Chapter 2
The Origin and Early History of NOW as It Happened

Mikael Fortelius, Jordi Agustí, Raymond L. Bernor, Hans de Bruijn, Jan A. van Dam, John Damuth, Jussi T. Eronen, Gudrun Evans, Lars W. van den Hoek Ostende, Christine M. Janis, Jukka Jernvall, Anu Kaakinen, Wighart von Koenigswald, Kari Lintulaakso, Liping Liu, Majid Mirzaie Ataabadi, Hans-Walter Mittmann, Diana Pushkina, Juha Saarinen, Sevket Sen, Susanna Sova, Laura K. Säilä, Alexey Tesakov, Jouni Vepsäläinen, Suvi Viranta, Innessa Vislobokova, Lars Werdelin, Zhaoqun Zhang, and Indrė Žliobaitė

Abstract The NOW database of fossil mammals came to be through a confluence of several initiatives spanning multiple decades. The first public version of NOW database was released in 1996 and the first Advisory Board was established the year after. Originally, NOW stood for *Neogene of the Old World* but with the gradual expansion of the database the acronym was eventually reassigned to stand for *New and Old Worlds*. The structure of what would become NOW was originally cloned from the ETE database of the Smithsonian Institution and the first NOW version accessible over the internet was a node of the ETE database. The first standalone, online version of NOW was launched in 2005 and the first formal steering group was established in 2009. During its existence, NOW has been funded, directly or indirectly, by several organizations but fundamentally it has always been an unfunded community effort, dependent on voluntary work by the participants.

Keywords Fossil Mammal • Species List • Stratigraphic Age • Functional Trait • Ecometrics • Database

M. Fortelius (✉) · J. Jernvall · A. Kaakinen · L. Liu · D. Pushkina · J. Saarinen · S. Sova · L. K. Säilä
Department of Geosciences and Geography, University of Helsinki, P.O. Box 64, 00014 Helsinki, Finland
e-mail: mikael.fortelius@helsinki.fi

M. Fortelius · K. Lintulaakso · I. Žliobaitė
Finnish Museum of Natural History LUOMUS, University of Helsinki, P.O. Box 44, 00014 Helsinki, Finland

J. Agustí
Institut Català de Paleoecologia Humana i Evolució Social, Universitat Rovira i Virgili, 43002 Tarragona, Spain

R. L. Bernor
College of Medicine, Department of Anatomy, Laboratory of Evolutionary Biology, Howard University, 520 W St. N.W, Washington DC, 20059, USA

Human Origins Program, Department of Anthropology, Smithsonian Institution, PO Box 37012 Washington, DC 20013-7012, USA

H. de Bruijn (deceased)
Department of Earth Sciences, University of Utrecht, Utrecht, The Netherlands

J. A. van Dam
Department of Earth Sciences, University of Utrecht, Utrecht, The Netherlands

Institut Català de Paleontologia Miquel Crusafont (ICP-CERCA), Universitat Autònoma de Barcelona, Cerdanyola del Vallès, Barcelona, Spain

J. Damuth
Department of Ecology, Evolution & Marine Biology, University of California, Santa Barbara, CA 93106, USA

J. T. Eronen
Ecosystems and Environment Research Programme & Helsinki Institute of Sustainability Science (HELSUS), Faculty of Biological and Environmental Sciences, University of Helsinki, P.O. Box 65, 00014 Helsinki, Finland

BIOS Research Unit, 00170 Helsinki, Finland

G. Evans
Freelance, formerly Institute of Biotechnology, University of Helsinki, Helsinki, Finland

L. W. van den Hoek Ostende
Naturalis Biodiversity Center, P.O. Box 9517, 2300 RA Leiden, The Netherlands

C. M. Janis
Bristol Palaeobiology Group, School of Earth Sciences, University of Bristol, Bristol, BS8 1RL, UK

Department of Ecology and Evolutionary Biology, Brown University, 80 Waterman Street, Box G-W, Providence, RI 02912, USA

J. Jernvall · S. Sova
Institute of Biotechnology, University of Helsinki, Biocenter 2, P.O. Box 56, 00014 Helsinki, Finland

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Introduction

The advent of computers accessible to ordinary academics very quickly generated widespread interest in systematic computational analysis of observational data that had been developing for a long time, in some disciplines for centuries. One such discipline was paleontology, where a vast archive of formal descriptions of fossils had accumulated since the late eighteenth century and even earlier, scattered over an enormous range of scientific journals and monographs from several disciplines and in many languages. One of the first attempts to harness this information for computational analysis, and arguably still the most widely known, was Jack Sepkoski's "compendium" from the later 1970's, of first and last occurrences of known marine metazoan taxa of the Phanerozoic (see Sepkoski, 2002). For terrestrial vertebrates an early manifestation of this trend was the *Workshop on Computerization* organized by the Society of Vertebrate Paleontology in 1989 and the resulting *Guidelines and Standards for Fossil Vertebrate Databases* (Blum, 1991).

W. von Koenigswald
Steinmann Institut für Geologie, Mineralogie und Paläontologie, Bereich Paläontologie, Nussallee 8, 53115 Bonn, Germany

M. M. Ataabadi
Department of Geology, Faculty of Science, University of Zanjan, 45371-38791 Zanjan, Iran

H.-W. Mittmann
Retired, formerly Staatliches Museum für Naturkunde, Karlsruhe, Germany

S. Sen
Laboratoire de Paléontologie du Muséum, CR2P-CNRS-UPMC, 8 rue Buffon, 75005 Paris, France

A. Tesakov
Geological Institute, Russian Academy of Sciences, Pyzhevsky 7, 119017 Moscow, Russia

J. Vepsäläinen · I. Žliobaitė
Department of Computer Science, University of Helsinki, P.O. Box 68, 00014 Helsinki, Finland

S. Viranta
Department of Anatomy, Faculty of Medicine, University of Helsinki, Haartmaninkatu 8, 00014 Helsinki, Finland

I. Vislobokova
Borissiak Paleontological Institute, Russian Academy of Sciences, Profsoyuznaya 123, 117647 Moscow, Russia

L. Liu · L. Werdelin
Department of Palaeobiology, Swedish Museum of Natural History, P.O. Box 50007, 104 05 Stockholm, Sweden

Z. Zhang
Key Laboratory of Vertebrate Evolution and Human Origins of Chinese Academy of Sciences, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, 100044, China

The roots of the NOW database (originally *Neogene of the Old World*, subsequently *New and Old Worlds*) run deep in this fertile ground, or perhaps more accurately, it first developed as nothing but one branch of several of the *Evolution of Terrestrial Ecosystems* (ETE) database, developed by John Damuth and the ETE Consortium. Based at the Smithsonian, the ETE Program designed a novel kind of database for the terrestrial fossil record. Such a database would not include merely species-occurrence data for particular fossil localities, but in addition would include pertinent interpretations of sedimentary context, ecological environment and taphonomy (for localities) and biological and ecological trait characteristics (for the species). Such a database could be used to explore terrestrial paleoecology in a way not previously possible with large compilations of data. One could ask not only, "Where/when is such-and-such a taxon found," but also questions such as, "Where during this time do we find localities with species of grazing mammals over 100 kg?" Such a database asks much of its compilers and needs frequent revision as ideas and techniques develop. But even a small set of relatively basic ecological variables opens up a wide array of avenues of research. This concept resonated with the small community of researchers involved in the beginnings of NOW.

What follows here is a long and strange story, littered with coincidences and lucky breaks and not devoid of passion. One might think that databases are just neutral repositories of primary data, necessary but boring. Instead, they seem to call forth strong personal ambitions, emotions and impulses, including the darker urges related to possession and ownership. The collective history of fossil databases is accordingly dotted with drama – at least one field catalogue of fossils even ending up as an item in divorce proceedings. But, while seemingly unavoidable and prudent to keep in mind, this dark and gossipy side is largely irrelevant to the real purpose of databases and we shall not review it further here. At the end of the story there is a moral: a public database is fundamentally really a kind of museum collection. And, like all museum collections, it needs dedicated care and curation to deliver its potential for discovery, insight, beauty, and wonder. Just as the objects in a museum and data in a database tell a story of their own, we can only appreciate the collection as a whole if we know the ambitions and quirks of those who caringly brought them together. We have accordingly allowed a certain amount of local color and "fun facts" in the text that follows and trust that readers familiar with the events will not object. Such detail is rarely preserved and may help future generations to put things in context. For a timeline of the events and developments described, see Fig. 2.1 and for the growth in size and spatial coverage see Fig. 2.2. More technical and current aspects of NOW are described in Žliobaitė et al. (2023).

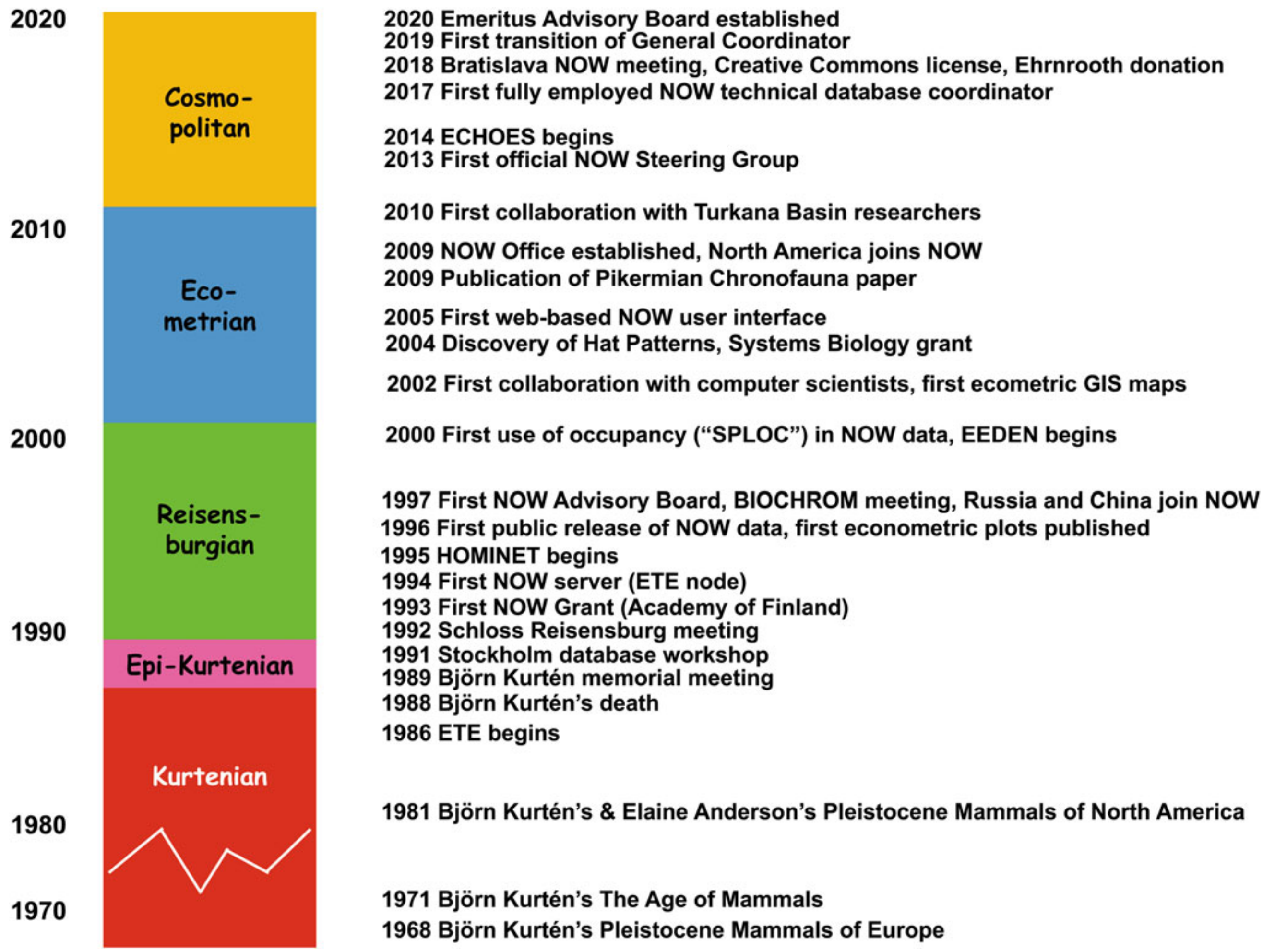


Fig. 2.1 Timeline of the prehistory and history of the NOW database, showing the sequence and timing of key developments mentioned in the text. The division into stratigraphic eras is heuristic and purely informal. Note that most of the Cosmopolitan Era postdates the time frame of this chapter

The Kurténian Era and the Epi-Kurténian

The Setting

The NOW database was long in the making. It has deep roots in the legacy of Helsinki mammal paleontologist and writer Björn Kurtén, his emphasis on function and ecology and his strong will to systematically compile and organize information about fossil mammals and environments, as in his classic books *Pleistocene Mammals of Europe* (Kurtén, 1968), *The Age of Mammals* (Kurtén, 1971), and *Pleistocene Mammals of North America* (Kurtén & Anderson, 1980). Together with his then PhD students Lars Werdelin and Mikael Fortelius, Kurtén as early as the early 1980s developed a plan and a proposal for a basic database of Quaternary fossil mammals, based primarily on the raw data in the appendices to the 1968 and 1980 books, which would have run on mainframe computers using punched cards for data input (Fig. 2.3). Thinking back to this heroic initiative one must admit that the Academy of Finland may have been right in turning the proposal down. Neither the hardware nor the software available then were quite up to the task, nor was the conceptual understanding of database structure. Nevertheless, it is undeniable that the idea was there at a very early stage. Nor can it be considered a coincidence that Kurtén's former students were later to play an important role in furthering the idea.

