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Can Bayesian Statistics Be Used to Analyze Phenomena in Folk Zoology?

Floe Foxon

Folk Zoology Society, PO Box 97014, Pittsburgh, PA, 15229.

floefoxon@protonmail.com

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In a recent issue of the *JSE*, Bauer (2022), using a Bayesian approach, argued for high odds of Loch Ness Monsters being real but unidentified animals. In this *Letter*, an alternative interpretation of the data is respectfully provided as balance for interested readers who may be less familiar with Bayesian statistics and the underlying assumptions.

The Bayesian approach to 'updating' odds in light of evidence (sometimes called the 'diachronic interpretation') is as follows.

1. The first step is to define a hypothesis H. In the case of the analysis by Bauer, H is the hypothesis that unknown Loch Ness animals are real. Conversely, 'not H' or the 'complement' of H is the hypothesis that is in some way opposite to H and is denoted H^c. In this case, H^c is the hypothesis that these animals are not real.
2. The probability of H is the 'prior probability', denoted $P(H)$. The odds of H are the 'prior odds' defined as $O(H) = P(H)/[1-P(H)]$. Similarly, the probability of H^c is $P(H^c)$, and the odds of H^c are $O(H^c)= P(H^c)/[1-P(H^c)]$.
3. Next, evidence relevant to H is collected. In the case of the analysis by Bauer, these are the five lines of evidence: (1) eyewitness reports, (2) surface photographs, (3) moving films, (4) sonar findings, and (5) underwater photographs. These are the 'data', each denoted D.
4. For each D, the probability of D under H is found. These are the 'likelihoods', denoted $P(D|H)$. Conversely, the probability of D under H^c is found and denoted $P(D|H^c)$. The ratio between these probabilities is the 'Bayes factor', $BF = P(D|H)/ P(D|H^c)$.
5. The prior odds are successively multiplied by each Bayes factor to obtain 'posterior' odds given D, denoted $O(H|D)$. This is the process of 'updating' the prior odds. In the case of the analysis by Bauer, $O(H|D)= BF_1 X BF_2 X BF_3 X BF_4 X BF_5 X O(H)$.

In the original article, Bauer acknowledges that "[t]he nature of the evidence does not allow for definitively quantitative calculation of Bayes Factors" (step 4 above), and herein lies a very serious complication in applying Bayesian methods to Loch Ness, and by extension, similar cryptozoological phenomena.

As described above, the posterior odds are, by definition, the mathematical product of the prior odds and Bayes factors. If the Bayes factors are >1, then the posterior odds are necessarily greater than the prior odds, as is the case when the evidence supports H. Conversely and crucially, if the Bayes factors are <1, then the posterior odds are necessarily *less than* the prior odds, as is the case when the evidence does *not* support H, and indeed goes against H. Thus, while Bauer correctly argues that the "starting point $[P(H)]$ matters not very much," the likelihoods (and so the Bayes factors) matter tremendously.

Because we cannot definitively calculate the Bayes factors, Bauer assumes in the original article that each of the five lines of evidence provide Bayes factors > 1, and so support ***H***. This assumption necessarily leads to posterior odds greater than the prior odds, even when starting with a "pessimistic, disbelieving" prior probability. In other words, Bauer describes the scenario in which the evidence is "reflected in a somewhat positive Bayes Factor that would modify the low prior probability to a somewhat higher posterior probability."

The testimonial and circumstantial evidence (i.e., non-autoptical evidence) characteristic of cryptozoology is certainly interesting and, in some cases, may well warrant serious scientific exploration, but many authors offer a different interpretation of the Loch Ness data to the one presented by Bauer. Those authors argue that the Loch Ness evidence, which includes hoaxes and cases of mistaken identity, do*es not* support the hypothesis that unknown Loch Ness animals are real. In that case, the data would be reflected by Bayes factors < 1 that would modify the low prior probability to an even lower posterior probability, precisely the opposite result to that of Bauer.

Bayesian analysis represents strong statistical theory, but when applied in this way to Loch Ness, this approach fundamentally boils down to the same question as in all cryptozoological debates: Does cryptozoological evidence support the existence of ethnoknown animals not recognized in conventional zoology? Cryptozoologists may argue 'yes' and assume Bayes factors > 1. Skeptics may argue 'no' and assume Bayes factors < 1. By assuming Bayes factors >1, the analyst implicitly assumes that eyewitness reports, sonar findings, and photography *do* support the existence of Loch Ness Monsters. If, however, these lines of evidence are contested, then the opposite conclusion can be drawn. The Bayesian argument in this context is a circular one; if we assume *a priori* that the evidence supports the existence of Loch Ness Monsters (Bayes factors > 1), then the posterior odds will be high, and the Bayesian approach will support the existence of Loch Ness Monsters. If we instead assume *a priori* that the evidence does *not* support the existence of Loch Ness Monsters (Bayes factors < 1), then the posterior odds will be low, and the Bayesian approach will not support the existence of Loch Ness Monsters.

While the original article does admit that "many people have misinterpreted natural phenomena," that "there are many ways to be fooled into thinking one has seen a Nessie when one actually hasn't," and that no known animal forms "fit comfortably with all the evidence," the case of Bayes factors <1 was not explored in that work. Bauer laments that 'facts do not suffice to change long-ingrained beliefs', and this is surely true, but what of long-ingrained belief in Loch Ness Monsters?

In the absence of evidence that allows for definitive estimation of Bayes factors, Bayesian analysis provides limited insight for cryptozoology phenomena, at least for the kind presented at Loch Ness. In other contexts, such as in medicine, astrophysics, and perhaps certain other cryptozoological phenomena, Bayesian methods can provide valuable insight and should continue to be explored in future scientific works.

REFERENCES

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