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Meiri, Shai

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The smartphone fallacy – when spatial data are reported at spatial scales finer than the organisms themselves

Shai Meiri^{1,2}

¹ School of Zoology, Tel Aviv University, 6997801, Tel Aviv, Israel

² Steinhardt Museum of Natural History, Tel Aviv University, 6997801, Tel Aviv, Israel
uncshai@post.tau.ac.il

Abstract. Thankfully, the days when specimen localities could be described in extremely vague terms such as “Peru” or “Indochina” are long gone. But the pendulum has swung too far the other way. Latitude and longitude data of specimens and study areas (such as small nature reserves) are nowadays commonly reported to the 0.000001 of a degree (or 0.01 of a second) or even more “precisely”. This is done either because of converting across measurement systems or because hand-held devices and internet sources provide this kind of precision. We probably report this degree of precision because we are reluctant to round – feeling it would make the data better and more “scientific”. I point out the scale referred to by different degrees of geographic precision (e.g., ~10cm for 6 decimal places) and argue that such degree of precision is false for two reasons: first, it is finer than actually achievable by hand held devices such as smartphones and GPS receivers (and much finer than we can tell from a map). Second, for large animals, such precision can refer to one part of the organism, and not another. I urge scientists to use simple reality checks when reporting latitude and longitude data and report precision at meaningful scales.

“In the various works on natural history and in our museums,” one of the founders of our science (Evolutionary Biology, Biogeography, you name it), Alfred Russel Wallace, complained:

we have generally but the vaguest statements of locality. S. America, Brazil, Guiana, Peru, are among the most common; and if we have ‘River Amazon’ or ‘Quito’ attached to a specimen, we may think ourselves fortunate to get anything so definite: though both are on the boundary of two distinct zoological districts, and we have nothing to tell us whether the one came from the north or south of the Amazon, or the other from the east or the west of the Andes. Owing to this uncertainty of locality, and the additional confusion created by mistaking allied species from distant countries, there is scarcely an animal whose exact geographical limits we can mark out on the map. (Wallace 1852)

No interesting biogeographical questions “can be satisfactorily answered till we have the range of numerous species accurately determined”, he rightly observed.

Indeed, not reporting the accurate and precise locality of a specimen sighting or collection locality for a natural history museum specimen may be the greatest sin you can commit against biogeography. Luckily, we have come a long way from Wallace’s

time (partially thanks to him) – now 8-year-old kids have GPS apps in their smartphones allowing them to know their location (“near the candy store”) much more accurately, and at much better spatial precision, than pioneers such as James Cook or Wallace himself. But perhaps our phones are lying? And, although accurate, are they now too precise to be useful, helpful, or even real?

I am a museum curator, a biogeographer, a macroecologist, a field herpetologist, and an obsessive data collector. So, I record and collect a lot of locality data from various sources, and spend way too much time georeferencing animal localities. This obviously must be done just right. We are scientists after all – we pride ourselves on being careful, accurate, and precise. We even hide our ignorance under a thick veil of precision – we want to give very accurate, statistical definitions of just how wrong we may be (at a given degree of certainty or type 1 error, a degree we generally pluck out of thin air).

And then there is physics envy. Too many of us think of physicists as engaging in superior science *because* they can be *very* accurate. Physicists (we biologists are certain) can measure the location, speed, and trajectory of an elementary particle (although obviously not at the same time!), or whatever it is that we imagine physicists do, to a level of precision we cannot achieve with anything biological let alone with an organism. So we play with numbers. And sometimes, just sometimes, we delude ourselves into thinking that if

Table 1. degrees of geographic precision and their meaning in distances at the equator and the 45th parallel (note that differences across latitude are in longitudinal distances, whereas traversing latitudes is approximately equal across latitudes)

Decimal places	Decimal degrees	DMS (degrees, minutes, seconds)	Distance at the equator	Longitudinal distance at the 45 th parallel
0	1.0	1°00'00"	111.3km	78.7km
1	0.1	0°06'00"	11.1km	7.8 km
2	0.01	0°00'36"	1.13km	787m
3	0.001	0°00'3.6"	113m	78.7m
4	0.0001	0°00'0.36"	11m	7.9m
5	0.00001	0°00'0.036"	1.13m	79cm
6	0.000001	0°00'0.0036"	113mm	79mm
8	0.00000001	0°00'0.000036"	1.13mm	0.8mm

we played with really small numbers, I mean almost particle physics-level small, we are helping someone.