After Björn Kurtén's death in 1988 there was a strong wish among his many colleagues worldwide to arrange a memorial meeting and publish a volume to honor his legacy. The meeting took place in Helsinki in the autumn of 1989, incidentally coinciding with the fall of the Berlin wall, and a resulting volume was eventually published as a special issue of *Annales Zoologici Fennici* (Forstén et al., 1992). The

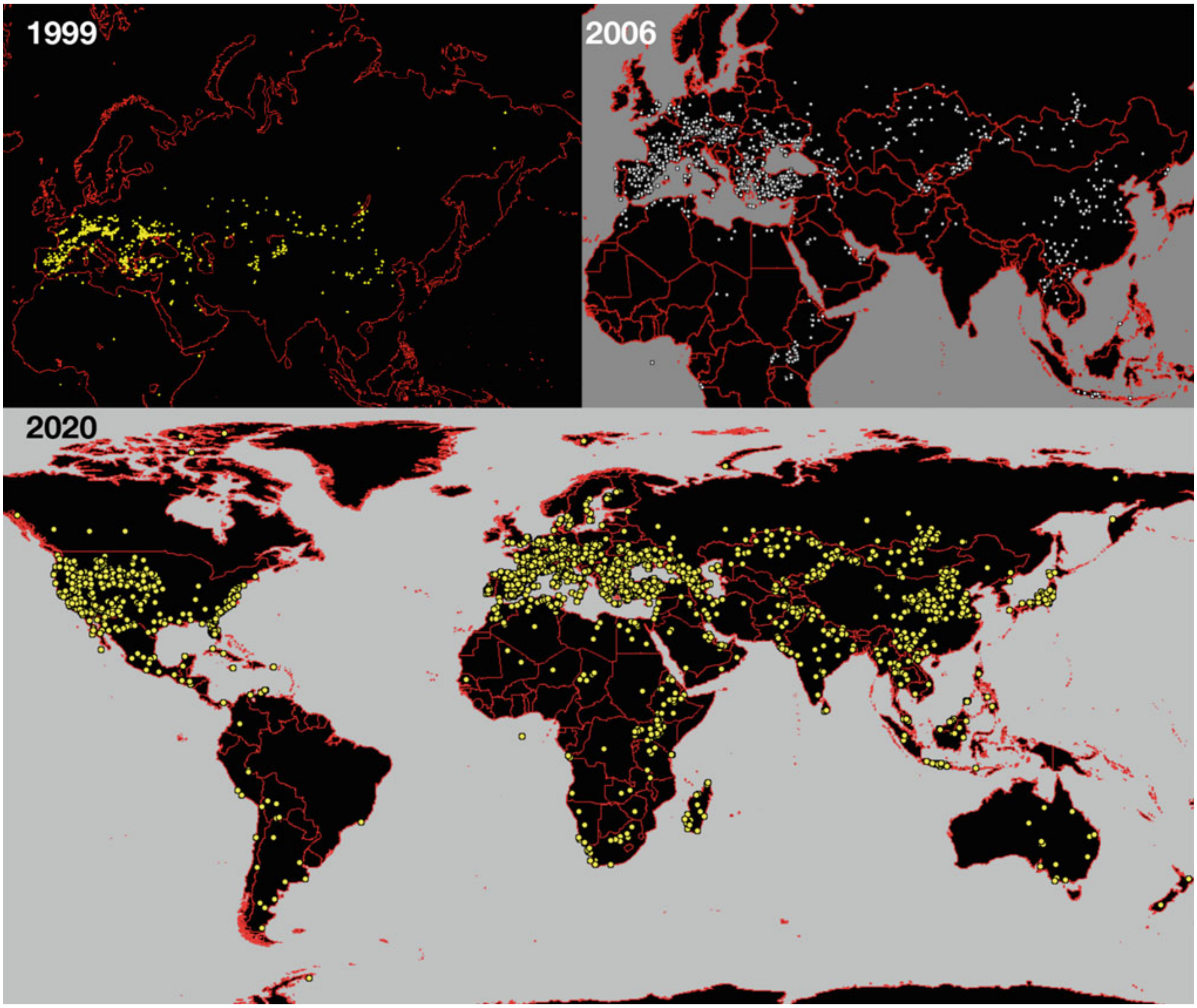
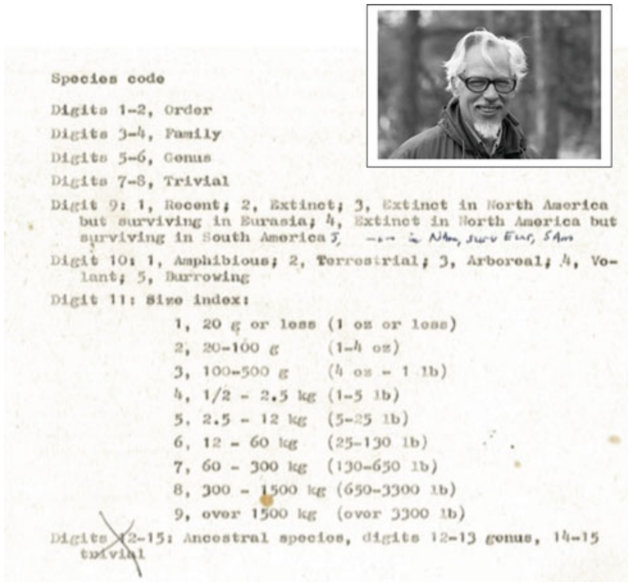


Fig. 2.2 All public NOW localities plotted at different times of the development of the database, showing the successive expansion of spatial coverage. *Graph*: Mikael Fortelius and Indrė Žliobaitė

original idea had been to publish a much more comprehensive book in the tradition of Kurtén's own synthesis volumes, but these were the days of the first enthusiasm for computerized databases and the book initiative accordingly soon evolved into a project for a database. A proposal to this effect was submitted to the European Science Foundation, which eventually funded a *Network on Quaternary Mammalian Faunas* for 1991–93. One explicit goal of the Network was the establishment of a database of Quaternary Mammals of Europe, a parallel to the American initiative FAUNMAP (FAUNMAP Working Group, 1994), with a similar concept and structure.

In September 1991, Lars Werdelin hosted a technical workshop in Stockholm (Fig. 2.4) where the properties of a Quaternary Mammal Faunas database were discussed in some detail, under the expert guidance of Russell Graham of FAUNMAP, a Quaternary fossil mammal database currently part of the Neotoma Paleoecology Database (https://www.neotomadb.org/) and David Mayhew, a database professional with roots in mammal paleontology. An unpublished report with detailed plans was later circulated as "Report #1" of the Network (Werdelin et al., 1992). The Stockholm meeting fed directly into the first of three ESF-funded meetings under the Network, *Mammalian Migration and Dispersal Events in the European Quaternary* at Andernach on the Rhine, hosted by Wighart von Koenigswald in October of the same year. The Network was quite successful and arranged two more workshops, at Dijon in 1992 and at Sant Feliu de Guíxols, north of Barcelona, in 1993 (Agustí & Werdelin, 1995; Chaline & Werdelin, 1993; Von Koenigswald & Werdelin, 1992). Data on the occurrence of Quaternary mammals were compiled in the process



Species code

Digits 1-2, Order

Digits 3-4, Family

Digits 5-6, Genus

Digits 7-8, Trivial

Digit 9: 1, Recent; 2, Extinct; 3, Extinct in North America but surviving in Eurasia; 4, Extinct in North America but surviving in South America 5, -- in NAm, surv Eur, SAm

Digit 10: 1, Amphibious; 2, Terrestrial; 3, Arboreal; 4, Volant; 5, Burrowing

Digit 11: Size index:

1, 20 g or less (1 oz or less)
2, 20-100 g (1-4 oz)
3, 100-500 g (4 oz - 1 lb)
4, 1/2 - 2.5 kg (1-5 lb)
5, 2.5 - 12 kg (5-25 lb)
6, 12 - 60 kg (25-130 lb)
7, 60 - 300 kg (130-650 lb)
8, 300 - 1500 kg (650-3300 lb)
9, over 1500 kg (over 3300 lb)

Digits 12-15: Ancestral species, digits 12-13 genus, 14-15 trivial

Fig. 2.3 Example of coding for Björn Kurtén's Quaternary mammals database in the 1980s. A bold but precocious initiative that never quite materialized. Scanned document from the archives of Lars Werdelin. *Inset*: Björn Kurtén in 1986. *Photo*: Mikael Fortelius

Fig. 2.4 The Stockholm database meeting in 1991. A. Group photo with Mikael Fortelius, Lars Werdelin, Patrick Brunet-Lecomte, Albert van der Meulen, David Mayhew. *Photo*: Russell Graham. B. Database structure presented by David Mayhew (lower right). *Photo*: Lars Werdelin

but an actual database did not yet materialize. Those data were eventually made available through the Gaia data depository, latterly Pangaea, and later gradually made their way into NOW.

Making It Work

Anyone who has been seriously involved with the development of scientific databases will recognize a number of universals. The first and also the most trivial of them is the early obsession with technical matters, such as the choice of software platform or programming language, on which hecatombs of time and effort have been and are still being sacrificed. Interoperability, industry standard query languages, open-source software, high-level object-oriented computer languages, and the internet itself were new ideas in the early 1990s. Accordingly, there was a fear (unreasonable, as it turned out) that if one did not choose wisely, one's data would become "stuck" in a particular system and format, and could not be recovered (anyone old enough to remember trying to extract large datasets from mainframe tapes to simple ASCII files recognizes the source of that fear and frustration). Hot on the heels of this comes the question of data access: who shall be permitted to use our incomparable database? In the present days of open access and open data it may not be obvious, but the instinctive and near-universal answer used to be some version of reciprocity: only if you contribute data will you gain access. This seemingly rational and fair choice of policy has spelled the doom of many a promising database. The population of potential contributors is simply far smaller than the population of potential users, and it is the latter that determines the visibility and perceived success of the database.

The NOW database was somehow blessed in avoiding the worst of such standard mistakes. The key factor here may paradoxically have been the lack of funding and resources in general. For software we just took what happened to be available, making progress through trial and error. The list is long and includes at least the early platforms *dbase*, *Kman*, *Clarion* and *Paradox*. Once you have built a relational database several times in different environments, passionate arguments for any one of them appear rather futile. The far more important matter of database structure and standards was never an issue for NOW, having been built originally as a clone of the ETE database.

