The Future of Entomological Collections

Die Zukunft entomologischer Sammlungen

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Zusammenfassung
Die Prinzipien der Sammlung und Administration von Insekten-Präparaten haben sich im Laufe der Zeit geändert. Gewebe-Banken, derzeit hauptsächlich umweltbezogen (mit Schwerpunkt auf Umweltverschmutzung) betrieben, könnten schon bald rapide an Bedeutung gewinnen. Die Möglichkeiten, die sich dadurch für die Systematik ergeben, sind beträchtlich, wobei die Molekular-Phylogenetik nur einen Teilaspekt darstellt.
Unsere Art des Umgangs mit auf Auswertung von Sammlungen basierender Information hat sich dramatisch verändert, wobei größere Durchbrüche zu erwarten sind.
Die entomologischen Sammlungen stehen vor der großen Herausforderung, den Status reiner Aufbewahrungsanstalten aufzugeben und sich zu Dienstleistungsbetrieben zu entwickeln. Die Informationstechnologie wird die Entstehung virtueller Sammlungen erleichtern, durch sie wird der Benutzer die benötigte Information sofort zur Verfügung haben. Um diese Veränderungen in einer Zeit, die zunehmend nach größtmöglicher Perfektion verlangt, zu überstehen, müssen Institutionen, die entomologische Sammlungen besitzen, entweder eine Nische finden – oder sich auf die Suche nach Kooperationspartnern begeben. Systematische Grundlagenforschung wird naturgemäß auch zukünftig größtenteils exemplargebunden passieren, da das jeweilige Exemplar die primäre Informationsquelle darstellt.
Nach 200 Jahren Sammlungstätigkeit sind wir noch weit davon entfernt, in den Museen der Welt über einen angemessenen Querschnitt der Insektenarten zu verfügen. Die verbesserte Erreichbarkeit selbst der entferntesten Orte der Erde eröffnet die historische Gelegenheit zu besserer, globaler Dokumentation. Diese Chance sollte genutzt werden, da es sonst schon bald zu spät sein könnte. Das Linné'sche Unterfangen, das Leben auf unserem Planeten, das zu einem großen Teil Insektenleben ist, zu dokumentieren, bedarf gesteigerter Effizienz. Da es sich hierbei um ein internationales Anliegen handelt, ist die verstärkte Mobilität von Exponaten erforderlich. Dieses Ziel kann durch langfristige Auslagerung von Exponaten im Rahmen eines taxonomischen Betreuungs-Modells erreicht werden.

Keywords
Insect collections, museum, systematic research, Entomological Collections Network, interoperability.

Insect collections around the world may contain upwards of half a billion specimens, and a relevant question would be: What do we want to accomplish with those collections? No one, in my opinion, has addressed this question as succinctly as Scoble (1997), who stated that "... if ever there is a way of fulfilling a core function of a natural history museum, [...] then surely the documentation of life on earth provides that means." In other words, the documentation of insect life, wherever it is found, that is our ambition. That is what insect collections are being built for. It is important to realize that insect collections, by and large, are products of society, and that society will pay for insect collections only to get something back. Insect collections have output, and society is the buyer of the products. Our efforts in documenting global insect life is a means of increasing the quality of human life, with quality in this context having a broad base, including scientific, economic, medical, psychological and ethical aspects. Scientific output may be the first and foremost product of insect collections. Sydhoff (1995) has addressed this in very general terms: "The concept of a museum will probably increasingly come to be identified with a centre of ideas and renewal and far less as a place for accumulating objects of the past." While she may not have hinted directly at insect collections, her statement certainly holds true also for these. We certainly are building collections of what with time will be objects of the past, but we earn our credits not as mere archives but by extracting and analysing the information from (and related to) our objects. Wunderkammern and cabinets of monstrosities may be stimulating eye-openers in public displays (Gould 1996), yet our insect collections are true scientific databanks that we utilize in our endeavour of increasing factual knowledge and in producing new and improved scientific hypotheses - ideas and renewal.