I will argue here, or rant as I am prone to do, that when we biogeographers attempt to show that our numbers are incredibly precise, we are sometimes making fools of ourselves.

I am talking about the false precision we all too often attach to our observational data. We often report them with a ridiculous degree of precision. It is not just us who are to blame: there are other culprits. Our, excessively smart cellular phones, fancy GPS devices, our tendency to skip between systems of measurement (without rounding), and the almighty Google Earth, all suggest to us, not too subtly, that we can achieve remarkable spatial precision. But in reality, we are just being a little bit silly by failing to consider the meaning of the decimal places we report.

The reality is that our Earth circumference is just over 40,000 km long, and it is divided into 360 degrees of longitude and 180 of latitude. Thus, latitudinal degrees are about 111 km long everywhere (I deliberately avoid making more precise claims), and the distances between longitudinal degrees range between just over 111 km at the equator to nothing at all at the poles. Traversing Africa near the equator, say between Libreville to Kampala, you thus need to go approximately 2570 km to cross about 23 degrees longitude (~9.5° to 32.5°E). Setting out from Anchorage, Alaska, at roughly 61°N, and going east for 23 degrees you will stop walking after only about 1230 km (measured with Google maps). Thus, at 61°N, one minute of longitude will represent a distance of less than 2km, and one hundredth of a degree (if you, like me, prefer the decimal system) will be about 1 km (Table 1).

What about seconds? Well, if a degree at the equator is 111 km, then a geographic second will be 0.03 km or ~31 meters there. If you report decimal latitude to 4 decimal places, you are facing roughly a 10-meter precision (Table 1). This is a sound ecological scale. But the zoological literature is rife, with measurements

reported to 6 decimal places. In fact, journals that commonly report range extensions, such as *Check List*¹, a fantastic journal that is dedicated to such reports for all taxa, seem to have the gold standard set at 6 decimal places. This is a 10-cm scale. It is similar to that achieved by those reporting degrees, minutes, and seconds (DMS) locality data to 0.01 parts of the second (e.g., the .23 and .48 seconds in 31°24'58.23"N 34°44'45.48"E). This scale is useful for finding where you lost your keys or the branch you need to pull for that secret passageway to open (to the pit of despair maybe?), but for reporting where you caught a lizard? If you stood up, you would move more than 10 cm. If you brought the GPS device closer to your face to see better, you would change the position by more than 10 cm. And if all you could get is a photographic voucher, well, the locality you measure is more precisely associated with the locality of the photographer than of the animal; you should not even attempt achieving such high precision.

Of course, if you report a snake's position to 6 decimal places, 0.01 of a second or a 10 cm precision, you are in effect reporting whether you measured the location of its head, its mid-body, or its tail (Figure 1). Needless to say, when you chased the animal to the other side of the tree, you moved in a 4–5 decimal point scale (depending on how big your tree was), and if you chased it all across the dune, the spatial scale, it might have been coarser still. Ecologists trying to pinpoint individual sessile organisms may strive for 5–6 decimal places using high precision GPS or LIDAR systems (if the tree is not too big). Biogeographically it is meaningless.