As for data contributors, it soon became clear that it was far easier to compile data on behalf of potential contributors than to persuade them to do so themselves. When actually faced with a complication of data, purportedly from her own published work, a normal scientist will be utterly unable to resist the urge to correct the mistakes. And even the few who resist this urge cannot prevent the database from compiling their data unless they (suicidally) refuse to allow public use of said data. This is recognised among professionals as *Damuth's Vice*. It was accordingly always obvious that NOW should have unrestricted access, right from the time that it was officially launched in 1996. But we are running ahead of our story. Let us step back and review the circumstances that surrounded the birth of NOW.

Building Blocks

To understand the beginnings of NOW it is necessary to appreciate the special problems of European mammal stratigraphy. In much of North and South America, Asia and Africa, fossil localities often occur in long, continuous and well-exposed stratigraphic sequences that can be dated directly by radioisotopic and/or magnetostratigraphic methods. In contrast, European fossil localities tend to lack a clear lithostratigraphic context; they also frequently have no datable rocks and are dependent on biochronologic dating techniques. Especially in central Europe, the fossils often occur in isolated patches of sediment or in fissure fillings and often the only means of dating them is the taxonomy of the fossils themselves. This is why the MN-system (from Mammal Neogene; De Bruijn et al., 1992; Fahlbusch, 1991; Mein, 1975, 1979, 1989), a chronology based on the presence (and, in some implementations, the evolutionary stage) of mammal taxa has been such a fundamental framework for the Neogene mammal stratigraphy of Europe.

Needless to say, fossil localities from long continental sequences, especially from Spain, were critical in the building of the MN system from the beginning and helped define its chronology and improve its resolution. These included the Early-Middle Miocene sequence of the Calatayud-Daroca Basin, the Middle to Late Miocene sequences of the Vallès-Penedès Basin and the Late Miocene sequences of the Teruel-Alfambra Basin. Thus, the important bipartition of the Vallesian into MN9 and MN10 was a direct result of the local biozonation proposed for the Vallès-Penedès Basin (Fahlbusch, 1976). Similarly, the tripartition of the Turolian into MN11, MN12 and MN13 directly followed the biozonation proposed by Anne van der Weerd for the Teruel-Alfambra Basin (Van de Weerd, 1976). Indeed, a more conventional alternative to the MN-system, applicable to such long sequences, was the definition of a number of European Land Mammal Ages (ELMA), such as the Vallesian, the Turolian and the Aragonian (Crusafont Pairó, 1950; Crusafont Pairó & Truyols Santonja, 1960; Daams et al., 1977).

The inception of what later became known as *The Reisensburg Concept,* focused on central Europe and the eastern Mediterranean, must be seen against this background of challenging stratigraphic relationships. This idea underwent a slow gestation period during a one-year Alexander von Humboldt fellowship that Ray Bernor enjoyed during the 1989–1990 academic year. This fellowship ended with a five week stay at the University of Helsinki with Mikael Fortelius, working on the horses from the Late Miocene Sinap Formation in central Anatolia, where Fortelius was co-directing a field project at the time. Along with the systematics of the Sinap horses arose clear evidence of provinciality of Pikermian faunas in general and hipparionin horses in particular. Bernor expressed interest in dissecting the Pikermian phenomenon to derive a clearer history of the rise, dispersion and fall of Late Miocene savanna faunas.

Upon returning to Howard University in July, Bernor formulated a plan for a workshop and study of Eurasian Miocene mammal faunas. Bernor originally approached Fritz Steininger in early September, 1990. Steininger showed interest but in fact was too occupied with the renovation of the Paleontological Institute in Vienna and rising interest in him becoming Director of the Senckenberg Museum, Frankfurt, Germany. Bernor then turned to Siegfried Rietschel, Director of the Staatliches Museum für Naturkunde, Karlsruhe and Volker Fahlbusch, Professor at the University of Munich. Both agreed to help Bernor undertake this project. Rietschel wished to host this meeting at the classic locality of Höwenegg, Hegau, Germany and to that extent opened a test trench across the site in the summer of 1991 to expose the geological section. Karlsruhe Biology Curator Hans-Walter Mittmann took over this organization at Rietschel's direction. In the meantime, Volker Fahlbusch applied to the VW Stiftung for money to support the workshop. This request was successful and funded the 1992 workshop. The workshop began in Immendingen, near the Höwenegg site and the invitees visited the site to see a complete *Miotragocerus* cranium retrieved from the site and Carl Swisher sampled the section for paleomagnetics and argon/argon dating (which successfully gave a congruent age of 10.3 Ma, MN9; Swisher, 1996).

The Reisensburgian Era

The Reisensburg Process

The primary objective of the Reisensburg workshop (Fig. 2.5) was to update the systematic framework for the small and large mammal groups being reported. Workshop participants agreed that revising the taxonomy and acquiring a contemporaneous view of systematics and evolution would lead to the best resolved report for Eurasian Miocene mammals. De Bruijn et al. (1992) provided a revision of MN

Fig. 2.5 A. Heinz Tobien and Ray Bernor at the Höweneg. Quarry in 1986. Photographer Unknown. B. Ray Bernor at the Schloss Reisensburg meeting in 1992, flanked by Carl Swisher III (left) and Jens Franzen (right). Dorsal view of Sevket Sen in the background. *Photo*: Mikael Fortelius

units, which subsequently was placed in the wider scope of circum-Mediterranean geochronology by Steininger et al. (1996). Swisher redated Höwenegg and Maragheh while large mammal and small mammal groups were revised by several invited specialists. Fossil plant occurrences were revised by Kovar-Eder and colleagues. Biogeographic and paleoecological interpretations were made by Bernor, Fortelius, and their collaborators. It took four and a half years to complete the project, from the time of the workshop in the summer of 1992 until the publication of the Reisensburg volume in 1996. It is true enough that there were some political challenges along the way, the pervasive one being "why is a young American vertebrate palaeontologist in such a prominent role for this initiative?" Volker Fahlbush and Siegfried Rietschel staunchly defended Bernor for leading this initiative and it should be told that Bernor's principal detractor was distinctly proud of the outcome that fifty colleagues produced in the Reisensburg Volume *Evolution of Western Eurasian Neogene Mammal Faunas* (Bernor et al., 1996).

The Reisensburg Volume was the originally envisioned end product of the meeting, promised to the VW Stiftung and the participants, along with a compilation of up-to-date raw data to be shared among the group. But by the time of the workshop, Fortelius already had one foot firmly in the world of databases and he accordingly brought up the idea of making the newly compiled high-quality data the core of a more permanent database, to be updated and offered to the scientific community in general. This idea received some support, but by the end of the meeting the matter was still undecided and no discussion of practical details had yet taken place. At this point another NOW coincidence occurred, paradoxical as in a Tang Dynasty parable, where good bad fortune cannot be told from good except in retrospect. Fortelius returned to Helsinki to learn that the Academy of Finland had unexpectedly failed to continue his main research project on the evolution of occlusal relationships in suoids and he was therefore both in acute need of a more fundable research project and free to commit himself fully to it. Given the situation, the idea of a database project based on the Reisensburg process and data seemed an obvious choice. We quote from p. 6 of the original proposal to the Academy of Finland, submitted in January 1993 and approved in May the same year:

> *Fossil land mammals offer both 1) a source of independent data for investigating the nature and timing of these and other similar changes, and 2) a direct window on other, related and/or simultaneous changes in the mammal communities in different habitats and on several continents. Conversely, the evolution of land mammals in relation to such an increasingly detailed background of environmental change offers challenging opportunities for evolutionary research with an ecological perspective and a geological time scale.*
>
> *An important step towards a more global analysis of the European fossil land mammals was recently taken by Bernor, Fahlbusch and Rietschel, who organised a roundtable workshop at Schloss Reisensburg (Germany) on the Evolution of Continental Biotopes in Central Europe and the Eastern Mediterranean (15-5 Ma) in July 1992. For this workshop specialists were invited to revise the material for all relevant taxa and for a large number of fossil localities from Poland to Iran, and to analyse temporal and biogeographic patterns. This particular area was chosen because it can be related to the history of the Paratethys complex, and the interval because major physical and faunal changes are known to have taken place then. The Neogene land mammals are diverse enough and have a sufficiently rapid turnover to allow quantitative treatment of the data. This data will form the basis of the first scientific investigation undertaken using the NOW database, a collaborative project between Fortelius, Bernor & Mittmann (Letter 1).*

The funding of this project instantly created the resources needed for going ahead with the database idea. It also raised some questions about the principles and practices of such an endeavor. In retrospect, one of them stands out as crucial:

should it continue to be an informal coalition of friends and collaborators or should a more formal structure be created? In particular, should there be a formal advisory board? The fact that this question was eventually answered by affirming the latter position may have been one of the most decisive steps in the early history of the NOW database, providing it with both the scientific credibility and the sense of commitments and continuity that a fledgling database so badly needs. The original invitation to the Advisory Board members is included as Appendix 2.1.

NOW Begins

Once the database was established other developments followed naturally. In 1995, the ESF approved a new network called "Hominoid Evolution and Environmental change in the Neogene of Europe" (HOMINET). The network was coordinated by Jordi Agustí and members of the Steering Committee included, besides Mikael Fortelius, also Peter Andrews, Lorenzo Rook, Louis de Bonis and George Koufos. Although originally centered in the climatic and environmental context of the hominoid species in Europe, one of the explicit main goals of the network was to produce a database of the hominoid sites, mainly those belonging to the Vallesian and Turolian European Land Mammal Ages.

In this way, the HOMINET became an early and major contributor to NOW. The original NOW was intended to include Neogene data from Spain, Italy, Germany, Hungary, Greece, Turkey and Ukraine, among other countries. In order to achieve these goals, three workshops were organized. The first one took place in 1996 at Sant Feliu de Guíxols north of Barcelona, Spain, organized by Jordi Agustí and devoted to "The Vallesian". A second workshop was organized in 1997 by Lorenzo Rook at Certosa de Pontignano, Siena, Italy, devoted to "Climatic and environmental change in the Neogene of Europe". As a result of these two workshops, a volume of more than 500 pages was published in 1999 by Cambridge University Press, edited by Jordi Agustí, Lorenzo Rook and Peter Andrews, entitled *The Evolution of Terrestrial Ecosystems in Europe* (Agustí et al., 1999). This volume included significant contributions such as *The paleoecology of the Pikermian Biome and the savanna myth* (Solounias et al., 1999) or *Vicariance biogeography and paleoecology of Eurasian Miocene hominoid primates* (Andrews & Bernor, 1999). A third workshop took place at Nikiti, Greece, in 1998, organized by George Koufos, under the title *Phylogeny of the Neogene Hominoid Primates of Eurasia*. Contributions included sites from Spain, Italy, Hungary, Greece, Turkey, Georgia and Pakistan. As happened with the first two workshops, a second volume was published by Cambridge University Press in 2001, edited by Louis de Bonis, George Koufos and Peter Andrews (De Bonis et al., 2001).

Smaller initiatives also added to the NOW. The insectivorans had fallen through the cracks at the Reisensburg meeting, considered to be "insufficiently known at the point" (De Bruijn et al., 1992). This struck a nerve with some colleagues who had either published on the group or even dedicated most of their career to the study of insectivores. During a meeting at Senckenberg, Frankfurt, the Working Group on Insectivores of the Neogene of Eurasia (WINE) was formed and two years later a volume on the fossil record of the group in many countries was published (Van den Hoek Ostende et al., 2005). Fortelius quickly recognized this as a welcome addition to the NOW and the data were transferred into the database, turning one of the lesser documented groups into one of the best elaborated, as it were, overnight. This was also the start of Van den Hoek Ostende becoming more involved in the NOW and taking on a role as Associate Coordinator of small mammals. Which was a quite remarkable conversion, considering that at the Senckenberg meeting he had opposed the idea of publishing the insectivores as a database in the first place.

