The Spatial and Temporal Domains of Modern Ecology
OR Ecology's Spatio-temporal Domains
OR Space, Time, and Ecology

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An abstract

The scales at which ecosystems are observed plays a critical role in shaping our understanding of how they are structured and function (*1, 2*). Ecological patterns emerge within temporal and spatial domains that may be coarser or finer than the processes that shape them, which means that investigation across multiple scales is the *sine qua non* for understanding ecological phenomena (*1*). Awareness of the importance of scale has grown rapidly since the 1980s, accelerated by the need to understand how changes in the global climate, ocean, and land systems are affecting everything from individual populations (e.g. cite) to entire biomes (e.g. cite), while technological advances in areas such as remote sensing and genetics are making it ever-easier to quantify ecological features across a broad range of scales (*2, 3*).

Given the importance of multi-scale studies for providing ecological understanding, and the growing ability to undertake them, it is important to rigorously assess whether ecology is becoming a multi-scale discipline. One approach to answering this question is to quantify the spatial and temporal domains within which observations in ecological studies are collected. Observations provide the necessary means for developing and testing the models that explain why ecological patterns vary in time and space (*1, 4*), thus it stands to reason that the temporal and spatial range of ecological observations, and their density within different portions of those ranges, will shed light on modern ecology's progress towards a holistic, predictive understanding of ecosystems (*1, 2*). In this study, we quantified the spatio-temporal domain of current ecological studies, using a representative sample of papers published between 2004-2014 in the top 30 ecological journals (by 2014 impact factor) to measure two key dimensions of spatial observation, resolution (grain) and total spatial extent, and their temporal corollaries, sampling interval and total temporal duration. We collected this information from 367 ecological observations (defined here as data collected from non-experimentally manipulated, or "natural" (*4*), systems) reported within a 148 paper subset of 299 randomly selected articles (1.4% of all papers).

In terms of spatial resolution, here defined as the two-dimensional space in which all measurable features of a natural object were recorded (as opposed to sub-sampled), the majority 63% were collected in plots having resolutions <1 m^2, while 25% were collected within plots of 1 m^2 up to 1 ha, and the remaining 12% in plots of $\geq$1 ha (Fig. 1A). The total spatial extent covered (the number of sampled sites multiplied by the spatial resolution) by 85% of observations was $<$10 ha, while 31% covered less than 1 m^2 (Fig. 1B). Only 7% covered an extent $\geq$10 ha, with just 1.1% spanning areas $\geq$10 million ha.

In the temporal dimensions, 30% of the assessed observations were "once-offs" that were not repeated (Fig. 1C). High frequency observations (ranging between as or more frequent

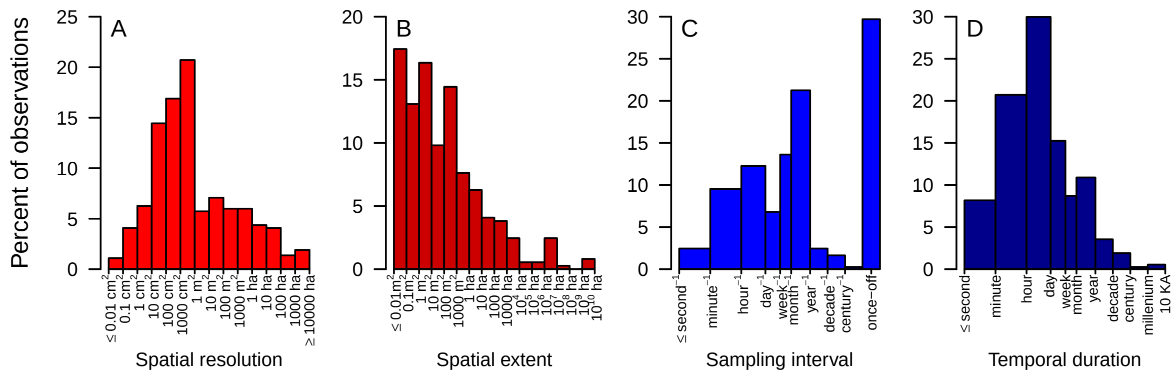

Figure 1: Histograms of the spatial resolution (A) and extent (B), sampling interval (C) and temporal duration (D) of ecological observations collected from the surveyed ecological studies. Bars represent percentage of the 367 collected records falling within each bin.

than once per second up to daily) comprised 25% of observations, 20% were made at daily to monthly time steps, while 35% and 4% were respectively made at monthly up to yearly and yearly to decadal intervals. The temporal duration of studies–the total amount of time the ecological feature was observed (the number of repeat observations multiplied by the effective sampling duration, SI)–was less than 1 day for 59% of sampled observations, 35% between 1 day and 1 year, and just 6% covering greater than 1 year (including several paleoecological studies covering centuries to millenia; Fig. 1D).