Even if the animal keeps still, you usually cannot really get a 6-decimal point precision. While my \$200 phone is happily informing me of its position using 7 decimal points (~1cm), it cannot actually know its own location so precisely. How accurate is the GPS to start with? Well, this is an industry secret (or maybe just a question that does not interest users much),

¹ <https://checklist.pensoft.net/>



Figure 1. Michaela (left) and Adva (right) holding an adult *Elaphe sauromates* (middle). **(a)** The snake, about 1.50m in total length, is oriented along an east–west axis at the Garden for Zoological Research, School of Zoology, Tel Aviv University. **(b)** A Garmin GPS reading showed the head is at 34.80782E, while the tail **(c)** is at a more westerly 34.80780E, clearly demonstrating the need to say which part of the specimen you are referring to when reporting location data to silly degrees of precision.

but a 0.5–5 meters precision under good conditions is suggested² as a good estimate. Another estimate (Zandbergen and Barbeau 2011) is for “a median horizontal error of between 5.0 and 8.5 m, substantially larger than those for regular autonomous GPS units by a factor of 2 to 3.” This means that most handheld GPS devices and smart phones provide accurate estimates at 4 decimal places but become uncertain in the 5th decimal. Certainly, there are highly precise GPS devices that can do a little better. These, however, are large devices needing their own infrastructure (i.e., large tripods), and they are certainly not the small handheld devices most of us use for our data collection. Thus, if we use a handheld phone or GPS devices, stand still,

and are not obstructed (e.g., a snake attempting to bite which would make us jump), we live in a world of no more than 5-places after the decimal degree precision. But I can cite data published in the last few years, including some from highly (and rightfully!) respectable depositories such as Vertnet³ that report animal localities with 10 decimal points (e.g., the gecko *Pachydactylus waterbergensis*), probably as a result of converting data from degrees/minutes/seconds systems into decimal ones. Even without conversions, there are data with seven (another gecko, *Hemidactylus kangerensis* for example, in *Comptes Rendus Biologies*⁴), eight (e.g., two snakes: *Psammophis longifrons* in *Journal of Threatened Taxa*⁵, and *Trimorphodon vilkinsonii* in

² <http://www.gps.gov/systems/gps/performance/accuracy/>, last accessed on 01/04/2018

³ <http://vertnet.org/>, last accessed on 19/04/2017

⁴ <https://www.journals.elsevier.com/comptes-rendus-biologies/>, last accessed on 18/10/2017

⁵ <http://threatenedtaxa.org/>, last accessed on 30/11/2017

*Herpetological Review*⁶; I deliberately refrain from citing these papers – they are good papers) or even ninth decimal places (the snake *Lampropeltis ruthveni*; also in *Herpetological Review*⁶). These data are in the 1 cm, 1 mm and 0.1 mm scales. This is plainly ridiculous.

Apparent precision is not precision. In their classical paper on “the illusion of precision,” Graur and Martin (2004) claimed that if you do not pay attention to (temporal) scale and errors around estimates, “we might ultimately be able to tell whether the human–chimpanzee divergence occurred on a Monday or not.” Of course we cannot estimate divergence times to that sort of precision, but this is similar to what we do when we claim to pinpoint the locality of a lizard to the nearest 1 mm. In fact, we cannot even measure the snake’s length to such a degree of precision: Cundall et al. (2016) actually claimed that snakes “have no exact size”. But it is easy to forget this when we use a device that offers us an illusion of greater precision.

I suggest that if you only know the village where you have seen an animal, 2 decimals is probably the best you can hope for. If you are at a plot, you are usually safe with 3 decimals. If you run after the creature, you are ok with 4 decimal places. If you are at a cave entrance or water hole, 5 may just be ok (if you trust your GPS). Six decimal places tell you which side of the snake it is you recorded (Figure 1). Personally, I fix a point when I collect the first animal, the next probably 100–200 meters from there, so 3 decimals usually work best for me. Lobo et al. (2006) tried to estimate the movement of the dung beetles they studied and arrived at a figure of 1km (obviously when flying, not chasing balls around). They thus recommend working with this degree or spatial precision for these fascinating mobile insects, roughly a 0.01 of a degree or 1-minute scale.