NOW as an ETE Node

In 1986, the Evolution of Terrestrial Ecosystems Program (ETE) was established in the Department of Paleobiology at the National Museum of Natural History (Smithsonian). One of its signature early projects was the development of a computer database for the terrestrial fossil record. By 1992, ETE had developed a design and detailed schema for such a relational database (Damuth et al., 1997). A chance meeting in the fall of 1992 between Mikael Fortelius and John Damuth (then of ETE) started a conversation about coordination of databases. Fresh from the Reisensburg meeting, Fortelius knew that the kernel of a database of Old World Neogene faunas had taken shape, but the remaining question was the technical issue of how best to turn the data compilation into a database that would have potential for longevity and growth. ETE offered a general, public structure that could guarantee a degree of generality without sacrificing functionality. Fortunately for NOW, it was also organized as a system of nodes in order to allow participants to work from multiple locations, independently of institutional affiliation.

The first version of what we now know as NOW was compiled in the autumn of 1993 by Mikael Fortelius and Suvi Viranta in *Paradox* for Windows, using the ETE structure. At this point Providence once more smiled upon NOW. In October the same year there was an infrastructure call by the Academy of Finland, to which Fortelius on short notice submitted an application for an HP-UNIX server to host the still embryonic database, with specifications to match those chosen by the ETE for its own database. Against all expectations, the Academy approved this application in December the same year.

Moving NOW to the University of Helsinki's server platform meant that not only the structure, but the user interfaces that ETE had developed could be used seamlessly by NOW. Furthermore, the rise of the Internet made it possible to update and troubleshoot the software applications remotely. Significantly, in the days before the Web, it was nevertheless possible to work directly with the database for research remotely, using the *X Windows* system in any terminal application that was available at the time in some form or other on all computer platforms. NOW could be *served*. The user logged in directly to the NOW server in Helsinki, and the interactive graphical user interface appeared on their own computer. This was based on a custom-designed GIS application written for ETE and would later provide the architectural foundation for other databases as well, among them the original Paleobiology Database. The user was presented with a digital map of the world and could zoom in on any region, specify a timespan, and the localities would appear as points. Their contents could be seen via mouse-over, and the map display could be queried for specific taxa or, for that matter, any properties recorded for the localities. Subsets of the data could be created this way and downloaded as delimited text files, or *SAS* datasets, or other useful formats. Even the map display with localities could be downloaded as a fairly basic *PostScript* file (this was before PDF). Additional features of the GIS interface included typical ones such as scale bars and measurement of distances. Another graphical interface could be used locally to manage the database.

In the summer of 1994, the latest *Paradox* version of NOW was successfully ported to the new server and over the ensuing months various bugs and implementation issues were worked out. By 1995, NOW had become a peer-node database in the ETE Consortium, and NOW and ETE were in regular communication. It may be of interest here to record that the Helsinki NOW office was using an early Linux Debian installation on a PC as a NOW terminal during this time, starting from November 1995. The first machine was very nearly installed by Linux creator Linus Torvalds himself, but owing to a mismatch of schedules it was eventually done instead by another early Linux legend, Lars Wirzenius. Linux support in those critical days was most generously supplied by Jussi Sjöström, IT support of Hanken School of Economics, Helsinki (which may or may not have been aware of these goings-on).

In time, the ETE Program reset its priorities, and by 2000 it was no longer building and hosting its own database. Significant subsequent American palaeontology database efforts such as PaleobioDB (https://paleobiodb.org/) and FossilWorks (http://fossilworks.org/) have focused on ambitious national projects to database the entire published fossil record, terrestrial and marine, at first primarily to study patterns of global Phanerozoic diversity. These projects necessarily have a different set of goals and a different relationship with the professional community than does NOW, which was a more focused but also more open-ended and actively maintained database effort.

Under these circumstances NOW had little choice but become an independent entity with its own infrastructure and institutional support. This was a time of trial and error, with false starts and temporary fixes of various kinds. But crucially, the NOW community persisted through the crisis and the building of the database continued without any serious disruptions. In this phase, crucial support from the Finnish Society of Sciences and Letters (one of the two national science academies of Finland) meant that students could be employed for data entry and checking. Thus, the database continued to grow in scope as well as in usefulness, providing an increasingly fertile platform for the kind of research that would later be labeled as *ecometrics* (Eronen et al., 2010a).

An Excursion into the Land of Nod

This chapter is the story of how the NOW database came to be and how it grew. There were, of course, all sorts of disappointments, setbacks and failures along the way but rehearsing them at length would serve no useful purpose here. But there is one spectacular failure that may be worth a brief section as it is of some historical interest as well as a great cautionary tale. This is the story of the EEDEN Programme.

As the first results of NOW analyses were emerging in the mid-1990’s there was considerable enthusiasm and hope that a new and better understanding of deep time ecosystem change might be within reach. The multidisciplinary ambitions of the HOMINET workshops mentioned above also provided a fertile substrate for thinking along such lines. Thus, it came to be that a remarkably ambitious initiative was conceived and proposed to the European Science Foundation as a Scientific Programme. The idea, first formulated in an informal conversation between Nicholas Shackleton and Mikael Fortelius, was to extend the scope of HOMINET to include the marine realm, add a strong modeling component, and to shift the emphasis from hominoid evolution to the collapse and recovery of ecosystems. In short, this was to be what today would be called Earth system science. The programme was approved by the ESF for the five-year period 2000–2004. As a programme,

Fig. 2.6 Mosaic of participants from several meetings of the EEDEN Programme. A. Sabadell, Spain, 2001: Jordi Agustí, Zlatko Kvacek, Louis Françoise, Jan A. van Dam. B. Frankfurt am Main, Germany, 2002: George Doukas, Silvia Iaccarino, Johann Meulenkamp, Jussi Eronen. C. Frankfurt am Main, Germany, 2002: Mikael Fortelius, John Damuth, Volker Mosbrugger. D. Stara Lesna, Slovakia, 2004: Hans de Bruijn, Gudrun Daxner-Höck, Madelaine Böhme. Photographers unknown

rather than a network like HOMINET, it had substantial resources for researcher mobility and research as well as for meetings.

The EEDEN programme organised a series of inspiring meetings with memorable discussions between participants who were in many cases being exposed for the first time to completely different methodologies and viewpoints. Especially the world of modeling was new to many and not everybody was ready to embrace it without reservations, but over time there was genuine increase of understanding. Many transdisciplinary friendships were also formed under the EEDEN umbrella, especially among the young researchers who benefited from the laboratory visits that EEDEN made possible (Fig. 2.6).

There is little doubt that EEDEN contributed significantly towards integration in a broad sector of earth and life sciences and was in that sense a real success. It nevertheless failed spectacularly to achieve its specific goal of providing a synthetic, system-level understanding of ecosystem collapse and recovery. Indeed, it even failed to overcome the technical obstacles it had identified at the outset and promised to clear away, such as mismatches between regional stratigraphic schemes or a routine for easily plotting present-day coordinates on paleogeographic maps. Much incremental progress was made during the tenure of EEDEN in its individual participant groups but, apart from inspiring discussions at meetings, it was largely business as usual. Perhaps the time was not yet ripe. Years later concepts such as “critical transition”, “tipping point” and “system state shift” would enter into the global change debate and public vocabulary as a result of quite different efforts (e.g., Barnosky et al., 2012; Scheffer, 2009; Steffen et al., 2011). In the history of the NOW database, EEDEN passed almost without a trace.

The Ecometrian Era

The Birth of Ecometrics

In the late 1990s, there was a surge of interest in using fossil vertebrate faunas to quantitatively reconstruct aspects of Neogene and Paleogene habitats and paleoclimates. Other than in the province of Pleistocene and Holocene vertebrate researchers, who often can directly rely on the known properties of extant species, vertebrate-based paleoecology of even deeper time must usually employ traits that have a more general, functional relationship with the environment. An early attempt in this direction was E.C. Olson's reconstruction of a Permian food web, which showed how different taxa occupied similar ecological roles over time (Olson, 1952). An ETE conference in 1987 on *Terrestrial Ecosystems Through Time* and the book resulting from it (Behrensmeyer et al., 1992) included discussion of what was then called *ataxonomic* characters, functional traits that would enable different taxa to be compared over long periods of time in terms of their ecological roles. The chapters on *Ecological characterization of fossil plants* (Wing & DiMichele, 1992) and *Taxon-free characterization of animal communities* (Damuth, 1992) are good examples of that novel direction.

An early example of using a trait-based approach to reveal paleoenvironmental patterns was Jernvall et al. (1996), using a global data compilation published in book form (Savage & Russell, 1983). The obtained patterns were also shared with Helsinki researchers in meteorology and atmosphere physics at an early date and their enthusiastic support for interpreting them in relation to past climates definitely contributed to thinking about them as potential climate proxies. A more database-oriented attempt to address this was carried out by a working group at meetings between 1998 and 2001 at the National Center for Ecological Analysis and Synthesis in Santa Barbara (Fig. 2.7). The results were somewhat disappointing and in retrospect the effort was perhaps premature. But what did emerge was yet another potential paleoclimatic relationship between rainfall, on the one hand, and mean hypsodonty divided by species richness on the other (Damuth et al., 2002). A parallel exploration of patterns of hypsodonty and lophedness in fossil data was also in progress at this time (e.g., Fortelius & Hokkanen, 2001; Fortelius, 2003) but these early efforts were severely hampered by the crude options available for displaying the results. In this intellectual climate, then, it may not be surprising that Fortelius was alert to something that he discovered by chance in 2001 while trying out a new kind of plot offered by a statistics package (incidentally during the Golden Dragon New Year celebrations in a wintery Beijing): the summed pattern of the distribution of molar crown heights in the totality of NOW data showed a striking resemblance to the present-day distribution of rainfall on the Eurasian continent. This suggested that hypsodonty alone, combined with the readily available NOW data, might be able to reconstruct geographic patterns of past rainfall.

The challenge of displaying these patterns was finally solved when Jussi Eronen joined Fortelius as a masters student and brought with him from his geography background cartographic skills including knowledge of the then still new-fangled GIS. Very soon after, the first mean hypsodonty maps were generated and presented to a broader audience at a meeting honoring the 70th birthday of Hans de Bruijn in May 2001 (Fortelius et al., 2003). Technically more advanced maps of a similar kind were published more accessibly the following year in *Evolutionary Ecology Research*, one of the first journals to make space for this emerging field (Fortelius et al., 2002; Fig. 2.8), significantly with Helsinki meteorologist Juhani Rinne as one co-author. The support of professional meteorologists was critical at this early stage, but eventually the need to anchor the colorful and suggestive maps in more than scientific intuition led to the development of the mean ordinated hypsodonty proxy for past rainfall (Eronen et al., 2010a, 2010b, 2010c; Fortelius et al., 2006a), the beginning of a vigorous line of research that continued to produce interesting results over the last decade. But we must leave the narrative at this point, ten years before the time of writing this text.