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Looking into the future is intimately connected with looking back. Trends and tendencies would not be trends and tendencies if they had no beginning, no history, and even the most unlikely scenario will be a product of our historically constrained minds. If we could make a bold leap back in time some 2-300 My to the Mesozoicum, we would find lush tropical forests with an abundant insect life, and even if not quite as rich as today it would be strikingly different. We know that the insect fauna has changed dramatically during time, continuously under pressure from climate, catastrophes and competition. Think of how wonderful it would be to have a collection of pinned insects from the Mesozoicum; what new insight this would bring. Unfortunately we do not, for the simple reason that there were no entomologists to build insect collections, and we are left with a scanty array of fossils that only give us a dim, distorted picture of the variety of past insect life. My point here is rather straightforward: we build collections not only for our immediate pleasure and well-being, but for the benefit of future generations as well. This has a sombre actuality as we know that we are right at the beginning of a tremendous mass extinction - caused by ourselves - with species disappearing at an alarming rate, their last habitat being burned, ploughed and poisoned to become farmland, plantations and holiday resorts. Our collections will contain an increasing number of unreplacable specimens representing species no longer in existence; and I am not even touching upon the issue of local extinction and loss of intraspecific variation. One excellent example may be taken from Central Europe. Two hundred years ago, in 1794, the German entomologist Georg Panzer described a fly that he found on a dead dog around his home in Mannheim, and

he named it *Thyreophora cynophila*. This fly was rather common at that time and was often seen in Germany, around Paris in France and in Austria. A beautiful redheaded fly which liked walking slowly around on big cadavers like dead dogs, mules and horses in the early spring. Suddenly, 50 years after its discovery, it disappears. No more specimens are collected and the species is now considered extinct. Only a few museum specimens exist today, but fortunately we still have these few specimens of the magnificent *Thyreophora cynophila*. Thanks to our insect collections.

Insects have always fascinated humankind, a fascination that perhaps grew out of a strange mixture of admiration and fear - admiration of their intense beauty and fear of their dark side, their abominable powers of destruction. This ambivalence is firmly embedded in our culture. One of the early giants in the world of entomology, a Swedish nobleman and a contemporary of Linnaeus, Charles De Geer, expressed his fascination of insects in a very explicit way: "*Si l'histoire naturelle en général fait l'admiration de l'esprit humain par la multitude infinie des objets, par leur varieté surprenante & par le méchanisme ingénieux caché souvent sous les dehors les plus simples, j'ai été convaincu par expérience, que l'histoire des Insectes seule mérite nos recherches par toutes ces considérations*" (De Geer 1752). In short: If we admire the variety and complexities of natural history, the insects will provide this in abundance and

Fig. 1: One of 18 drawers comprising the insect collection of De Geer (1720-1778). Few changes may be expected in the physical storage of dried insects, but information technology is rapidly changing the way we manage and disseminate the associated information. (Photo: S. Waerndt)