The juxtaposition of these scales of observations provides further insight into the spatio-temporal distribution of ecological observations (Fig. 2). Vast majority of cases, plot resolution scales directly with the total extent of the study–these are field studies. Those with

Reflect nature of observation approaches. Use of remote sensing still relatively rare in ecological studies–thus the synoptic view of ecosystems not being seen.

High frequency, high resolution sampling also rare–gap into which UAS is only just allowing to be filled.

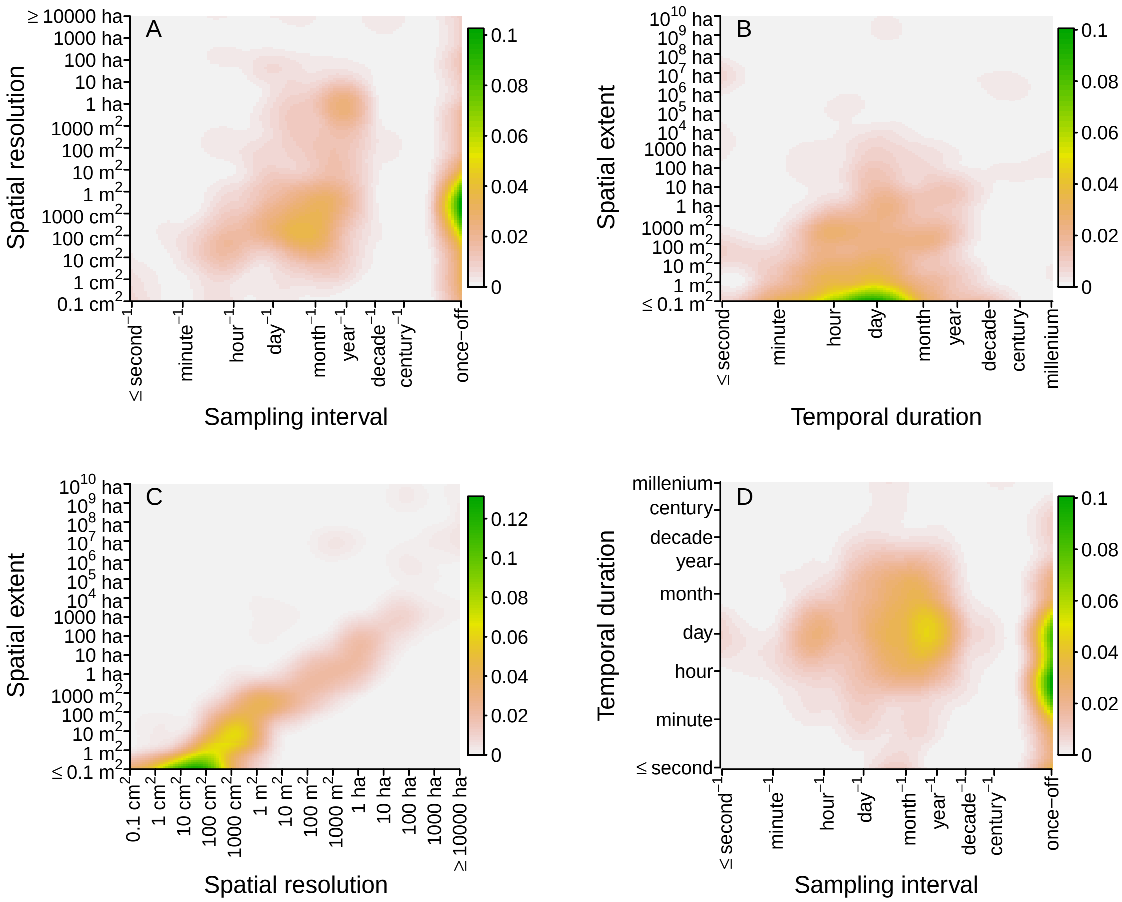

Figure 2:

1. What we did

   (a) We recorded the scales that were actually covered by the observations, rather than potential scales that the collected data might represent–this would require information on autocorrelation length, which is not provided.

   Limitation for ocean studies, we did not study third dimension, volume (might be more relevant).

2. What we found

    (a) Of these, the vast majority (X%) were field-based studies, while Y% involved automated collection of data via instrumentation, and just Z% made use of remote sensing.

3. Implications

    (a) Although limited sample size, insight into the scales at which science of ecology is making bulk of observations

    (b) Despite recognized importance of making observation across scales (*1*), this does not appear to be happening.

    (c) Technical capabilities for making observations are not achieving adoption, despite potential of remote sensing to provide multi-scale ecological data (*5, 6*)

Notes: Wheatley and Johnson (2009) citing arbitrariness of scales in wildlife studies (cited by Chave).

References and Notes

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