Fig. 2.7 Mikael Fortelius (left) and John Damuth (right) at the National Center for Ecological Analysis and Synthesis in Santa Barbara in 1998. *Photo*: Christine Janis

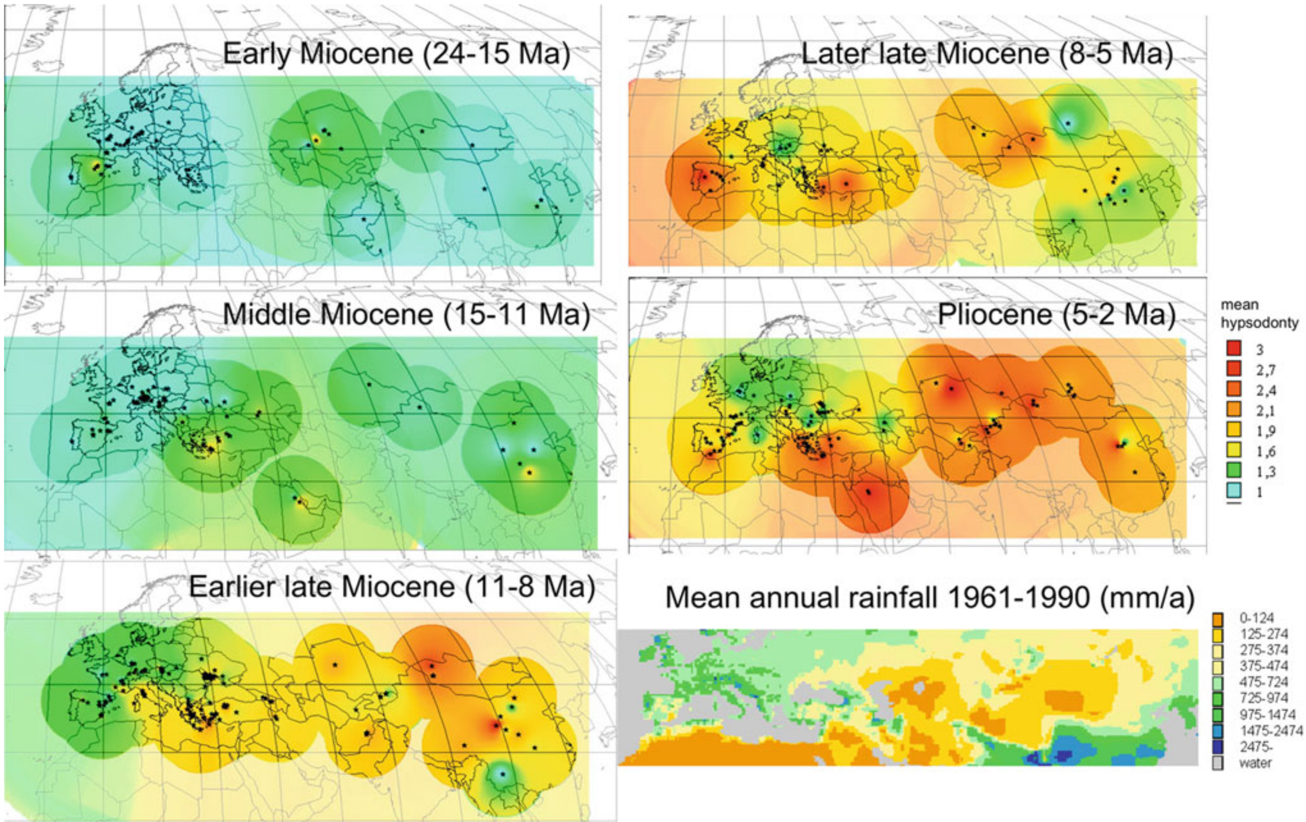


Fig. 2.8 Example of inverse-distance interpolated maps of ordinated mean hypsodonty overlain on a map of Eurasia, interpreted as changing rainfall distribution over Neogene time. From Fortelius et al. (2002)

NOW Comes of Age

Meanwhile, in parallel with the development of ecometric proxies for environmental conditions, a second line of NOW-based research was emerging. Here, the aim was not reconstructing environmental patterns of the past as such, but rather to understand the evolutionary dynamics generating them, through adaptive trait evolution driven ultimately by biotic interactions as well as changing physical conditions. The first to reach publication was Jernvall and Fortelius (2002), showing that the changes in spatial hypsodonty patterns in the European Neogene were due mainly to the evolutionary success of herbivores with increased crown height, which became progressively more common relative to herbivores lacking this key feature. The follow-up study of Jernvall and Fortelius (2004) delved deeper into the dynamics, looking at the history of the most common lineages in the same dataset. In retrospect, the most significant finding of the paper was undoubtedly the discovery of what is known today as the hat pattern: the unimodal occupancy history of taxa in the fossil record (Foote et al., 2007; Liow & Stenseth, 2007), currently another subject of vigorous research, still partly involving NOW data.

The first explicitly NOW-based publications are from 1996, all but one of them (Fortelius et al., 1996a) being contributions to the Reisensburg Volume (Bernor et al., 1996), described earlier in this narrative. These early papers were strongly focused on the analysis of quantitative patterns of diversity, turnover, biogeography and community structure, but following years saw a broadening of the scope, with a steady stream of papers citing NOW for their data. Some of these papers are cited on the NOW webpage (https://nowdatabase.org/now/publications/) but the list is surely incomplete. It is striking in retrospect how many of these early papers were concerned with age and timing (among others, Agustí & Oms, 2001; Agustí et al., 2001; Garcés et al., 2001; Krijgsman et al., 2000). Paleoecological and paleobiogeographic work of course continued (Bernor & Rook, 2008; Bernor et al., 2009; Casanovas-Vilar et al., 2010; Furió et al., 2011; Koufos, 2003; Koufos et al., 2009; Madern & Van den Hoek Ostende, 2015; Nargolwalla, 2009; Solounias et al., 2010). Some of the earliest papers to computationally assess the completeness of the mammalian fossil record (Alba et al., 2001; Bingham et al., 2007; Saarinen et al., 2010) also used NOW data, as did some early

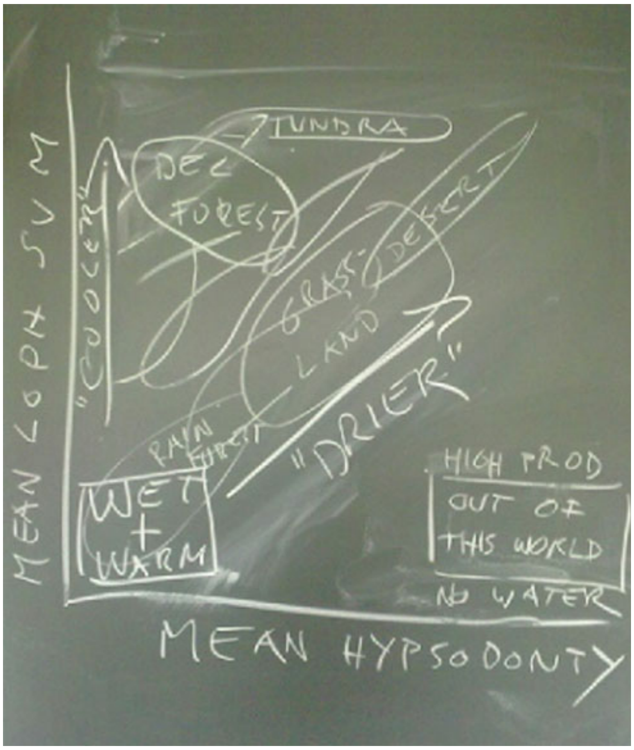


Fig. 2.9 Towards resolving the ecometric biome space. Snapshot of the blackboard in Fortelius' office in 2010, showing an early version of the work published by Liu et al., 2012. *Photo*: Jukka Jernvall

work on computational biostratigraphy (Alroy et al., 1998; Fortelius et al., 2006b; Puolamäki et al., 2006; Ukkonen et al., 2005). Macroevolutionary work also started to emerge at this time (Liow et al., 2008; Peláez-Campomanes & Van der Meulen, 2009) as did paleoclimatology (Eronen et al., 2009; Liu et al., 2009; Micheels et al., 2009). The research fed by NOW has continued to grow and diversify and many more publications have appeared over the last decade but a description of those developments is beyond our present scope. Figure 2.9 shows an example of work in progress from 2010, moving towards an ecometric concept of paleobiome space.

It is important here to emphasize that NOW has always served two main functions: to provide datasets for quantitative analysis and publication, but equally, if not even more importantly, to function as an online source of information about fossil mammals and localities. This latter role is difficult to quantify (and records from the early years do not exist), but a rough idea is given by the number of mean monthly visitors (173 in 2012, 485 in 2020) and by the number of mean monthly pages visited (1933 in 2012, 3059 in 2020). These numbers should be compared to the size of the relevant research community, which, although numbers are not readily available, is probably on the order of a few thousand individuals worldwide. For example, ORCID (https://orcid.org/) queries matching variant spellings of paleontology gave 3,677 researchers in January 2021. A search at the Web of Science Core Collection provided 4,817 authors for the Web of Science Category "Paleontology" for publications during 2017–2021. Similarly, the Society of Vertebrate Paleontology reports its membership as "approximately 2,000" while the Palaeontological Association gives "well over 1,000" and even the Facebook groups of these two have only about 5,000 and 2,200 members, respectively. A more detailed search at the Web of Science Core Collection (https://clarivate.com/webofsciencegroup/solutions/web-of-science-core-collection/) provided 1,086 authors for the Web of Science Category "Paleontology" for publications during 2017–2021 with additional 60 keywords, including "Mammalia", "Mammals", "Mammalian" and 57 taxonomic order names listed in NOW database. In this perspective, hundreds of visitors per month is quite a respectable number.

Connecting People (and Disciplines)

As is often the case in research, funding opportunities can inspire creative solutions by connecting previously separate disciplines and people. One such opportunity was the 2003 call of Academy of Finland on Systems Biology. Whereas systems biology and fossils did not exhibit any obvious links, Jukka Jernvall, Irma Thesleff, and Mikael Fortelius nevertheless proposed that studying mammalian teeth from evolutionary, ecological, and developmental biology perspectives could in fact be considered systems biology. A key component of the proposal, which ended up being fully funded, was the aim to examine ways to link NOW to datasets ranging from molecular data on developing mouse teeth to digitized, three-dimensional tooth shapes. Here, a key person hired in the project was Gudrun Evans, who developed the database structures to link the different kinds of data. One outcome of the collaboration was that it set NOW in motion towards incorporating specimen level data, something that continues to this day. Dental morphology of extant taxa posed its own challenges as the same specimen could be represented by multiple *instances* in the data. These kinds of cases include tooth wear data obtained from wild animals captured multiple times (King et al., 2005), or time-lapse images of growing teeth on the petri dish (Harjunmaa et al., 2012). For these vastly diverse kinds of phenotypic data, Gudrun and Alistair Evans constructed a MorphoBrowser database (http://pantodon.science.helsinki.fi/morphobrowser/) that houses many of the datasets collected in individual studies (e.g., Evans et al., 2007; King et al., 2005; Wilson et al., 2012). Serendipitously, MorphoBrowser also became the basis for a new database in the US, thus continuing the transatlantic exchange of ideas that had been part of NOW from the onset. In 2008, Doug Boyer was working at Stony Brook University with Jernvall when an opportunity arose to re-engineer MorphoBrowser, resulting in the widely used MorphoSource database (https://www.morphosource.org/), currently coordinated at Duke University by Boyer (Boyer et al., 2017).

One of the aims of the systems biology collaboration was to develop methods to compare very different, almost incomparable morphologies. To do this, teeth from morphologically diverse taxa were studied using new taxon-free approaches (Andrews & Hixson, 2014). Initial steps included molar crown types that provide a simple tabulation of number and position of tooth cusps and crests. These ecometrical descriptions were incorporated into NOW and used in some of the early analyses of environmental patterns (Jernvall & Fortelius, 2002, 2004). Crown types were soon followed by more quantitative methods that were developed with Alistair Evans and Gregory Wilson (Evans et al., 2007; Wilson et al., 2012). Unlike work on tooth morphology, tooth genes remained a more protracted challenge. Already by 1998, Irma Thesleff had established a database for genes expressed in developing teeth (Nieminen et al., 1998). Whereas this Bite-It database allowed the visual inspection of hundreds of genes expressed in developing teeth, the actual number of genes expressed dynamically in a developing tooth is in the thousands (Hallikas et al., 2021). Indeed, new, fast-throughput methods to acquire huge amounts of gene expression data, increasingly at single cell resolution, have transformed the field of developmental genetics to rely on large international data depositories. Combining these system-level data on genes with data on phenotypic detail remains a challenge, but NOW-inspired 'ecometrics of genes' have provided new ways to disentangle the principles of development (e.g., Hallikas et al., 2021; Morita et al., 2020).

The Cosmopolitan Era

Opening the NOW Database up to the World

The very first attempt of making NOW open to the world was made by Kari Lintulaakso using the development tools of a private software company where he was working at the time. During 2001–2002 Kari made a proof-of-concept solution of a regular, HTML-based user interface that allowed adding and editing the data. Eventually, the solution proved to be too costly for the essentially volunteer-based NOW, and it was sadly buried without further development.

