# There and Back Again, or the Problem of Locality in Biodiversity Surveys*

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We argue that 'locality', perhaps the most mundane term in ecology, holds a basic ambiguity: two concepts of space—nomothetic and idiographic—which are both necessary for a rigorous resurvey to "the same" locality in the field, are committed to different practices with no common measurement. A case study unfolds the failure of the standard assumption that an exogenous grid of longitude and latitude, as fine-grained as one wishes, suffices for revisiting a species locality. We briefly suggest a scale-dependent "resolution" for this replication problem, since it has no general, rational solution.

> Biodiversity is largely a matter of real estate. And, as with other real estate, location is everything. (Kiester at el. 1996)

**1. Introduction.** 'Locality' (or 'location'),[1] perhaps the most basic, mundane and undertheorized concept in biology, reveals a problem not yet discussed by philosophers and biologists but clearly felt by the many users of biodiversity databases (National Research Council 1995). It is precisely because the problem is so basic and mundane that it is not yet discussed, like the glasses perched on the end of one's own nose. We present a case

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[1] 'Locality' is typically used interchangeably with 'location' by biologists studying species distribution.

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study of a long-term resurvey of animal distribution across California, conducted by the Museum of Vertebrate Zoology (MVZ) at Berkeley. Our study will show how assuming a space with fine-grained, fixed point localities, exogenous from the organisms that occupy them, literally stops the work of analyzing the data (i.e., results from trapping animals) and significantly changes the work of collecting the data (i.e., where to put traps). Researchers cannot reliably replicate a visit to a locality, nor is their data "interoperable," that is, directly usable by others for the next resurvey.[2] In this article, we formulate the problem of returning to "the same" locality in the field. The related problem of recording "the same" locality data in a database is elsewhere discussed (Shavit and Griesemer 2010b).

Let us begin with "the ultimate subject matter of ecology: the distribution and abundance of organisms—*where* organism occur, *how many* occur there, and *why*" (Begon, Townsend, and Harper 2006, 1; emphasis in original). Any ecological explanation necessitates, at a minimum, an identified locality, a description of a population or species[3] distribution pattern, and a comparison of distribution patterns on one or more spatial scales. Variables that correspond to pattern change may thus point to the process or processes that caused such change. Recently, many studies correlate species number in a locality with change in average temperature and discuss possible species responses to climate change (Guisan and Thuiller 2005; Sarkar 2005, 130–132). We will argue that the first move—deciding what counts as "the same locality" in the field—is anything but conceptually simple.

The problems of sameness of locality we discuss are not restricted to ecology. Early studies of blood group variation among humans were conducted opportunistically, with samples taken from soldiers who happened to be in Salonika after the British and French landed in 1915 (Gannett and Griesemer 2004, 140). Soldiers were classified by "racial" and "national" categories with language use as a primary basis for assignment of 'location' (or 'place of origin'). Toward the end of the twentieth century, an attempt was made to standardize a protocol for blood group sampling. The human genome diversity project provoked controversy over whether sampling should be conducted according to a regular geographical grid or use populations themselves as delimiters of place. Gannett and Griesemer argue that "grid coordinates cannot provide the basis for a priori

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[2] As the *IEEE Standard Computer Dictionary* states, interoperability is the ability of two or more systems or components to exchange information and to use the information that has been exchanged.

[3] Conceptual disagreements over 'species' do not affect the 'locality' ambiguity and thus will not be mentioned here.

classification" (2004, 145) because people interact with each other and their social–political contexts to *make* their place.

Sarkar noticed that "talk of 'place' takes us into intuitively trivial but, strangely, relatively uncharted territory philosophically" (2005, 159). He argues that "in the context of biodiversity conservation, we have to worry about the peculiarities of individual places—what entities they contain, what processes they admit, and what constrains those processes, all of which is subject to the contingencies of biological and geophysical history" (160). We completely agree. The scientists in our case study hold very high standards for data collection and curation, which brings the conceptual challenges of resurveying the same locality in the field into sharp relief. Indeed, the more rigorous the science, the more serious is the problem.

A locality resurvey trivially implies a replication of an original survey, yet it is more or less established that "no one ever repeats an experiment." Experiments are improved rather than replicated (Hacking 1983, 231). From a sociological standpoint, Collins adds, "it would be virtually impossible to find a case of replication being used as a test in 'normal science'" (1992, 170). Hacking and Collins opened the discussion on replication, yet they were not concerned with explicating the standards for practices that scientists rely upon for adequate replication. Following Gerson (2007) on work articulation, our interest, as philosophers, is in the theory ladenness of this *replication practice* of returning to "the same" location.

Kiester and White (forthcoming, 4) argue that biodiversity research requires two concepts of space,[4] one "nomothetic" and the other "idiographic," following Windelband's ([1894] 1980) distinction of two kinds of purposes of scientific investigation. The former names the focus of pursuits of lawlike generalizations, while the latter names the focus of causal explanations of historical sequences of particular, unique cases and circumstances. Each mode of study inextricably figures in the other, since empirical explanation depends on both the general and the particular. Kiester and White (forthcoming) observe that the nomothetic mode is often associated with a regular partition of space whereas the idiographic mode is typically associated with objects defined as irregular, sometimes overlapping, spatial entities. An example for a nomothetic partition of space would be regular quadrats according to longitude and latitude, while an idiographic partition to the same area would be irregular polygons according to average rainfall. Kiester and White argue that the "most

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[4] For one to have a 'concept of space' implies the minimal demand that one has an idea of some kind regarding space that one can correct or argue about in public (following Hacking 1999, 10).

effective way to analyze biodiversity from a policy point of view is to use a hierarchy of scales with an alternation between two concepts of space as one goes up or down the hierarchy" (forthcoming, 2). For example, one first partitions space according to average rainfall and then chooses an area with the same rainfall, divides it to small identical quadrates and randomly chooses a cell for sampling.

