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Opinion

The Origins of Modern Species Distribution Modelling: Some Comments on the Vasconcelos et al. (2024) Review

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Abstract: A recent review of species distribution modelling (SDM) published in *Earth* contains much useful information. However, the introductory paragraphs lack basic information about the first SDM package called BIOCLIM, which became available in January 1984. For example, BIOCLIM-related advances underpinned the development of the most used SDM variables and data. The first SDM climate change studies published in 1988 highlighted the importance of ex situ and native distribution data. This brief note highlights the importance of the early SDM work and its continuing relevance.

Keywords: arid; BIOCLIM; climate; climate change; ecological niche modelling; species distribution models

A recent paper published in *Earth* [1] reviewed ecological niche modelling (ENM) and species distribution modelling (SDM), concentrating on studies in arid and semi-arid areas. It addressed nine key questions and provided a very useful overview. However, the introductory paragraphs and the cited references lacked important details about the origins of modern ENM/SDM that are still relevant to current studies (for examples of recent applications using some of the pioneering work, see [2,3]). The purpose of this brief note is not to revisit the nine aims of the Vasconcelos et al. review [1] but to highlight the following points: (i) Modern ENM/SDM began in Australia in 1984 with the creation of the BIOCLIM program. (ii) Improvements in the climatic interpolation methods made by the BIOCLIM group provided the basis for the most used source of SDM data. (iii) The set of 19 variables developed for BIOCLIM have become the most used SDM variables. (iv) The first SDM climate change studies were published in 1988 and still have great relevance for the current SDM studies. (v) Far from there being only one pertinent SDM reference for the period 1985–1999, as suggested in Table 2 of the recent review [1], there are many relevant arid/semi-arid BIOCLIM studies from this period.

Pioneering ENM/SDM studies date from 1924 [4] but were limited by their lack of dependable environmental data over broad areas. The BIOCLIM program became available in January 1984 [5,6] and provided reliable climatic data across the relatively arid continent of Australia [7,8]. The program collected species locational data (latitude, longitude and elevation) and the estimated mean monthly values for maximum temperature, minimum temperature, and precipitation for these locations. A set of bioclimatic variables, initially 12 and later extended to 19 in 1996 [9], was calculated. These included variables such as mean annual temperature and mean temperature of the wettest quarter (i.e., consecutive three-month period). The BIOCLIM program identified gridded locations that satisfied the range of suitable climatic conditions for the target species (For example, see Figure 1).

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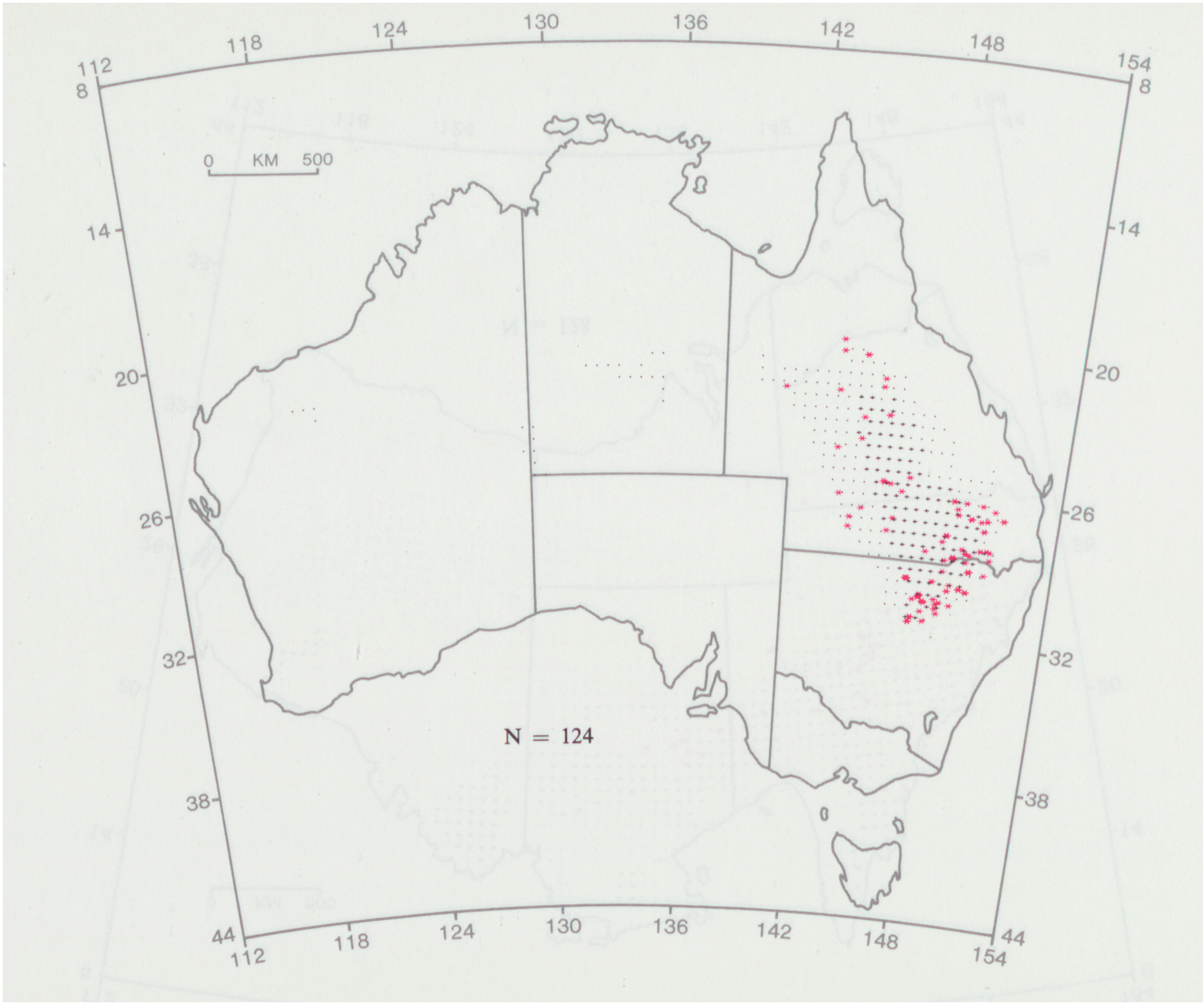