When Gudrun Evans took on the role of technical database coordinator in 2004, the existing UNIX version of NOW still only allowed users to view data remotely, but not to make any changes to it. Gudrun designed the structure for the new Systems Biology database, which linked the NOW database to the new MorphoBrowser and the Gene database (Fig. 2.10). She rebuilt the NOW database in MySQL, replicating the ETE-based table structure, and strengthening it by enforcing data rules restricting many fields to specific entries at the database level. Significant work was then undertaken to clean the data to meet these rules, and the data was subsequently transferred to the new MySQL database.

Evans created a new, user-friendly web interface in Servoy (Java-based, cross-platform software, able to be used by both Mac and Windows users). By downloading the client software, users were then able to directly search and view the database remotely and were also able to log in and enter and edit data directly from anywhere in the world. To maintain the integrity of the data, individual users were granted access to edit only a restricted set of data, which related to their area of expertise, determined either by taxonomy or locality. Researchers were able to edit records that they themselves had contributed, and regional and taxonomic coordinators were able to edit records related to their field. All changes were logged and could be checked by coordinators. Servoy offered the benefit that the interface could be developed relatively quickly, allowing focus to be directed to how the data should be displayed, and what functionality was required. It also allowed further time to be spent cleaning the data to improve the integrity of the dataset – many issues came to light as the data were able to be searched and viewed in more detail, including adequately dealing with diacritical marks in names, locality and taxon synonyms, consistency in usage of 'cf.', and errors in calculations of fractions of age in time units, errors in latitude and longitude, and of course spelling errors and inconsistencies in taxa, localities and museums. This is a very time-consuming process, but an essential part of ensuring database integrity, so that a user conducting a search will be able to find all the matching records. Evans created synonym tables and functions for creating synonyms and merging duplicate records to assist with this process. With increasing numbers of users able to edit and enter data remotely, it was also essential to keep track of user permissions, and to create a log of changes that keeps track of who made what changes when and why (by linking these to a reference). It was also important to ensure that the database was being backed up regularly and adequately.

As a result of the Systems Biology project described in the previous section, a new Systems Biology database, incorporating NOW, was hosted at the University of Helsinki on a new server called Pantodon. Evans was helped by database technician Joonas Kauhanen, who set up this server and created back-up routines, and also a website traffic monitoring feature so that we could keep track of the number of visitors to the site. Kauhanen continued his association

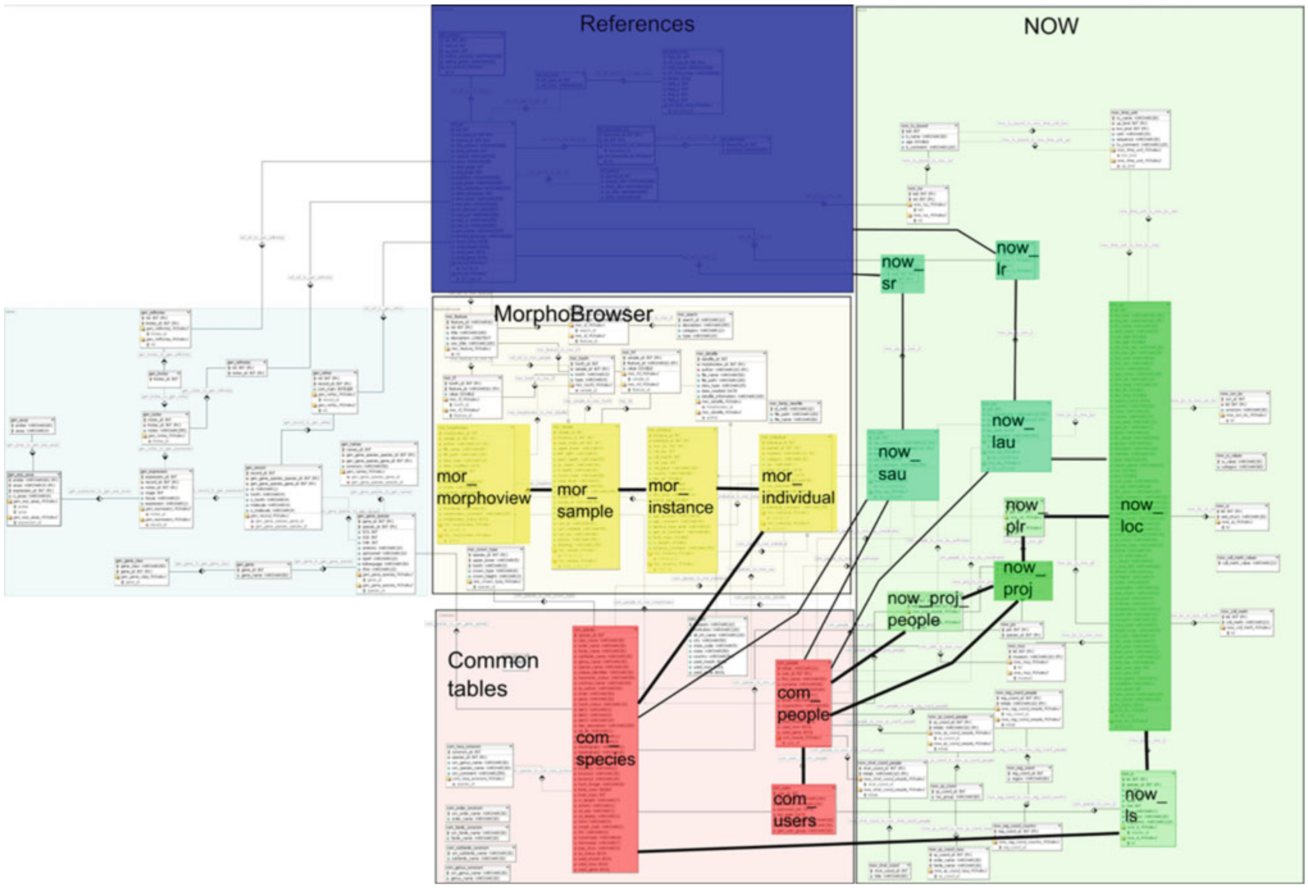


Fig. 2.10 The structure of the "Systems Biology" database, integrating NOW with the MorphoBrowser. *Graph*: Gudrun Evans

with the project for a number of years, and his expertise was invaluable in trouble shooting many issues as the database and interface were developed. The Servoy user database interface went live in April 2005.

Over time the limitations of using Servoy became apparent: many users experienced problems using the client software, the server software required updating frequently, which inevitably led to necessary fixes in the interface, and there was an annual license fee that was unsustainable in the long term. Therefore, in 2007, Evans commenced building a new user interface in PHP, replicating the look and functionality of the Servoy interface, still connecting to the MySQL database and using an Apache server (Fig. 2.11). This eliminated all the problems with Servoy, but it was more complicated to develop and took longer to create because everything had to be coded manually. Evans designed and created much of this interface herself, but was helped by a few database technicians, each of whom brought invaluable expertise to the project. Veli-Pekka Kestilä helped check the new interface for potential security flaws before it was released, and also helped move the database from the aging Pantodon server to a new server called Mutikka, hosted by the Finnish Museum of Natural History, in 2008. Jouni Vepsäläinen from Enporia Oy was contracted to write a log-in function and editing, saving, and logging functions for the PHP interface in March 2008, essential requirements before being able to open the interface to internet access. Jouni continued his association with NOW,

Fig. 2.11 Gudrun Evans in the office at Helsinki, coding the new PHP interface for NOW. *Photo*: Alistair Evans

Fig. 2.12 From left to right, Gudrun Evans, Susanna Sova and Mikael Fortelius at the farewell party for Gudrun and Alistair Evans in 2008. The tiramisu cake by Susanna Sova shows the NOW logo by Noira Martiskainen. *Photo*: Alistair Evans

helping Evans on various aspects of the interface development, and finishing the implementation of the database after Evans moved back to Australia in June 2008, with Susanna Sova taking over the management of the database (Fig. 2.12). The new PHP interface finally went live in October 2009, and users were now able to view and edit the data directly over the internet, without the need to download any client software. This was a critical step in the development of what was by then fast becoming a serious, international resource maintained by an interconnected NOW community.

Although NOW at the time of writing enjoys a comfortable and hopefully long-lasting relationship with the Finnish Museum of Natural History, the first attempt to place the database within the museum was not successful. In 2010, the database moved servers again, this time to a server called Mormyrus, hosted by the Institute of Biotechnology, part of the University of Helsinki. Atro Tossavainen provided a lot of assistance moving the database, and getting it functioning correctly on the new server. Evans continued her association with NOW from Australia for some years, communicating with Jouni Vepsäläinen and Atro Tossavainen as the database continued to be developed, working with Susanna Sova who was preparing the Harvard Siwaliks dataset for entry, and, together with Alistair Evans, on preparing the North American dataset for upload: the latter were uploaded in 2011, as described below.

Across the Vastness of Asia

Inevitably, and as has already been testified, the history of the NOW database was always intertwined with the individual histories of its participants. A case in point concerns its expansion from the original scope of central Europe versus the eastern Mediterranean to cover the entire Eurasian continent. While the NOW database was being born, Fortelius was shifting his field project from western to eastern Asia. This was a very deliberate move, motivated partly by the decline of the Sinap Project in Turkey (Sen, 2003:14) and partly by a (retrospectively remarkably naïve) hypothesis arising from the first analyses of the initial NOW data: that the faunal developments seen in western Asia (e.g., Fortelius et al., 1996b) might be mirrored on the eastern half of the continent. After a few false starts, a cordial collaboration was initiated with the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP) in Beijing and a first visit and planning session took place in Beijing in May–June 1996, where the junior Chinese colleague Zhaoqun Zhang was given the task of minding the guests Mikael Fortelius and Juha Pekka Lunkka and keeping a record of the daily negotiations. The area selected for field work was the Miocene section at the Bahe River by Lantian town in Shaanxi Province near the city of Xi'an, known from previous work to sample strata from the Middle to Late Miocene and therefore an appropriate match for the previous work in the Sinap Formation in Turkey. The first field season was agreed for September 1997 and young IVPP staff members Zhaoqun Zhang and Liping Liu were given the task of preparing the project and surveying the field area. The first field season was a challenging one, not least because Fortelius broke his leg just before it and therefore arrived in China three weeks late and on crutches. He was met in pouring rain by a dispirited field party, which had endured exceptional heat and very meagre findings in the previous weeks. Despite further challenges of similar kind, the field season was not only completed but became the beginning of a successful collaboration that still continues at the time of writing.

From the very beginning, the project was set up with the dual purpose of data compilation as well as field work, and it naturally became the task of Zhang and Liu to help with the practical aspects of the database part as well, joining the NOW the advisory board along with a few more senior colleagues. The data compilation progressed well in the early years of the project and had by the turn of the millennium reached a sufficient stage of completeness to provide a first inkling of continental-scale patterns, as related above. One startling detail in the hypsodonty patterns, which might well have been ignored without critical ground-truthing through the field work at Lantian, was the reversal of the temporal sequence familiar from Europe and North America. Instead of a gradual drying during the later Miocene a reversal to more humid conditions at about 8 million years ago was indicated by mean hypsodonty values. This reversal was interpreted by Fortelius et al. (2002) as showing an intensification of the east Asian summer monsoon. Later work has largely confirmed both that this regional reversal of the planetary climate was real and that it allowed the establishment of the characteristic and diverse Chinese *Hipparion* fauna of the latest Miocene, known since the earliest days of Chinese paleontology from the famous dragon bone mines in the Red Clay deposits of the Loess Plateau (Fortelius & Zhang, 2006; Jokela et al., 2005; Liu et al., 2009; Passey et al., 2009).

