Subjectivism as an unavoidable feature of ecological statistics

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Abstract

Subjectivism as an unavoidable feature of ecological statistics.— We approach here the handling of previous information when performing statistical inference in ecology, both when dealing with model specification and selection, and when dealing with parameter estimation. We compare the perspectives of this problem from the frequentist and Bayesian schools, including objective and subjective Bayesians. We show that the issue of making use of previous information and making *a priori* decisions is not only a reality for Bayesians but also for frequentists. However, the latter tend to overlook this because of the common difficulty of having previous information available on the magnitude of the effect that is thought to be biologically relevant. This prior information should be fed into *a priori* power tests when looking for the necessary sample sizes to couple statistical and biological significances. Ecologists should make a greater effort to make use of available prior information because this is their most legitimate contribution to the inferential process. Parameter estimation and model selection would benefit if this was done, allowing a more reliable accumulation of knowledge, and hence progress, in the biological sciences.

Key words: Ecology, Previous information, Frequentists, Bayesians, Parameter estimation, Hypothesis testing

Resumen

La subjetividad como característica inevitable de los análisis estadísticos en ecología.— En este trabajo abordamos la gestión de información previa al realizar inferencia estadística en ecología, tanto en la especificación y la selección del modelo como en la estimación de los parámetros. Comparamos las perspectivas que aplican a esta problemática la escuela Frecuentista y la Bayesiana, que comprende a los bayesianos objetivos y subjetivos. Mostramos que la problemática de utilizar información previa y tomar decisiones *a priori* no es solo una realidad para los bayesianos, sino también para los frecuentistas. Sin embargo, estos últimos tienden a pasar por alto esta cuestión debido a la dificultad habitual de encontrar información previa sobre la magnitud del efecto que se considera relevante desde el punto de vista biológico. Esta información previa debería utilizarse en las pruebas de potencia *a priori* para buscar los tamaños de muestra óptimos para alcanzar la significación estadística y biológica necesaria. Los ecólogos deberían hacer un mayor esfuerzo por hacer uso de dicha información previa, pues es su contribución más legítima al proceso inferencial. De esta manera, la estimación de parámetros y la selección de modelos se verían beneficiadas, lo que permitiría que el proceso de aprendizaje fuera más fiable y, por tanto, que las ciencias biológicas pudieran progresar.

Palabras clave: Ecología, Información previa, Frecuentistas, Bayesianos, Estimación de parámetros, Contraste de hipótesis

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It has become more and more common worldwide in academic departments of biology and several other sciences to question whether frequentist statistics is the right tool to solve our ecological questions or whether Bayesian statistics should be used instead (Efron, 1986; Clark, 2005; Fidler et al., 2006; Hobbs & Hilborn, 2006; Burnham & Anderson, 2014). Apart from the conceptual and methodological differences between these two approaches, a question of great interest in order to make best use of our costly–to–obtain field data is how to handle previous information when performing statistical inference in ecology.

Previous information and model specification

The first scenario in which ecologists are forced to use their previous knowledge, whether they are adopting a Bayesian or a frequentist point of view, is when performing model specification. For any ecological problem, it is important to set an adequate model to work with, and this decision implies some previous knowledge about the problem. Also, when we are selecting a model —and we cannot usually consider every possible model— choosing a set of adequate models from which to select the best one is also a matter of previous information (subjectivism). This step is important because the result can be biased by this decision. For instance, when adopting a frequentist approach, the whole process of model (= hypothesis) selection, based, for example, on Akaike's Information Criteria, could be biased if a wrong set of hypotheses has been previously selected. As a result, the best thing ecologists can do is to trust in their cumulated experience on the study question and system, and define and contrast the set of hypotheses that is most adequate with the information so far available.

Previous information and parameter estimation for objective and subjective Bayesians