In this article, we consider two theoretical perspectives on space: the "exogenous" perspective, which assumes a geographical environment unaffected by its inhabitants; and an "interactive systems" perspective in which organisms and environments codetermine one another.[5] The exogenous perspective is committed to a nomothetic concept of locality for modeling species distribution, with the goal of revealing general ecological and evolutionary patterns; while the system-interactions perspective represents distribution phenomena via an idiographic concept of locality, with the goal of finding the historic causes of specific distribution events, in order to improve biodiversity conservation in particular places. A theoretical perspective coordinates models and phenomena by enforcing specific modes of representation (Griesemer 2000). In our case, adopting a certain perspective on space—exogenous or system interactions—commits the researcher to a nomothetic or idiographic concept of 'locality', thus expressing a preference for different standards for data quality, sampling design, spatial scale partitioning, and revisiting methods (see Table 1).

Parameters of the geographic environment, for example, spatial structure and elevation, along with parameters of the ecological environment, for example, temperature and precipitation, are typically represented as exogenous to the organisms studied (Hutchinson 1978, 159–160). Although long known that organisms can modify their local environments (e.g., via their behavior, dispersal mechanisms or histories of occupancy), it is assumed that model predictions work well enough even while ignoring such organism-environment interactions.

However, from an organism-environment interactive systems perspective, such as in models of niche construction (Odling-Smee, Laland, and Feldman 2003) and landscape modulator (Shachak et al. 2008), the environment is not "simply out there," independent of its inhabitants and their interactions, but rather is intertwined with and partly defined by them. In these models, 'locality' is not just 'on the ground' or 'in the map'

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[5] Other philosophical traditions that explore the co-determination of organism and environment include Levins and Lewontin's (1985) dialectical perspective, developmental systems (Griffiths and Gray 1994, 2001; Oyama 2000; Oyama, Griffiths, and Gray 2001), and Sterelny's (2001, 2003) environmental engineering approach.

but also in the evolutionary and ecological history that shaped and was shaped by its defining interactions (Shavit and Griesemer 2010a).[6]

It seems dreadfully complicated to revisit a species' locality when both the species and its geographical environment interact and change. Thus the standard idealizing assumption that the geographical environment remains independent of its inhabitants may seem better. It may not be completely realistic, depending on scale, but it seems to render the detection of species locality feasible and straightforward, which is a prerequisite for any biodiversity survey. Despite the apparent advantages, we doubt such a commitment is either practical or conceptually sound in the long run. Moreover, as our case study will show, consideration of the long run is as important as the short run in establishing practices leading to reliable results. We argue that while the assumption of an exogenous locality may simplify theory, it does not simplify *the work*. As the work becomes complicated in order to maintain the utility of its results, simplifying theory becomes less useful. The exogenous locality assumption fails as a heuristic in the case study we discuss, and in so doing tells us that interactions between organisms and their environments cannot be safely ignored but are actually crucial for the scientists' ability to track their system of study.[7]

To show why the heuristic failure of the exogenous space perspective presents a conceptual problem for biodiversity, we report on the details of one of the most thorough resurveys yet to be done on small vertebrate distribution, conducted by researchers from the MVZ, who rely on the exogenous perspective to design their database and analyze their data. The challenges they encountered with tracking and recording localities support our argument.

## 2. A Day in the Life (of a Survey Expedition).

For Richard M. Hunt—an MVZ assistant curator—a typical day in the field, such as July 19, 1924, did not begin by opening topographical maps but by questioning a ranch owner near their campsite. While enjoying a "most agreeable" breakfast, Hunt heard from Mike Kelley about river otters spotted near Willow Lake. Sure enough, on that same day a new campsite was set up at Willow Lake and 40 traps were placed, beginning in the moss bog on the northeastern side of the lake, then climbing through White Fir trees and manzanita shrubs, to end in a cave inhabiting signs of Bushy-tailed

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[6] Brandon (1990, Chapter 2) distinguishes between external, ecological and selective environments. Applying Brandon's distinctions to our case study: a 'geographical' parameter of elevation is a kind of 'ecological' variable in exogenous perspective, while it can be a 'selective' variable according to an interactive systems perspective.

[7] On the usefulness of heuristic failure, see Wimsatt 2007, Chapter 4.

