between baseline population-weighted death rates (on the X axis) and the difference with one of the following years (on the Y axis). There is a consistent negative correlation explaining a substantial part of the variance in the difference. This is compatible with the hypothesis that alterations in death registration systems caused a significant part of the difference.*

a. Average 1993-95 as baseline, difference with population-weighted death rates of 2015.

b. Average 1996-98 as baseline, difference with population-weighted death rates of 2002.

c. Average 1996-98 as baseline, difference with population-weighted death rates of 2015.

d. 1993 as baseline, difference with population-weighted death rates of 2003.

We use the vulture distribution overlap data with the three common species as calculated by F and S. We did not calculate it afresh from the maps. If we assume that the presence of at least one species is enough for the important ecological service of scavenging, then 81.6% of districts have full overlap (i.e., an index of 1), and only 18.6% of districts have partial overlap (an index < 1). Even the ones with an index <1, the majority have >0.95. Given the inevitable edge error in distribution mapping, whether 0.95 is different from 1 is questionable. Only 5.1% of the districts have overlap < 0.95. Thus, if the assumption that one species of vultures is sufficient to fulfil the ecological role of vultures holds, then there are hardly any districts with low vulture "suitability" for any meaningful comparison.

If we forget the "at least one species" logic for the time being and use average overlaps with three species as used by F and S, the districts having an index of 1 reduce to 57%. If we take > 0.95 overlap as suitable, nearly 75% are suitable. But leaving aside the question of whether 0.95 and 1 are ecologically meaningfully different, we analyze using groups having overlap index 1 versus having <1, making the group sizes more comparable.

With the death rates corrected for the increased efficiency of reporting, we find no significant correlations of vulture suitability with the difference in population-weighted death rates at any point in time between 2001 and 2015. This is true whether we take the baseline rate as in 1993 alone or the three-year average 1993-95 or 1996-98. If we use data without the above correction, the correlations (parametric or non-parametric) still remain non-significant. If instead of correlations, we make two groups of index 1 and <1, the group with index 1 has a higher mean in most comparisons, similar to what F and S report. But we do not find this pattern consistently in the medians. Given the skewness of distributions, medians need to be considered more reliable than means, and by this standard, the F and S conclusion breaks down.

In addition, we also observe that in 1993 itself, the population-weighted death rates in the suitable versus unsuitable groups are different (Figure 3). The group means are significantly different by a one-tailed t-test (means 0.387 and 0.464 respectively, one-tailed p by unpaired t-test without assuming equal variance = 0.0259), but the medians are not different by a non-parametric comparison (medians 0.345 and 0.375 respectively, Wilcoxon two-sample rank test p = 0.35). Similarly, correlations (parametric as well as non-parametric) between vulture overlap indices and population-weighted death rates are not significant.