Another scenario where it is necessary to handle previous information is when assessing data available for the parameters. In the Bayesian approach, this is done by introducing a prior distribution for the parameters, although in the frequentist approach this can be somewhat trickier, and sometimes cannot be done. Let's review how assessing previous information for the parameters can be performed in both frameworks. Making use of previous information is considered one of the main characteristics of Bayesian statistics. Within this framework, the Bayes' theorem is used to combine the likelihood (a function that measures our trust in a parameter value given our data) and prior information (*i.e.* the probability distribution of our parameter) to obtain a posterior probability distribution of our parameter given our data. Depending when and how we introduce our previous information, there are two approaches within the Bayesian framework. Subjective Bayesians argue that one can define a prior distribution for unknown parameters according to personal experience and impression, recognizing that the opinion of experts has a value and it is better than nothing. This is highly criticized by frequentists, who claim a more objective procedure. It is also one of the reasons why non–statisticians avoid Bayesian methods. An objective Bayesian approach is then an attempt to unify frequentist and Bayesian statistics, as pointed out by Bayarri & Berger (2004). Objective Bayesians defend the idea that no other information should be considered apart from that introduced during model specification. As stated in Berger (2006), 'the most familiar element of the objective Bayesian school is the use of objective prior distributions, designed to be minimally informative in some sense'. This procedure provides similar results (even exactly the same results under some circumstances) to classical frequentist analyses, although parameters are treated as random variables. In addition to allowing a non–subjective point of view, the objective Bayesian approach can also be useful in scenarios where choosing priors for our parameters is difficult or even unfeasible. For instance, in the presence of a large number of parameters a subjective specification of all priors could be too time–consuming. Alternatively, it would be more practical to invest time in improving model specification (Berger & Pericchi, 2001). However, whenever good previous information about parameters is available, it is important to make use of it, and the Bayesian subjective approach could be a good tool to achieve this goal.

Prior information and parameter estimation in frequentist analyses

In the frequentist framework, assessing previous information for the parameters is different from the Bayesian approach but, importantly, also existent. Many ecologists feel that this problem of dealing with previous information about parameters is not present when using frequentist methods. We think, however, that introducing this sort of previous information is the largest contribution that ecologists can make to the inferential process. The main situation in which one can introduce previous information about parameters in the frequentist world is when seeking the right sample size needed to test informed null hypotheses during the stage of experimental design. In this case, prior information about the magnitude of the effect that is considered to be biologically relevant needs to be introduced. The sample size can be chosen by running a priori power tests (note that here we mean 'a priori' power tests, rather than 'a posteriori' power tests, a highly criticized procedure). For this purpose, the magnitude of interest of the effect is used (Steidl et al., 1997; Thomas, 1997; Peterman, 1990; Nakagawa & Foster, 2004). Note that this sort of prior information is intrinsic to frequentist analyses because it is intended to maximize the power of the tests. In the Bayesian context, as by construction there is not power of tests, the issue of a small sample size is solved by incorporating previous knowledge through more informative prior distributions. The problem is that using a priori tests and the magnitude of effect is seldom done in the real world of ecological statistics, because ecologists seldom know the magnitude of the effect that corresponds to a biologically relevant effect is (*e.g.* Martínez–Abraín, 2007, 2008, 2014). This is easier to know in experimental (Beaumont & Rannala, 2004) and production–based sciences (such as animal breeding science (Blasco, 2001, 2005) than when dealing with free–ranging wild species. What is the biologically relevant difference between the wing lengths of two bird populations? We simply do not know. So basically, the vast majority of ecologists often cannot inform their analyses better (Martínez–Abraín, 2013). That is why we ecologists end up using uninformed null hypotheses of equality to zero (Anderson et al., 2000), and hence get the feeling that in a frequentist framework, the problem of dealing with previous information is not an issue. It is, however, but we are forced to overlook it and use null hypothesis testing in a poor way because of the types of problems and data we deal with.

Conclusions

Irrespective of which statistical inference approach one decides to use to estimate a parameter or to contrast hypotheses, one cannot avoid the uncomfortable step of making rather subjective decisions in the scientific process of solving questions. All the information from past experiments and observations, performed by ourselves or by others, is of great value, and it is the ecologist's task to make the best possible use of this information. To show a practical example that affects our research with Mediterranean seabirds, the finding by Ruiz et al. (2000) that the first egg in Audouin's gull *Larus audouinii* decreased in size by 5 cm^3 when food was particularly scarce during clutch formation is a valid piece of previous information that can and should be used when assessing differences in egg size between Audouin's gull populations in the future. In this case, we would use this value as a guiding clue when assessing if the difference in the mean egg size between two populations is biologically relevant. Specifically, we would perform a priori power tests, with 5 cm^3 as our effect size of interest (instead of using zero differences between populations as our default reference), and will determine the sample sizes required to obtain statistically significant results if (and only if) the difference between the two study populations is at least of that magnitude (5 cm^3). Alternatively, a 'safe' arbitrary minimum percentage of change in egg size could be established by consensus among researchers if we do not have a concrete reference value of effect size available from previous studies. This is, in fact, our most legitimate contribution to a process that, in all other respects, is in the hands of statisticians. It is good that we acknowledge for once that in the presence of previous information, we do have proper tools to handle it, and that both the precision of our parameter estimates and the results of our hypothesis contrasts can improve substantially if we focus more on this slippery but fundamental compartment of our daily research.

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