Wood Rats (*Neotoma cinerea*).[8] Recording local information was part of the MVZ's standard fieldwork procedure, explicitly demanded by the museum director, Joseph Grinnell (1938, 6), yet trapping at Willow Lake is not the goal. Grinnell was clear that adding specimens to the collection, by itself, is not a project worthy of his research museum:

> At this point I wish to emphasize what I believe will ultimately prove to be the greatest value of our museum. This value will not, however, be realized until the lapse of many years, possibly a century, assuming that our material is safely preserved. And this is that the student of the future will have access to the original record of faunal conditions in California and the west wherever we now work. (Grinnell 1910, 166)

Grinnell (1917, 1924) noticed the rapid economic changes in California and was aware of its geologic and geographic movements; hence, he aimed for a series description of species and subspecies distribution in the same localities over time, to facilitate future research on the processes causing speciation and extinction (Griesemer and Gerson 1993). Grinnell was well aware that it will not be easy for "the student of the future" to replicate visits to the same localities; hence an elaborate protocol for note taking and tag recording was developed in the MVZ (Grinnell 1938). A distinction was made between two modes of recording a locality: on a specimen's tag, and in the collector's field notes.

The tag, a small piece of paper attached at the end of the day to any specimen captured during that day, named the species, the collector, the date of collection, and one to two sentences providing a "descriptive locality" of the general site (typically the campsite) where the animal was collected. This text typically encompassed the air distances from the site, the county and state name. This method still prevails today "to allow validation of GPS coordinates, in which errors are otherwise difficult to detect" (Cicero and Conroy 2005, 2). No wonder a descriptive locality can validate a questionable GPS point, as both methods hold a nomothetic concept of locality, where an exogenous abstract grid is imposed on the landscape (e.g., 2 miles north of the intersection of Highways 37 and 89) and the grid's point of reference is exogenous to the species occupying that locality (e.g., a road intersection, a town, a national park).

To clarify why we call both these methods nomothetic, consider two adjacent places—Yosemite National Park and the nearby town of El Portal—identified by an exogenous grid. If a trap were placed just outside the park, then the smaller of the aerial distances—to the park or to the

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[8] MVZ online archive, http://bscit.berkeley.edu/cgi−bin/mvz_volume_query?special=page&scan_directory=v1368_s4&section_order=4&page=119&orig_query=629042.

town—would be the grid point of reference. But proximity to the park may affect the probability of occupancy of a given species since the conservation policy of the national park is (by assumption) different from that of the town. Since this point of reference was chosen because of its aerial proximity to the trap rather than because of the interaction of the location referred to with the organism, in that sense the procedure employs a nomothetic concept of locality.

A second source of locality information was the field notes each researcher kept (and still keeps). The field notes are divided into three sections according to different activities performed in the field: (*a*) a *journal* describing the collector's daily route, chance animal observations, and relevant human encounters; (*b*) a *catalog* listing the daily specimen catch results; and (*c*) a *species account*, describing targeted observations on animal behavior. The field notes, particularly the journals, contain detailed descriptions of the path, landscape, weather, micro and macro habitat, the type and number of traps per trapline and the number of nights each trapline was open. Grinnell explicitly demanded of all his staff to "write *full* notes, even at risk of entering much information of apparently little value. One cannot anticipate the needs of the future, when notes and collections are worked up" (Grinnell 1938, 5; emphasis in original).

**3. A Genealogy of a Resurvery.** In January 2001, Grinnell's vision began to materialize. Craig Moritz, the newly appointed MVZ director, read the 1910 paper and suggested a resurvey of Grinnell's sites for the museum's centennial celebration. In December 2002, a phone call arrived from Yosemite National Park, offering a resurvey in the park.[9] The MVZ submitted a proposal with the aim to "quantify changes in the diversity and distribution of the park's vertebrate fauna over the past century and, where possible identify causes of such changes" (Patton 2003, 1). The first step was returning to Grinnell's sites, which was considered doable since "[Grinnell] and his colleagues quantified their observations, and left a record that is rare or absent among the works of their contemporaries" (Patton 2003, 1).

Fortunately, in 2003 the MVZ's online database—SYBIL at the time, ARCTOS today—already had detailed information about general localities extracted from tags attached to every specimen in the museum's historical collection. These locality descriptions were employed by local undergraduate students for retrospective georeferencing according to guidelines developed by John Wieczorek.[10] That is, they read the locality

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[9] The Inventory and Monitoring program (I & M) requires all U.S. national parks to maintain a database of their natural resources.

[10] See georeferencing guidelines: http://manisnet.org/GeorefGuide.html.

description on the tag, tried to place it on a map, derived longitude and latitude coordinates from it, and then used Wieczorek's computer program to calculate the uncertainty radius around that point. This "maximum error distance" measures the degree of accuracy implied by the "lat/long" expression, in this resurvey typically 0.7 km. To further reduce the maximum error, researchers who worked on different transects or taxa from Grinnell's original survey "mined"—that is, extracted information in a standardized manner—certain field notes for recording in several local databases.

Three years later, the work expanded both geographically and theoretically, its goal stated in the title of the new NSF grant, "The Grinnell Project: Using a Unique Historical Record to Document Responses of Mammals and Birds to 100 years of Climate Change." All those involved in the project, from Grinnell and his contemporaries to the current MVZ researchers, 'trust in numbers' (Porter 1995) in the sense that quality data is obtained by giving a quantitative description that constrains the researcher to strictly follow an explicit and impersonal protocol.