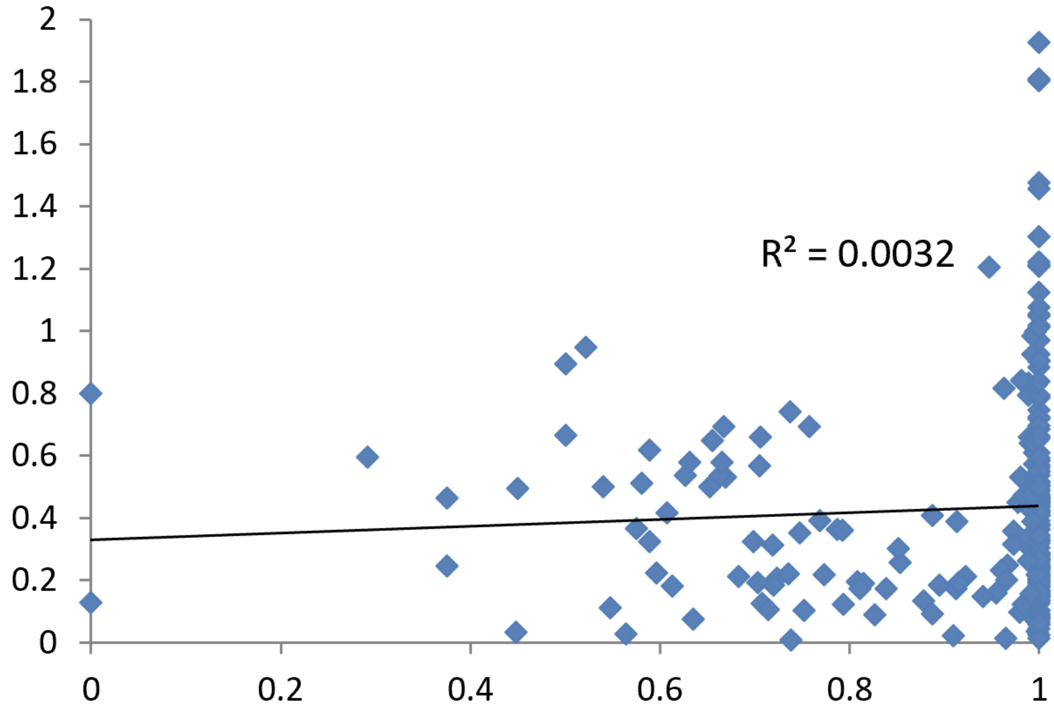

Figure 3. *The relationship between the average vulture distribution overlap index (taking three species) and the population-weighted death rate in 1993. Note that there are many outliers at the overlap index of 1. This gives a significant difference in death rates if we make two groups with the overlap index <1 and 1 (Means 0.387 for the group <1 and 0.464 for 1, significant by t-test p = 0.026). However, the correlation is not significant. Note that in 1993, no vulture decline was reported, which indicates the possibility of factors other than vulture decline being responsible for the difference.*

If we ignore the correlation and median-based non-parametric comparisons for the time being and go by the F and S approach, the finding that 1993 already has a difference in suitable versus unsuitable districts has an important implication. Since any notable decline in vultures was yet to begin in 1993, there are likely to be factors independent of vulture decline that could be causing differential death rates between the two groups. This strengthens our suspicion that in the complex interaction of ecology, public health, social, cultural, and governance systems, the dynamics of the vulture population is likely to be correlated with some other factors and cannot be assumed to be independent. These factors might have continued to act differentially post-1993, and the apparent differences in vulture suitable and unsuitable areas could be the effect of these unknown factors. We have no idea of what these factors are and whether they work additively, multiplicatively, or in any other way. Since F and S take the difference in death rates from the baseline, an additive effect may be assumed to be taken care of. But if it is anything other than additive, taking the difference may not be an adequate solution.

We also consider the possibility that the differences that F and S find are because of the heterogeneity between different parts of the land. In order to minimize the effect of heterogeneity, we compare the difference in population-weighted death rates between vulture suitable and unsuitable districts of only one state at a time. We performed this analysis for 2003 and 2005, taking 1993 as the baseline and taking the states having at least 20 districts and death record data for both the years being compared. Since the sample size becomes small in state-wise comparisons, we do not expect statistical significance separately for every state. We see only whether the average difference in population-weighted death rates is greater in districts with an overlap index of 1 than in those with <1. We find that for 2003, out of the 10 districts that allowed comparison, only 4 satisfied this condition. For 2005, 11 districts allowed comparison, out of which 6 satisfied this condition. This is most likely to happen by chance alone. There are substantial variances in vulture overlap indices between states (for example, Madhya Pradesh having almost all districts with an index of 1 and Tamil Nadu with the majority of districts with <1). With carcass disposal practices as well as death registration systems being substantially different between states, the difference that F and S obtained may just reflect differences among states.

In short, if we do the analysis with a different set of assumptions, or an alternative statistical approach, the inferences do not remain the same. This indicates that the inferences are fragile. Shortly, in addition to unreliable data, inconsistency between data sources, plausibility of alternative causal inferences, and the fragility of statistical inference itself, together indicate that the estimate of excess human deaths due to vulture decline is unlikely to capture reality. Our analysis cannot be taken to mean that vulture disappearance caused no human health effects, since the data sources themselves are unreliable. The same is true for the F and S analysis. So we refrain from making a definitive conclusion about the effect of vulture decline on human deaths. But at the least, our analysis raises doubts about the inference that vulture decline caused the claimed excess human deaths. We do not rule out the possibility that some public health consequences of vulture decline could have been there. But we should only say that we do not have sufficient and reliable data to estimate the effects quantitatively. Nevertheless, owing to the news coverage of the F and S paper by Science magazine and subsequently by global media, a misleading impression is likely to remain in the minds of people. Science should avoid the temptation of headline hunting with weak evidence. Therefore, it is necessary to emphasize the slippery nature and marginal reliability of the quantitative conclusions.

We have no doubt that the loss of vultures is a serious problem and that restoration measures are badly needed. People are already supportive, and vulture restoration attempts are taking good shape in many parts of India. Therefore, support for vulture conservation need not be based on exaggerated claims with a weak foundation from questionable data.

Conflict of interest statement: The authors declare no conflict of interest. In fact, there is a convergence of interests. We agree with F and S on the ecological value of vultures and the need for conservation and restoration. It is only in the interest of science that we need to point out the inadequacy and unreliability of the quantitative conclusions.

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