These developments left the interior of the Asian continent still largely unsampled by NOW, but this was soon to be remedied. By the beginning of 1990s, the reference Neogene mammal faunas that occupied a mid-latitude Eurasian belt, from Moldova to the Transbaikalia and Mongolia, had been already correlated with the European Neogene Mammal Units (MN system), and those from Asia also with Chinese Land Mammal Ages due to their intensive investigations mainly by specialists from the Paleontological Institute of the Russian Academy of Sciences (PIN) and Geological Institute of the Russian Academy of Sciences (GIN), and due to input from researchers of academic institutions of the former Soviet Union republics (Ukraine, Georgia, Kazakhstan). The correlations were based on biochronological evidence and also on the paleomagnetic dating and correlations with marine stages for some of them. After the International Congress BiochroM’97 in Montpellier in 1997, Innessa A. Vislobokova (PIN) joined the NOW team as a Coordinator, and later Alexey Tesakov (GIN) also took part in this work. It was not an easy task to convert many faunas from this huge territory to NOW standards, because some old localities were tied only to the regional stratigraphical schemes, and their place in the NOW database was uncertain. Vislobokova and Tesakov subsequently continued in charge of these questions and with the updating of mammal lists from the localities of this territory. In 2000, Diana Pushkina joined the work on the NOW database, mainly searching for the interglacial Eemian faunas on the former USSR territories, while completing her PhD under Mikael Fortelius’ supervision.

Yet another NOW-story merits brief mention here. One morning in April in 2000, Fortelius was traveling on the morning train to downtown Helsinki and happened to bump into a friend who was at the time employed at the Academy of Finland. In the course of the 11-min commute the friend urged Fortelius, known for his habit of “going to strange places”, to apply for funding for collaborative research with partners from the Islamic Republic of Iran. The Academy had opened a call for this but had received disappointingly few proposals and the deadline was fast approaching. Thus, it came about that a research project was constructed at lightning speed, possible only because of the network that the newly established EEDEN programme offered, and funding was received in due course for a visit by Fortelius and then PhD student Anu Kaakinen to prospect for terrestrial mammals in the poorly sampled but paleobiogeographically crucial Oligo-Miocene of Iran. The continental red beds bracketing the marine Qum Formation in the Central Desert were selected as a first target, with structural geologist Ali Hamedani of Isfahan as a most obliging and helpful host. While this first exploration in August 2001 turned out to be futile in the sense that no significant discoveries were made during the two weeks it took, it was the beginning of a collaboration that is still ongoing at the time of writing, twenty years later. The key person here has been Majid Mirzaie Ataabadi, who joined the excursion as an undergraduate student assistant and thereby later came to get his Ph.D in a very much NOW-based project in Helsinki (Mirzaie Ataabadi, 2010).

Into the New World

In the mid-1980s, Christine Janis (Fig. 2.13) hatched the idea of compiling a book on North American Tertiary mammals (i.e., Paleogene and Neogene mammals, the term “Tertiary” is now obsolete): the Pleistocene was excluded because of the existing compilation of Pleistocene North American mammals by Kurtén and Anderson (1980), and additionally the fact that including this time period would have vastly expanded the nature of the project. The notion was to encompass a who’s who for each family that also included information on taxonomy, higher level systematics, ecomorphology (including a molar measurement for body size estimates), evolutionary patterns, standardized phylogenies and figures showing range times for each genus, and – perhaps most importantly in terms of future utility for databases such as NOW – a link for each species to a specific fossil locality. The locality list was compiled as a separate appendix with numbered localities ordered by geographic region (e.g., the prefix CP = Central Great Plains), and the locality numbers then assigned to each taxon. In this sense the *Tertiary Mammals* (TM) book concept was unlike faunal compilation books of the time (such as Maglio & Cooke, 1978, *Evolution of African Mammals*) and more in the spirit of Savage and Russell, *Mammalian Paleofaunas of the*

Fig. 2.13 Christine Janis contemplating the ecomorphology of *Hypohippus*, a pony-sized browsing horse (Anchitheriinae) from the Middle Miocene of North America. *Hypohippus plushie* by Savannah Olroyd. *Photo*: Christine Janis

World, 1983, although with a more detailed locality compilation.

Janis initially embarked on this project with the editorial help of Kathy Scott and Louis Jacobs, but the process of trying to organize the many contributors was a process akin to not just to herding cats, but with some of the cats having behavioral issues. A problem with a volume of this nature, unlike most edited volumes, is that it is simply not an option to leave out a recalcitrant contributor (and hence omit a taxon). A decision was eventually made to turn the book into two volumes and to go ahead with the taxonomic groups with all of the contributions in place, and in 1998 the first volume (TM1 *Carnivores, Ungulates, and Ungulate-Like Mammals*; Janis et al., 1998) was published by Cambridge University Press. The second volume (TM2 *Small Mammals and Marine Mammals*; Janis et al., 2008) was published a decade later, this time with new contributing editors, Gregg Gunnell and Mark Uhen. This second volume also had some updates of both the locality information (including additional localities and some new dates) and the taxa covered in the first volume.

Although this book was not originally devised as an online database, the hope always was that somebody would make such use of the information. Starting in 2008–2009, in the aftermath of the publication in the *Proceedings of the National Academy of Sciences of the United States of America* of a paper entitled *Distribution history and climatic controls of the Late Miocene Pikermian chronofauna* (Eronen et al., 2009), Janis began corresponding with Fortelius and others about North American chronofaunas. This turned into an endeavor to include TM1 and TM2 into the NOW database. The work started in late 2009, and went through 2010 and 2011, producing the first synthesis papers soon after (Eronen et al., 2012; Figueirido et al., 2012). Laura Säilä-Corfe and Jussi Eronen were responsible for the correspondence and much of the work in addition to Mikael Fortelius and Susanna Sova. The locality-related work and issues (see below) took much time, correspondence and travel. For example, Eronen and Janis were working on the TM1 and TM2 data in Providence when hurricane Sandy hit the Eastern Seaboard of the United States in 2012. The process of incorporating the Tertiary mammals data into NOW concluded in 2016, when they were made public, and the North American data have been subject to normal updates since then.

A potential problem with converting the TM locality data to the NOW format is that Janis had not separated all the localities to the level of individual sites as was done in NOW (and in other databases such as the ETE or the Paleobiology Database. So, for example, locality CP110 (the Olcott Formation in Nebraska) includes around three dozen separate quarries or sites of varying sizes and quality (which are named in the locality list but not separately numbered). At least 10% of the localities are of this nature. This ‘lumping’ approach was taken for several reasons: (1) contributors often did not provide the necessary detailed information; (2) it was considered that, for the purposes of the book, a degree of locality lumping would actually be more informative, rather than reporting on every little sample individually; (3) given that Janis was working essentially alone, and at least for the first volume without the type of computerized assistance (e.g., Excel files) that we now all take for granted, she likely would still be completing TM1 had she decided to include every locality incidence. However, this lack of faunal locality equivalence with the existing structure of NOW remains a problem to be rectified.

Running NOW

From the beginning, the NOW interface was designed to be as intuitive as possible so that the users can concentrate on its essential reason for being – the data. The aim was that even a lazy but excited researcher can insert the data smoothly. Adding data was made as straightforward as possible, human mistakes were minimized, and collecting information in different ways was steadily improved. Rules were enforced at both the interface and the database levels, restricting the range of possible entries in many fields, and enforcing the integrity of relationships between the various fields. Gudrun Evans was the main person behind this thinking and Jouni Vepsäläinen continued on the same track. We were very lucky to get Jouni just before Gudrun and Alistair Evans left Helsinki for their native Australia. It has been a surprise how much abstract thinking in three dimensions database development requires and Jouni had that ability in spades. Jouni quickly took the technical aspects in hand and his meticulous work enabled the development of NOW without compromising the safety and robustness of the database.

NOW officers all had database-related projects of their own, which made them alert to errors and inclined to think about improvements. Thus, the interface was continually improved in many small steps. Localities with unknown coordinates no longer ended up in the Gulf of Guinea, under the armpit of Africa and the *Map*- and *Export*-functions became easier to use and adapted for a range of different purposes. The biggest improvement to the user interface may have been the *Import*-function. Previously, large, curated datasets had required a great deal of manual labor in harmonizing the data exactly to the NOW format, but with the improved *Import*-function, automatic format checking and reformatting was introduced. Jussi Eronen was the first brave NOW participant to actually use it, successfully as it turned out, for importing the North American data described above. This import significantly increased the records in the database, which in turn made it important to further develop checks on the consistency of logic as well as the formal validity of entries. History has shown the value of these improvements again and again, as many datasets still come to NOW as Excel-files that may have grown over years or even decades, with changes in usage that typically occur over time.

From 2009 onwards, the NOW office has worked together with the taxonomic coordinators, updating and unifying taxonomic information of all families, under the umbrella of 'NOW synonymy project' (ridding the database of synonymous entries). This was initiated by Laura Säilä during her post-doctoral period in the Academy of Finland funded research project *Extinction dynamics of taxa in the fossil record*. This has vastly improved the taxonomic accuracy of the NOW database and how it can be reliably used for large-scale evolutionary studies that rely on taxonomic data. Additionally, improvements in how changes are recorded, and can be viewed, in the references of each locality and taxon entry and how synonymies and other taxonomic issues are detected in the database were implemented. Simultaneously, enhancements took place in search functions for taxonomic entries and their geographic/temporal occurrences in both the main database and its Export and Maps interface, and the types of data that could be exported out of the NOW database were increased.

One late but crucial development must be mentioned here, even though it falls outside the temporal scope of the main narrative. One of the main challenges of running NOW during its first two decades was the lack of an employed curator to provide stability and continuity. This was finally remedied when, in the autumn of 2016, the University of Helsinki received a major donation from the *Ella & Georg Ehrnrooth Foundation* and decided to use this, in accordance with the wish of the donor, for furthering the research into hominin paleoenvironments that had sprung up as a collaboration between Fortelius and Meave Leakey's research network centered on the Kenyan Turkana Basin. This donation both allowed the university to establish a professorship of Hominin Environments and to finally establish, in the Finnish Museum of Natural History, a permanent technical data coordinator position that includes responsibility for the maintenance of the NOW database. For this position Kari Lintulaakso was fortunately available, a person already involved with NOW for many years and intimately familiar with the structure and purpose of the database. This way, NOW finally achieved an administrative position in accordance with its international role and weight.

As is evident from this narrative, NOW came together gradually, through an unplanned and rather amorphous process of collaboration between friends and colleagues who for various reasons shared an interest in developing this common resource. In retrospect it seems clear that what gave NOW direction, coherence and credibility in the critical early phase was the establishment of an Advisory Board of respected scholars, many of whom had also been active during the gestation period that preceded the formal launching of the database (cf. Appendix 2.1). At the time this was by no means seen as a necessity by all and several early participants indeed felt that it would be an unnecessary complication or even a waste of time. Nevertheless, the Board was established and was immediately engaged in the daily running of the database, some members taking a more active part than others. Despite its name, the Advisory Board did not at any time collectively advise. Rather, it provided individual scientific expertise and opinion in specific cases and in this way acted as a filter and quality control, deciding on such matters as how errors should be handled and how new results and opinions should be considered. It was during this time that an important NOW principle came to be established: more than advisors, the Board members should be rulers, with dictatorial power to decide on such issues as taxonomic nomenclature and stratigraphic correlation. *It doesn't have to be right, consistency is everything!* has always been a key slogan for NOW data development and in this NOW differs significantly from other leading databases, for example the Paleobiology Database (https://paleobiodb.org/), which instead favors recording of alternative scientific opinions. While both systems have their advantages, the dictatorially induced consistency of NOW definitely makes it easy for users to locate all occurrences of a species, but inevitably also creates extra work for users who disagree about synonymy. Needless to say, few if any decisions of this kind have ever been made without consultations among coordinators and with the approval, implicit or explicit, of the general coordinator. NOW was always very much a consensus-based community effort.

Originally, NOW had no administrative organs, there was just the somewhat misnamed Advisory Board, an Overall Coordinator and an Associate Coordinator. When executive decisions had to be made, this was done by the signatories of the founding document (Appendix 2.1), ironically self-styled as the *NOW Mafia*. As NOW grew and new members joined the Advisory Board it was gradually realized that some more transparent administrative structure was desired. A new structure was accordingly put in place in December 2013 with a Steering Group appointed by the now renamed General Coordinator and approved by the Advisory Board. At this time a five-year cycle of membership in both the Steering Group and the Advisory Board was also introduced. The main task of the Steering Group has been to decide on major issues such as the appointment of new board members or updating the stratigraphic reference for the NOW Time Unit Table. Thus, the daily running of the NOW database gradually caused its administrative structure to stabilize and mature.