However, the way of sampling localities during the nineteenth and early twentieth century generates biases in the distribution data (Peterson and Cohoon 1999). Natural history scientists such as Hunt typically place their traps according to ad hoc practices: where a reliable local has spotted animals of interest, near a road or campsite, and with a varying number of traps, trap types, and trap nights. Given the constraint of returning to the original survey's locations, the resurvey will remain biased unless it accounts for such imperfect and varying methods of detection (MacKenzie et al. 2003). In much of the literature, a brief acknowledgment is made of possible biases or variance while comparing past and present results as if no discrepancy existed. However the MVZ resurvey, led by population ecologist Steve Beissinger, compares trapping results via an especially rigorous method: an extended mark-recapture statistical model, "Program MARK."[11]

Program MARK can statistically control for variation in detection effort and the bias of reduced capture in traps opened for several nights in the same locality. It reports the likelihood that a species is present at a locality by the probability that it will be detected, if present. Program MARK can help the resurvey minimize: (*a*) omission errors—a species previously detected is no longer found due to change in detection effort rather than change in occupancy, and (*b*) commission errors—a species found in the resurvey was not detected in the survey since no one pre-

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[11] Program MARK, developed by Gary White of the University of Colorado, Boulder, provides parameter estimates from marked animals when they are reencountered at a later time (http://www.warnercnr.colostate.edu/~gwhite/mark/mark.htm).

viously looked for it there (e.g., because land development created a new or different habitat type on the same lat/long coordinates or a trap type not capable of detecting this species was used in the survey). Gradually the sampling design became explicitly constrained by the occupancy analysis. In order to avoid commission errors the resurvey looked for species only in the same habitat—the boreal habitat—and only in those areas that did not experience land use change.

A reliable statistical comparison of the survey and resurvey results requires a large sample size of independent localities. To increase statistical power, the spatial scale of a locality represented in the local database is reduced in order to increase sample size by counting each trapline within each original survey locality as a separate resurvey locality. To maintain independent sampling it must be decided how far apart two traplines should be placed in order to detect different populations—that is, sample different specific localities—within the same general locality.

In the local database of the Yosemite National Park transect, the smallest unit of locality is a trap type within a trapline.[12] For most uses, this small spatial unit is not considered more fundamental or accurate than larger units, but rather a tentative solution to the sample size problem, to be discarded when more localities accumulate. The next spatial scale is a trapline, yet most of the survey's traplines are located too close together to be independent for the species they attempt to detect. So the smallest scale for valid statistical analysis is an aggregate of traplines.[13] Traplines are aggregated according to their air-distance proximity, elevation similarity, and species home range; and expert judgment rather than a general protocol construct these units. Finally, the largest spatial unit is the 'general locality', which is written on the specimen tag and stored in the MVZ collection database.

For program MARK to compare variance in detection effort more easily between the present resurvey and Grinnell's original survey, a regular and replicable resurvey trapline in today's work is a practical necessity, which led to discussions and a detailed protocol for collecting (Perrine 2007). The trapline structure in the resurvey had to change so as to exclude any mammal—such as rare beavers or common gophers—requiring a trap type other than a Sherman or Tomahawk, and identical

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[12] For example, all mousetraps in a single trapline (I.D. no. 145) placed by Charles Camp on December 19, 1914, constitute one locality and all rattraps in the same trapline constitute a second locality. (We thank Juan Luis Parra for sharing with us his database.)

[13] For example, Camp's traplines nos. 145 and 146, and Hollinger's traplines nos. 305 and 306 are all within a 200 foot elevation range in similar habitats next to Indian Creek in Yosemite Valley, hence are all aggregated into 'Yosemite Valley-2' out of 10 within the general locality of 'Yosemite Valley' (Juan Luis Parra's database).

trapline composition (the same number of trap types, opened for four consecutive nights with standard aerial distance between traps) was demanded.

A trap should detect the organism present; hence it should track particular, idiographic, species-specific signs of recent organism activity constructing its habitat (e.g., runways, clippings, fresh burrows) and be given particular names as described above. Random distribution of traps within a regular, exogenous grid is the sign of a novice naturalist.[14] However, classic ecological practice randomly assigns arbitrarily named localities (1, 2, 3, or A, B, C) within an exogenous regular grid of quadrats or square hectares, a practice imported from controlled studies in agriculture experimental stations and physiology laboratories (Kingsland 1991, 2; Kohler 2002, 120). Outdoors, both ecologists and naturalists use nomothetic regular grids alongside idiographic particulars (Shavit, personal observation), yet ecologists foreground the former and "merely adjust for" the latter, and conversely for the naturalist.

To illustrate, imagine an abstract 'scientific naturalist' and a 'standard ecologist' who go out on a field resurvey. Both look at maps prior to their departure to decide roughly where to sample for particular species along an environmental gradient. Given that both use a map and GPS in the field, their order of attention in the field is nonetheless reversed. A 'scientific naturalist' will first identify a habitat that is appropriate for her targeted species, then set her trap nonrandomly within a microhabitat with signs of organism activity, and only then take GPS coordinates of that trap. A 'standard ecologist' will first identify in the field the point that corresponds to the lat/long she chose at random, prior to departure, from an exogenous grid of lat/long cells, use her GPS to locate her trap precisely at that point in the field, and only then record the habitat surrounding her trap.[15]

**4. A Day in the Life (of a Resurvey Expedition).** On another summer day, August 25, 2007, an MVZ curator arrives at Willow Lake. The general locality of the lake is well known and thanks to Hunt's lengthy descriptions, the curator attempts to revisit the exact historic localities (including the wood rat cave). That is, given the behavior and the scale of this species distribution, replacing the traps within a 10–15 meter radius biologically means replicating Hunt's traps exactly.