Figure 1. This figure shows 1 of 73 maps created for elapid snake distributions in 1986 using BIOCLIM. The data shown are for the De Vis' banded snake (*Denisonia devisi*). Red stars indicate 124 observed occurrence locations. The dark '+' symbols indicate core locations and the lighter '.' symbols indicate marginal locations where the species might also be found according to the BIOCLIM analysis (from [5]).

The lasting importance of BIOCLIM is in part related to the use of both the interpolation method [8] and the set of 19 bioclimatic variables developed for BIOCLIM [7,9] by the WorldClim team [10,11]. Unfortunately, the WorldClim papers [10,11] made no mention of BIOCLIM or the interpolated climatic surfaces that had been prepared by the BIOCLIM group for Australia, Africa, and much of Asia [7,12]. The set of 19 BIOCLIM variables from WorldClim has become the most used data and variables for SDM studies [13]. The recent review [1] cites the most highly cited SDM review paper [14] in its opening paragraph. However, this review by Elith and Leathwick was published in 2009, only a few years after the first version of WorldClim became available in 2005 [10]. So, Elith and Leathwick could not appreciate the important roles of BIOCLIM and WorldClim in underpinning modern SDM development.

The earliest SDM climate change studies were published in 1988 [15,16]. Though not for arid areas, these BIOCLIM studies indicated the desirability of considering not just species native distributions but also their ex situ climatic tolerance [17].

The recent review [1] found only one relevant arid/semi-arid zone SDM reference for the period 1985–1999. However, using the search terms 'BIOCLIM AND arid' in Google Scholar™ and a custom range of 1985–1999 identifies 223 studies for this period. Many of these studies would not be considered relevant for reasons described in the 'Search Query' section of the Vasconcelos et al. review [1]. However, these 223 papers have been cited a total of 17,311 times, which suggests at least some would be of interest to readers. Clearly, only citing one reference for the 1985–1999 period in the Vasconcelos et al. review [1] greatly underestimates the influence of the BIOCLIM package.

Effective developments of ENM/SDM depend on a good understanding of the early work. This can be illustrated by three examples. First, efforts have been made to expand the set of 19 variables [18] without understanding either their BIOCLIM origin [7] or that the BIOCLIM group extended the set to 35 variables in 1999 [9,19]. When used correctly with the expanded set of variables, the performance of the BIOCLIM algorithm has been rated as "good" in comparison to the "excellent" result produced by the widely used Maxent method [20] for both current and climate change conditions [21]. Second, relatively few current ENM/SDM climate change studies go beyond analysing only species native distributions [17]. For example, in a review of 125 SDM climate change studies of more than 500 tree species published between 1998 and 2017 [22], only 18 studies gathered data at continental or broader spatial extents. However, analysing ex situ climatic adaptability has obvious relevance for anticipating the likely effects of climate change on species [17]. Third, the BIOCLIM program [5–7] included the climatic interpolation relationships for Australia. Estimates of climatic conditions were made for the actual species occurrence locations and not for some gridded point in a climate database that may be hundreds of meters away and at a very different elevation.

The continuing relevance of BIOCLIM is well illustrated by the 2023 TreeGOER study [23]. This analysed the climatic and soil requirements of 48,129 tree species based on the analyses of data from more than 44 million occurrences. It used data for the 19 BIOCLIM climatic variables, as well as the BIOCLIM analysis method to describe their environmental requirements. The species analysed included some species found in semi-arid environments.

In conclusion, there is much useful information in the recent review [1], but readers would benefit from also being aware of the early SDM work on which much of the current work is based.

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