Often, however, we cannot even be that precise. When dealing with verbal descriptions such as those accompanying many museum specimens — or given in papers by less than biogeographically minded authors — we sometimes only know that an organism came from a certain named locality. We can (usually) easily find the place in Google maps afterwards. All one needs to do then is right click, select “what’s here”, and get latitude and longitude data at 6 decimal place (and 0.1 of a second) precision. I think that for most instances, unless you really need to know what rock a creature was found under (e.g., when habitat selection is the focus), such precision is not only false but also useless. It helps nobody. Unless you actually measured ecological characteristics around this rock yourself (in which case, you certainly did not need the GPS to locate it), the environmental data we use in biogeography are usually very far from such a resolution. We are lucky if they are at the 30 seconds scale (e.g., CHELSA; Karger et al. 2017). And of course, this is based on extrapolation: the actual data are often gathered at much coarser scales. Some remote-sensing data (e.g., coming from LIDAR or high-precision drone flights) can achieve better accuracy over small spatial extents, but most climatic data are extrapolated to a high resolution from weather stations that are, at best, kilometers apart. In ecology a fine scale (probably meters

or tens of meters) may be desirable in many instances. In biogeography it will be no less than a nightmare: imagine how long it would take a complicated spatial model to run with a 0.000001 degree resolution data. It is also very likely to be meaningless for the kinds of questions tackled by biogeographers (Hortal et al. 2010).

We are sometimes committing worse errors than describing data to a ludicrous degree of precision. Not uncommonly, I found (e.g., Meiri 2016) out that a type specimen was associated with a datum that was simply wrong – an honest mistake of 1, 2 or 3 degrees from than the actual *terra typica*. And I was more likely to have found these errors if the wrong datum for a land vertebrate fell in the ocean. It is less obvious wrong if it falls in land (but it happens, see e.g., Costa et al. 2018). We often mix decimal and DMS data – sometimes for two specimens in the same publications and sometimes probably for the same specimen: I cringe when I see a datum such as “7°04’94”N, 11°59’76”E” – but it is not uncommon. We also sometimes mix latitude and longitude data (difficult to detect in places such as Turkey where the numbers are very close). Reporting longitude before latitude or just changing the datum one reports first can be really confusing; I confess to have erred often when dealing with such data (I hope I found out all such cases, but some may well be lurking in the shadows) or omitted the all-important minus sign for the Western and Southern Hemispheres. And I do wish that scientists, often the ones residing in Britain, Portugal or Spain, stopped referring to “the Western Hemisphere” when they mean “America” or “the New World”. It may sound more scientific but wake up – you are most likely in the Western Hemisphere as well (ok, the River Cam is just east of Greenwich and so is Barcelona, but most universities in the UK, even along the Thames, and those in the Iberian Peninsula are well west of the prime meridian).

Wallace (1852 and in general) was right. Georeferencing is *good*; if we rely solely on data such as place names, we are likely to err or invite future errors. Hence, scientists rightfully make major efforts to convert place names found in the literature and in museum-databases and using other ancillary variables recorded in the field (see e.g., Garcia-Milagros and Funk 2010) into accurate latitudes and longitudes. Place names change; some are spelled in multiple ways and are often resilient to our efforts to convert them into scientifically meaningful places. When I was trying to find where museum specimens that I measured during my PhD were collected, I learned, to my horror, that California alone has ten places called “Round Mountain” and British Columbia hosts no fewer than seventeen “Beaver Creeks.” To this day I have never found where “Tikkiradsuk, Labrador” or “Ban Sob Pa, Salwin River, Burma” are. Reporting the latitude and longitude (correctly, preferably in decimal degrees, with the correct signs) is useful and scientific. But it has to be done with some thought.

Some guidelines to good georeferencing can be found at iDigBio Wiki⁷. I further suggest running some reality checks before publishing spatial data.

⁶ <https://ssarherps.org/publications/herpetological-review/>, last accessed on 02/10/2017

⁷ https://www.idigbio.org/wiki/index.php/Georeferencing_locality_descriptions, last accessed on 01/04/2018

Are they in the same hemi/quarter sphere where they are supposed to be? Are they in the sea or on land? Entering the latitude and longitude into Google Maps or GIS software can easily show us whether our data are reported in the part of the world they are meant to be. It is, however, also important to pay attention to the spatial resolution of the reported data, making sure it is possible that we even know it to a certain degree of precision. We need to verify that data are reported at a biogeographically or ecologically meaningful precision and no better than our device can read. It could be a nice exercise in humility.

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