As 83 years before, a collector's day does not begin with opening topographic maps. Rather, he rereads Hunt's journal while looking at a

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[14] We thank Jim Patton for this comment. Resurvey Meeting October 15, 2007.

[15] Interview with Jim Patton on February 1, 2007, and with Yael Lubin on July 23, 2007.

U.S. Forest Service section map. Detecting the animals in the field according to the collecting protocol is the goal, but as the day progresses it becomes clear that this goal is unattainable: the database standard and the field standard do not coincide. In accord with the standardized sampling ideal, the curator places the individual traps a uniform 20 meters from one another. Yet within the dry mixed canopy habitat, on the smallest scale of an individual trap, a patch of wet grass is discovered with possible signs of Vole activity. He read that Hunt had trapped Long-Tailed Voles (*Microtus longicaudus*) on his trapline in the original survey; hence after brief contemplation he placed two individual traps, in apparent close proximity, inside this small grassy patch. Standardized, regular sampling—a nomothetic ideal—was sacrificed, yet the curator's expedition detected the Voles he suspected he would find based on Hunt's field notes.

Another challenge was yet to come, however. After the curator activated all 40 traps on the trapline and had successfully trapped Wood Rats in them, he discovered the cave Hunt had described. In this case, on trapline scale, the curator did not place new traps in the cave and his sampling effort remained unchanged. The main reasons, however, were the lack of distinctive Wood Rat signs in the cave today and that he had already found Wood Rats in his traps on the trapline outside the cave. For an ecologist, placing a trap according to your expected result is "circular reasoning." For the curator, however, much as for Hunt or Grinnell, placing a trap where you think it is not likely to detect that species, where the distinctive smell Hunt reported in 1924 was lacking for example, whether in a well-preserved cave or a parking lot built upon that cave, is a waste of time and would produce meaningless results. As a resurvey, the curator attempted to reask his predecessors' question and redo their practice, hence a trap should not be placed where it is not likely to detect.

In the field, a species locality is a concrete, scale-dependent interaction between organisms, scientists and their environments. On the scale of an individual trap, an idiographic locality of a particular organism is assumed. On the scale of a trapline, a regular exogenous grid of aerial distances provides a better sampling of a species' locality. While collecting, the larger unit of locality does not fully contain the smaller unit (Huston 2002) but rather the researcher alternates between the idiographic and nomothetic perspectives of space for different spatial scales. A few days later the locality at the trapline scale is recorded by GPS measurements; later still, when uploading results into the local database for future data analysis, lat/longs play a central role in representing the locality; and later yet, months later, lat/longs are the only relevant metadata for correcting species distribution data in the MVZ database (see Section 5). Through this work, 'locality' is gradually stripped of its biological and historical contexts.

TABLE 1. Different Concepts of Locality Are Associated with Different Research Standards

| | Perspectives on Space | |
|---|---|---|
| Quality Standards | Nomothetic Concept of Locality | Idiographic Concept of Locality |
| Species distribution data | Representative data | Comprehensive data |
| Species richness estimation method | Statistical sampling | Exhaustive detection |
| Subdisciplinary tradition | Agricultural field stations, experimental field ecology | Scientific natural history, systematics, biogeography |
| Spatial scale | Homogeneity of smallest relevant spatial scale | Heterogeneity at all scales |
| | Multiple spatial scales are not a problem | No standard to aggregate/disaggregate locality units across scales |
| Replication of a survey to the same locality | In the abstract: first set trap on a randomly assigned lat/long point, then record context, e.g., habitat, signs of animal occupancy, etc. | In the abstract: first set trap in the relevant habitat with signs of animal occupancy, then record the trap's lat/long point |
| | In practice: survey the same type of locality across the gradient, regardless of whether it was surveyed before | In practice: resurvey all token localities in a certain radius from the assumed locality originally surveyed |

**5. The Failure of the Exogenous Geographical Environment Assumption.** As we have seen, the exogenous geographical environment heuristic failed to simplify a locality revisit in the field. The idiographic concept of locality used in the survey one hundred years ago—and still representative of collecting practices today—could not be abandoned in favor of a purely nomothetic approach in the contemporary resurvey, even by ecologists, as we noted at the end of Section 3, if the problems of the original survey were to be pursued. This is not to say that the nomothetic approach should be rejected. To the contrary, both nomothetic and idiographic perspectives should be used.

Table 1 summarizes the conceptual problem. Each column represents a theoretical perspective on space, while each row represents a quality standard: for data collecting, sampling design, subdisciplinary tradition, scale partitioning, and revisiting method. Since both perspectives on space are necessary for doing rigorous fieldwork, yet each perspective commits the researcher to a different concept linked to different working procedures to uphold its standard, and since one cannot employ both procedures for the same set of locality data collected on the same spatial scale, locality ambiguity is conceptually unavoidable.

A plausible resolution to the lack of a common measure for the two concepts of space is to alternate concepts between scales. That is what the MVZ curator did while revising Willow Lake. This is what Kiester and White (working paper) suggest as a practical method for biodiversity management. So while there is no general algorithm to resolve the ambiguity in the concept of locality and one cannot avoid negotiations and compromise, this is not a problem that need stop the work or cause major concern to the biologists involved.