Looking at the structure of the NOW and the people involved, it is clearly an international consortium serving a global community. At the same time, history leaves no doubt that the main office of this consortium is in Helsinki. As is clear from the narrative above, it was this firm ground that allowed the database to develop all of its technical and conceptual aspects, supported by the Finnish academic infrastructure. Many colleagues and students travelled to Helsinki over the years and these visits were the basis for fruitful discussions and collaborations. However, they were still individual visitors enjoying the hospitality of the Finnish team. A major step towards creating a stronger community feeling came, when in 2016 NOW switched to a creative commons license, expressing the role of the community in each reference made to the database. In addition, in 2018, the long-cherished wish of having a NOW meeting finally came to be, when Lars van den Hoek Ostende and Peter Joniak organized the workshop NOW and the future of the past in Bratislava (Fig. 2.14). The benefits of having users and developers at one table became quickly apparent and the meeting produced a long list of action points to be taken.

Fig. 2.14 Pablo Peláez-Campomanes, Lars van den Hoek Ostende and Peter Joniak at the Bratislava NOW meeting in 2018. *Photo*: Laura Säilä

Cauda: Changing of the Guard

Following the pioneering ecometric papers by Jernvall and Fortelius (2002, 2004), a new line of research was opened in Helsinki that relied on collaboration with computer scientists. This successful initiative actually came about by administrative fiat, a rare occurrence in academia. In October 2002, Fortelius was extolling the virtues and potential of the hypsodonty proxy for rainfall to then University of Helsinki Rector Kari Raivio, who asked the critical question “would you need money or people?”. Upon receiving the reply “People, or money only to acquire them”, Rector Raivio promised to give the matter some thought. Soon after, Fortelius was contacted by Academy Professor Heikki Mannila, a prominent data mining scientist, and a meeting was agreed. Discussions ensued and it soon appeared both that the complex and fragmentary nature of the NOW data offered a highly attractive object for algorithmic analysis and that realizing the potential would require serious and patient two-way exchange of information. Thus began an enjoyable and productive collaboration with Mannila and his group (Bingham et al., 2007; Eronen et al., 2010a, 2010b, 2010c, 2011; Fortelius et al., 2006a, 2006b, Heikinheimo et al., 2007, 2012; Kallio et al., 2011; Liu et al., 2012; Puolamäki et al., 2006; Saarinen et al., 2010; Ukkonen et al., 2005), which unexpectedly came to an abrupt near halt when Mannila was appointed Vice Rector of the newly founded Aalto University in 2009. When he went on to become President of the Academy of Finland in 2012 the need for a replacement became urgent.

In this situation, with an abundantly proven concept and the opening prospect of a collaboration with Meave Leakey and her network of collaborators on the legendary fossil record of the Turkana Basin in northern Kenya (see Fortelius et al., 2016), one might have expected that it would be easy to find such a replacement. Instead, it gradually became clear that the long and patient discussions that preceded the actual collaboration could not be easily repeated and that the slow rate of progress in paleontological research was seen as a major deterrent by most hypothetical candidates for this post. Fortunately, one of the early collaborators from Mannila's group, Aristides Gionis, came up with a long-shot suggestion that a Lithuanian postdoc at Aalto University, Indrė Žliobaitė, might be interested in trying her hand at fossils in the newly funded Turkana Basin project ECHOES (Academy of Finland, 2014–2018). An interview was accordingly agreed and, after the differences in expected salary levels between geoscience and computer science had been overcome by good will and creative solutions, Žliobaitė accepted an offer to become the ECHOES postdoc. This was the beginning of a second wave of computer science collaboration based on the NOW data that would eventually see Žliobaitė transformed into a paleontologist in her own right and the successor of Fortelius as the General Coordinator of NOW. But this is another story.

Acknowledgments Although there has been some dedicated funding for NOW, including the Academy of Finland grant 1993-1996 that made the first implementation possible, NOW was always overwhelmingly an unfinanced community effort. Most of the work has been contributed by NOW participants in their own time, and much has no doubt been sponsored by a large number of academic employers worldwide, knowingly or otherwise. In addition to the Academy of Finland we would like to acknowledge generous support from the European Science Foundation, the Volkswagen Foundation, the Finnish Society of Sciences and Letters, the Finnish Museum of Natural History, the University of Helsinki, the Naturalis Biodiversity Center, the Hanken School of Economics and the CSC – IT Center for Science. Our special gratitude goes to the Ella and Georg Ehrnrooth Foundation and Mrs. Elsa Fromond for the generous endowment that enabled, among other things, the establishment of a position at the Finnish Museum of Natural History that includes technical database coordination of NOW. This is R.L. Bernor's NSF FuTRES publication 35.

Appendix 2.1. The Original Invitation Letter to Join the First NOW Advisory Board

NOW
c/o Prof. Mikael Fortelius Department of Geology
P.O. Box 11
FIN-00014 University of Helsinki Finland
Vox: + 358-9-1912–3419
Fax: + 358–9-1912–3466
Email: gem_dig@gaia.pc.helsinki.fi

Dear colleague,

15.10.1997

The first years of the NOW database have gone, and with them the years of highly coherent and organised data entry. NOW, such as it was used for the synthetic chapters of Bernor-Fahlbusch-Mittmann (and is available on request from *gem_dig@gaia.pc.helsinki.fi*), is far from free of errors, but it is still a uniquely up-to-date source of information regarding the occurrence and attributes of the Miocene mammals of Europe on a continental scale. It was never complete, and it still isn't. Several taxa (notably Proboscidea) are missing altogether, and most localities have incomplete faunal lists. The selection of localities is also somewhat random (the case of Austria was especially remarked upon in this regard). We are gradually filling in holes but there is no concerted effort comparable to the "Reisensburg Process".

In our opinion the database is already a valuable resource, and we would like to contribute to its being more extensively used than has been the case so far. In the long run, such databases have the potential of bringing fossil mammals into contact with neighbouring fields, for example palaeoclimate and biodiversity modeling and research. Meanwhile, we know from first-hand experience that the database is already a wonderful resource for many mundane, everyday tasks involving Eurasian Neogene mammals. We feel strongly the need to continue the process of building the database as well improve the quality of the data. We are writing to you in the hope that you might share our interests and be willing to participate in the next step of developing the NOW database.

To begin with, there are currently four main sources of new data into NOW:

1. Specific research projects that need to augment the existing data in some way (especially "ecomorphological" attributes of the animals)
2. The ESF "HOMINET", which is revising and adding (primarily) the hominoid-bearing localities of Europe
3. A collaboration project with the IVPP to database all Chinese later Cenozoic mammal localities
4. Data extracted from the literature by our students and ourselves.

In addition to these and somewhat different in nature are plans to fuse NOW with other existing databases with a similar structure (EUQUAM, ETE, FAUNMAP). Such plans will proceed independently of our development of NOW, and will not change the basic principles outlined below.

Not all the data arriving to the database are of equal quality, and not all specialists agree on the details of taxonomy or dating, to say nothing of interpretation that is more speculative. Only some relatively powerful verification mechanism can prevent the growing database from decaying into a chaotic state, with taxa represented by multiple *nomina* and perpetuation of various long-since- recognised errors.

In establishing such a verification mechanism one must balance several factors. It is important that the database retains a broad base in the field, so that it can grow as a common resource. On no account must it be seen as the toy, or worse, the exclusive research tool, of some small clique! It is also important to minimise the workload put on single individuals. On the other hand, for a database more important even than correctness is consistency. This means that once a certain classification and nomenclature has been adopted, any competing scheme must be put aside until, perhaps, it is verified and a conscious decision is made to adopt it. A similar principle applies to stratigraphic correlation and related issues, and these factors argue against having too many individuals directly involved with the supervision of the data.

What we propose here is the creation of an Advisory Board for NOW, consisting primarily of the core group from the original Reisensburg Process, augmented (or replaced) by colleagues who have since joined the project. The Board would feature specialists and taxa, on stratigraphy, and on particular regions, and would complement itself as required. The Board would rarely (if ever) be expected to act as a body, but would be more like the advisory board of a scientific journal, where individual members would advise on matters with their special sphere of expertise. The default duty would be to review (or distribute for review), perhaps once a year, data listings of various sorts, such as lists of localities and ages, lists of localities and their fauna, lists of taxa with ecological interpretation, and so forth. Beyond keeping an eye on the quality of the data in this manner, board members would be well placed to guide the direction of development and to initiate or facilitate research projects.

The first step in this direction was already taken when Hans de Bruijn kindly agreed to coordinate a complete overhauling of the small mammal data, a project currently underway. At the moment we visualise a Board of somewhat the following composition and primary responsibility:

***

Proposal for Advisory Board of the NOW database Taxonomy and ecomorphology

General small mammal coordinator – Hans de Bruijn

Mein, Höck, Bolliger, Römer… (Hans: please provide a list of your people!)

General large mammal coordinator – Ray Bernor
Hominoid Primates – Peter Andrews
Cercopithecoid Primates – Eric Delson
Feloid Carnivores – Lars Werdelin
Arctoid Carnivores – Suvi Viranta
Suoids – Jan van der Made
Tragulids – Elmar Heizmann
Cervids – Getrude Rössner
Giraffids – Nikos Solounias
Bovids – Alan Gentry
Equids – Ray Bernor
Chalicotheres – Louis de Bonis
Tapirs – Jens Franzen
Rhinoceroses – Kurt Heissig
Proboscideans – Bill Sanders
Hyracoids –Elmar Heizmann
Tubulidentates – Sevket Sen

Stratigraphy

General stratigraphic coordinator – Sevket Sen

Remmert Daams, Volker Fahlbusch, John Kappelman, Pierre Mein, F.F. Steininger, Qiu Zhuding

Regional coordinators

Western Europe – Jorge Agustí

Eastern Europe – George Koufos, Adam Nadachowski

Carpathian Basin – Kordos Laszlo

Southwest Asia – Sevket Sen

Russia – Innessa Vislobokova

Indian subcontinent – David Pilbeam

China – Qiu Zhuding

Geology and taphonomy

Sedimentology – J.P. Lunkka

Taphonomy – Miranda Armour-Chelu

Palaeoecology

Peter Andrews, Kay Behrensmeyer, Mikael Fortelius, Peter Ungar

Contacts with related projects

The ETE Consortium – John Damuth

The ESF Network on Fossil Insects – ?

Terrestrial molluscs – ?

Leaf floras – Johanna Kovar-Eder

Pollen floras – Jean-Pierre Suc

General coordination and development

Overall coordination and data entry – Mikael Fortelius

Database structure and technical development – John Damuth

Associate NOW coordinator – Suvi Viranta

***

A few words about the "data policy" that we have in mind. As agreed during the preparation of the Bernor-Fahlbusch-Mittman volume, all contributors are entitled to the full data set that was produced. It was also agreed that this data set would become public with the publication of the volume, and this is the basic principle that we intend to maintain. New data deposited in the NOW database can be kept under restricted access until a project is completed, but will eventually join the growing mass of public data available to all *bona fide* researchers. Another basic principle is that the NOW data should not be distributed directly to third parties. Everybody is required to get their data directly from NOW (*gem_dig@gaia.pc.helsinki.fi*), to ensure that the currently available version is used, and to allow us to keep track of how and where NOW data are being used. (Backup copies of older versions will, of course, be kept and made available for verification purposes.) In the future, a version of the public data will also be available on the world wide web, probably as a collaboration project with the ETE database.

We hope that you will accept our proposal and join the NOW database Advisory Board. Whether you do join or not, we hope that you will let us know your opinion and any suggestions you may have, including suggestions for additional people you feel should be involved.

With our highest hopes and best wishes,

Mikael Fortelius, Ray Bernor, Hans de Bruijn, Sevket Sen, Lars Werdelin.

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