What *does* cause concern to the scientists is a particular aspect of the problem of database interoperability: how will someone else, maybe holding a different perspective/scale resolution, revisit "your" locality outdoors via the locality data recorded in your database? Every long-term survey must deal with this, and the many complaints, followed by billions of dollars and euros invested in global biodiversity databases, attest to a pressing problem (National Research Council 1995). An interoperable database requires structured and standardized text, which goes against the narrative nature of the field notes (Bowker 2005, 29, 196). Well aware of the field notes' value, the MVZ displays these documents online without fully integrating them with its database (on the trade-offs facing biodiversity interoperability, see Shavit and Griesemer 2010b). A second look at the table can clarify why we expect the interoperability difficulty with revisiting a locality to increase with each new resurvey.

A species distribution database meets a comprehensive standard if it achieves complete detection, that is, all and only present species are detected and recorded. For a species distribution database to meet a representative standard, the procedure and effort for obtaining the data is standardized so as to be independently replicated in each sampling event. Independent replication insures that the data collected in a few sampling events is representative of the larger phenomenon of species occupancy, thus this particular data set can test a general occupancy model.

Methods for estimating how many species occupy an area (Kiester 2001) also adhere to different perspectives on space. Statistical sampling requires an unvarying sampling procedure with error estimation: one looks in the same way with the same effort, whether or not one finds it. If an unvarying procedure using a fixed grid leads to a parking lot, it makes perfect sense to place a trap on the asphalt. Yet exhaustive detection strategies seek something until it is found, possibly requiring variable effort and making error estimation irrelevant. Trap placements should *demonstrate* hypotheses about which species occupy particular localities, hence varying the distance between traps due to a suspected Vole makes perfect sense.

Yet none of this work, nor the protocols that guide it, laden with theoretical commitments and local resolutions, is represented in the MVZ database. The "metadata" (information about the nature and structure of the data)[16] on locality in the database holds instead variously formatted exogenous lat/long grids (e.g., decimal; seconds, minutes and degrees), exogenous political grids (e.g., TRS and section maps) and political polygons (e.g., county, country, continent). The abundance of such nomothetic metadata and the lack of idiographic metadata may imply that lat/longs determine what counts as "the same" locality in the field. However, we saw that the researchers could not make the lat/longs suffice; the idiographic field notes and natural history practice played a dominant role during fieldwork. In fact, it would have been deceptive to identify locality with lat/long, since multiple lat/long coordinates were mistakenly assigned to historical specimens that clearly came from the same trapline[17] and multiple names and elevations were given to a locality with the same assigned lat/long.[18] This problem was not unique to the historical reconstruction. The same occurred in the resurvey. Although the expedition leaders coordinated their expected localities on a topographical map prior to fieldwork, upon return it became clear that different names were sometimes given the same GPS coordinates and that different coordinates were given to the same specific locality name. These differences were resolved *not* by looking at maps but by a conceptual discussion. That is, a Grinnell resurvey staff meeting was devoted to detailed arguments over the theoretical and practical pros and cons of the protocol to adopt for recording a locality.[19]

Interoperability is especially important, and difficult, when data is aggregated from different subdisciplines, each with its own heritage of practices and research questions. In most biodiversity surveys, the concept of locality is itself "local" in two important respects. First, localities are

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[16] The concept of 'metadata' is familiar from the information in the head section of an html-based Web page, preceding the body of the page, between the tags <meta> and </meta>, which is used by search engines to catalog Web pages.

[17] For example, two specimens (both *Micotus longicaudus*) from the same trapline (I.D. no. 175) set on the same day (December 26, 1914) by two collectors (Camp and Grinnell) in Yosemite Valley were assigned different decimal longitude (−119.59 and −119.61, respectively). Such mismatch is quite common (Juan Luis Parra, interview, January 23, 2007).

[18] For example, there were 14 different text string permutations for "Dale's Ranch on Payne's Creek," based on alternate spellings and word order on the tag, which result in over 100 different localities in the database, though most of them with the same elevation. After consolidating these localities in the database, three or four localities with the same name and different lat/longs will remain. We thank John Perrine for this information.

[19] Grinnell resurvey meeting on November 14, 2006. A standard writing style was eventually agreed upon, with one of its major aims to maintain as close as possible to Grinnell's own tradition of naming localities. However for the next field season no specific names were distributed, so a similar naming problem could be repeated.

*question specific:* what counts as a relevant locality for one question may not count as relevant for another. Second, localities are *practice specific:* what counts as a reliable practice for documenting a locality for one subdiscipline may not be so for other. Moreover, questions and practices interact throughout the entire working process.

For example, in Grinnell's original survey and in the MVZ resurvey, one question is which species are present in the localities surveyed by Grinnell, because changing patterns of species presences can serve as indicators of climate change or changing selection pressures that cause the evolution and extinction of species. Thus, knowing that a particular species of burrowing rodent is in an area is relevant to that question. If the GPS grid point occupied by suitable scrub habitat in 1914 is now occupied by a parking lot, should this point be sampled? If the goal is a species list and not identification of causes that may account for this result then one can sample the parking lot, but if the question is whether climate change *rather than* other changes such as land-use changes accounts for changes in the species list, then sampling the parking lot would confound the two causes. A new concern then arises: is a scrub habitat a few kilometers away from the parking lot a suitable proxy for the original locality? If the research question is not about species presence but about population abundance, then the scrub habitat several kilometers away from the original grid point may not be a suitable proxy for the original locality because the former might represent the location of a *different* population than the one that is now extinct due to the construction of the parking lot.

Because research questions are often pursued with specific and importantly different practices, localities are also *practice specific*. Indeed, the available practices may decide the questions pursued because of the ways in which concepts of locality can be motivated, implemented in fieldwork and represented in a database. In this article, we contrast, on the one hand, a nomothetic concept of locality realized in practices of ecologists who initiate research by first committing to a statistical sampling design based on an exogenous regular grid, then discover what species and ecological features can be associated with the grid points, and on the other hand, an idiographic concept of locality realized in the practices of naturalists and systematists who initiate a collection by establishing endogenous localities (i.e., places the organisms would "choose," "construct," or "find themselves" in for ecological and phylogenetic reasons), placing traps based on informed guesses of the likely presence of species, and then discover what grid points their specimens and habitat features belong to.

Although the contrast between the methodology of the ecologist and that of the naturalist-systematist is here drawn starkly between nomothetic and idiographic concepts of locality, we stress that these differences are idealized and probably not realized fully by any practicing scientist. Indeed, we think that the MVZ resurvey makes use of both kinds of concept of locality, as did Grinnell, who was both a systematist and ecologist (Griesemer and Gerson 1993) and who worked at a time when these categories of practitioners and their problems were not only different than now but were perhaps more difficult to distinguish.

The above example did not demonstrate a general principle that practice specificity *determines* what questions could be pursued. Instead, the interaction of the nomothetic and idiographic concepts of locality in a particular stage of the work *in practice* determines what questions can be *readily followed up*. Clearly, the question of abundance mentioned above is not easily addressed from data produced by this mixed practice. Clearly, the species list question is answerable via this method. If asking how have species in general responded to climate changes over the timescale of a century (i.e., is there a general pattern of shift in species distribution upward in elevation?), then the devil's advocate might suppose this question can be answered by extracting only the nomothetic aspects of locality (e.g., by treating elevation as a proxy for an exogenous temperature and not as a proxy for habitat suitability). If a question about the mechanism that caused such a shift is asked, it will probably need to address particular species and circumstances, thus relying on the idiographic concept of locality as well. For example, the resurvey decided not to collect for Pika, even though it is believed to be an indicator species for global warming, because in the original survey, Pika were collected by shooting rather than trapping, which is now not permitted. So this "idiographic" deviation from a standardized collecting protocol was driven by an effort to maintain a standardized "nomothetic" collecting method and effort intensity for all localities and species.[20] Emphasizing one or the other concept of locality comes with a price. Idiographic practices producing grid-based data sets are likely to undermine analytical assumptions (e.g., a background model required for statistical evaluation of the data). Likewise, nomothetic practices leading to species-interaction-based data sets may undermine theoretical assumptions as well (e.g., data sets on species interactions with their enviroments that are relevant to ecological processes, are absent from species distribution databases and thus not available for "niche modeling," i.e., not available for predicting species geographic distribution based on the environmental conditions of localities where occurrences was already recorded).

Interoperability is commonly hampered by another parameter of lo-

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[20] We thank the journal's editor-in-chief, Michael Dickson, for clarifying this point.

cality ambiguity: spatial scale. The effects of geographical scale on describing and modeling distribution have been widely discussed in the last 2 decades. Levin clearly states:

> One must recognize that the description of the system will vary with the choice of scales; that each species, including the human species, will sample and experience the environment on a unique range of scales; and that, rather than trying to determine the correct scale, we must understand simply how the system's description changes across scales. (1992, 1953)

Since the idiographic descriptions of locality in our case study are species dependent, in the resurvey improving the lat/long resolution to single trap scale will not improve the locality data. On the contrary, increased accuracy of grid measurement can *blur* the phenomenon measured. A single trap does not accurately represent 'species location' but only an organism detected at a certain time (and just as likely detected in another trap in that same trapline). Species distribution must be sampled at levels above the individual (cf. Huston 2002), and overdetail reduces the model's success (Elith et al. 2006). GPSing every trap is also literally overkill, since the measurement time prolongs the animal's duration in its trap. Such value choices were important reasons not one of the resurvey researchers planned to GPS the locality of each trap on the trapline.[21]

Since the nomothetic lat/long method to represent 'locality' is not species dependent or scale dependent, it can help in layering several spatial scales for exploring generality and possible bias of pattern shifts across scales. Relying exclusively on this abstract representation of space, however, runs the risk of obscuring crucial constraints arising from scale differences, such as the need for independent sampling, the sample size sensitivity of Program MARK, and the biology of the particular species detected. If these constraints could be done away with, one could aggregate or disaggregate scales of locality according to a general protocol. However, the representation of species locality on different scales is *not* a simple, mechanical composition of "small" units into "big" ones. Judgment is required to decide what to aggregate and how. A naturalist expert, Jim Patton, builds each new level according to the particular species, habitats and research questions involved. Hence information cannot be easily added from the various specific localities to the general locality, and information from the general locality cannot be easily traced back to its components. Again, all these scale considerations are not represented in

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[21] Resurvey meeting, January 23, 2007.

the MVZ database, which cannot reflect the fact that the term 'locality' has different meanings to different contributors of data to the database.[22]

In order to replicate the work in the next resurvey, one would need to know its predecessors' method—in ideal and in practice—for a locality revisit in the field, and not just that visit's date and lat/longs. Indeed, huge funds, time and effort, were devoted by the MVZ so that anyone could read Hunt's field notes online just as an MVZ curator has done. The field notes were scanned and posted as an unstructured whole, since structuring the text to fit database requirements would alter its character and value.[23] In 2003, the MVZ database was long operational with a conceptual schema based on the specimen tag, recording the object collected rather than the process of collecting.[24] Nonetheless, the next resurvey, in the twenty-second century, if it holds similarly rigorous standards as the present resurvey, will need to read not only the database and field notes, but also the local databases, protocols, route maps, etc. Unfortunately almost all the data fields in these structured records regarding scale, effort, equipment, methods, and more do not integrate well with the data fields in the MVZ database. These crucial locality records must be accessed separately, which implies that interoperability of the locality data recorded by this resurvey does not look promising.

This lack of interoperability has a history (for details, see Shavit and Griesemer 2010b). It originated from Grinnell's distinction between 'locality' on the specimen tag and 'locality' in the field notes. Once the database structure was designed during the 1970s based upon the tag, and GPS technology allowed the georeferencing of each specimen record in the late 1990s, a commitment was made: that an exogenous representation of locality is often sufficient and always necessary while other representations of locality are only supplementary, required only for particular tasks. However, since replicating a visit to "the same" locality is the first step for any resurvey, and, as our case study showed, both concepts of locality are necessary for achieving that first step, then an idiographic concept of locality is just as important for studying species distribution. We agree with Bowker (2005) that databasing practices in the sciences are "memory practices": institutions that determine not only what to remember but also what to forget. It was a theoretical choice, not a mere technicality (though it may have seemed that way) to assume that an exogenous representation of 'locality' is sufficient. That theoretical commitment has im-

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[22] We thank John Perrine for this comment, December 17, 2007.

[23] We thank Craig Moritz (October 6, 2007) and John Perrine (December 17, 2007) for this point.

[24] Changing the database schema from its object-based focus to an event-based focus was briefly discussed yet discarded as totally impractical. Resurvey meeting May 10, 2007.

plicitly shaped the structure of the MVZ database, and thus may explain, at least partly, the lack of interoperability we have described above. As this resurvey appears to be one of the most rigorous to date, and its database structure and georeferencing guidelines accepted by many research museums around the world, the problem appears to be general.

**6. Conclusion.** 'Locality' is inherently ambiguous since the same term adheres to two different concepts committed to different practices, and while both concepts are necessary for rigorous biodiversity research, one cannot employ them both at the same spatial scale. The simplifying assumption of the nomothetic perspective on space in ecology, that geographical environments are exogenous to the organisms that inhabit them, and thus an exogenous pair of GPS coordinates plus maximum error are a good enough representation of locality, did not simplify the work nor promote the interoperability of the data in our resurvey case study. As a useful heuristic it fails and in so doing tells us that the interactions between organisms, observers and their environment cannot be safely ignored but are actually crucial for tracking a species locality. In biodiversity research a locality is dependent on the history of the species in its habitat as well as the history of the theoretical and technical tools and methods used for detecting and describing that species. The idiographic practices that produced locality data that were recorded in the database affect the pathways open for integration of new locality data; thus they should be recorded and made accessible to others.

There is no general solution to the problem of locality in biodiversity, though multiple local resolutions exist. In the field, alternating between spatial scales may facilitate a workable resolution, even without an underlying common measure for locality. Negotiating a somewhat analogous resolution in the MVZ database is logically and physically possible yet practically 'resolution' means 'workaround' rather than 'solution'.[25] Adding an idiographic concept of locality to the database schema, which may have been easy at the design stage of the database, is a major conceptual obstacle now that the database is in use (Gerson 2007; Wimsatt 2007, Chapter 7). Stated differently, we have argued that trading one perspective for another is in effect not plausible once the data is recorded, since, as we have shown, changing a perspective about space entails much more than extending a theoretical model while retaining the same data and methods to collect data in the field.

In order to manage this problem, we must begin to think differently

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[25] An indirect link between a page in the field journal and a georeferenced specimen in the MVZ database is established by tagging key words in the journal. For detail, see Shavit and Griesemer 2010b.

about locality. What is conserved in the replication of a survey is not a static location but rather a dynamic, relational location that needs to be retracked each time anew.[26] By accepting ‘locality’ as a process rather than a fixed state, one may be more alert to record its contexts from the start. “If you use it, record it” is our first promotion slogan, and, with interoperability in mind, “mind the gaps” that emerge from the articulation of multiple perspectives on space. We suggest that alternating between the different perspectives on space will not *solve* the problem of locality, but may serve as a way to *manage* its inherent ambiguity. Obviously much work still needs to be done and we hope this article may stimulate the interest of others. After all, our main point was that revisiting a species locality is not a given but a basic and multifaceted problem, worthy of much more attention from the philosophical and biological communities.

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[26] We thank Eva Jablonka for this framing.

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