they certainly deserve our attention as objects of research. Insect collections grew out of such admiration, and Charles De Geer himself built a marvellous insect collection that is deposited at the Swedish Museum of Natural History. Yet not all of humankind share De Geer's deep fascination for insects, and to many people the majority of insects are nothing but bugs and creepy crawlies: unpleasant, filthy, disgusting creatures that should be avoided or even fought by all means. Joseph Addison, a contemporary of De Geer, had his own provocative way of putting it: "It is indeed wonderful to consider, that there should be a sort of learned men who are wholly employed in gathering together the refuse of nature, if I may call it so, and hoarding up in their chests and cabinets such creatures as others industriously avoid the sight of" (Addison 1710 cited from Stearn 1981). Joseph Addison was an essayist and a politician, while Charles De Geer was a nobleman. Fortunately, economic independence made De Geer free to build an insect collection, which today is more than 250 years old and as such one of the oldest insect collections in the world - 18 magnificent drawers almost in their original condition (Fig. 1). Perhaps somewhat surprisingly, such old collections look very much like modern insect collections. We are better at writing labels today, De Geer often did not do that at all. The pins we use today are of a slightly better quality, but the practical difference is infinitesimal. The largest or most obvious difference is perhaps that most modern insect collections, at least in museums, are using a system of unit trays for more efficient handling and curation. 250 years with no major changes - 250 years, and the most obvious improvement is a small tray made out of cardboard. Either entomologists have no fantasy, no creative minds to come up with big improvements, or maybe the way we do insect collections is, after all, not that bad. Yet there are some smaller changes with great potential that may warrant our attention. Labelling, as I said, has improved considerably. In the beginning there were no labels or at most a small coloured tag to indicate the provenance of the specimen. This has evolved through time to much more detailed labels, and recently bar-coded labels have found their way into insect collections. Bar codes in themselves contain no magic. Bar codes are just a number; a number which is often written in full above or below the bar code. The only advantage with bar codes is that they can be read by an automated process, i.e., scanned, and associated information stored in a database can be extracted almost immediately. This is why companies dealing with and processing large numbers of objects have quickly adapted to barcodes. Today we see barcodes everywhere, for example in supermarkets and libraries. Insect collections certainly would benefit from using barcodes, but even barcode labels have a price, barcodes take time to put on the specimens, and insect collections usually are so financially constrained that we would have serious difficulties working up the backlogs of specimens. For new accessions the situation is different, and coding can be an integral part of the processing. We need not digitize every specimen in our collections. We may set priorities according to scientific importance. But if we are ever to convince politicians and other relevant decisionmakers that the specimens we have in our collections represent true scientific value, we cannot at the same time tell them that we hardly know what specimens we have and that we cannot easily extract the associated information. I am fully convinced that we will discover, that by capturing this information in digital form we will help ourselves tremendously; directly in our research and indirectly by becoming more active providers of information to society. In short: labelling as such may not see great changes in the future, but associating particular specimens with the large body of relevant information already

available, and having that information at our fingertips, is part of the near future. Barcodes in themselves may not be the solution. Technology changes rapidly, and so do standards for barcodes. Eventually barcodes will go extinct. Well-known letters and numbers, on the other hand, are already widely used, they are sufficiently versatile for our purpose, and they will survive for much longer. We are already seeing the first OCR-scanners for reading insect labels from specimens, and collection management software is currently available to deal with these issues.

When Linnaeus and De Geer built their collections, specimens were reference specimens for the species they were thought to represent. They served that purpose well and they still do. But the traditional dried insect specimen has at least one serious drawback - it is dead. A trivial point as the very thought of having live insects in our scientific collections may seem taken right out of the morbid universe of Alice in Wonderland. Yet perhaps not entirely. Today we are seeing tissue banks building up large collections of frozen tissue samples (Fig. 2), still mostly human tissue and such animal - even plant - tissues that have a bearing on monitoring of environmental contaminants like DDT, PCB and other chlorinated carbohydrates as well as quicksilver and heavy metals. Such tissues, if stored sufficiently cold, are very close to being alive with their enzymes and DNA fully intact; germ plasm and plant seeds, of course, are absolutely alive. With rapid advances in molecular techniques and growing insight in anatomical, physiological, and biochemical characters, the potential for phylogeny is considerable, as it is for population ecology, for monitoring local and global changes and for many other issues. Tissue banking is likely to become a key word for future insect collections.

Insect collections by their very nature are primarily research collections. Insect collections, with their dried, wet and frozen specimens, have a large potential for environmental and conservation research (Shaffer et al. 1998), yet they are still used mostly for systematic research. Systematics has experienced a series of important advances during the last few decades, from the emergence of the Hennigian paradigm with its still more sophisticated cladistic methodology, through vicariance biogeography and molecular phylogenies, to our growing understanding of the importance of a total evidence approach. Insect systematics, and systematics in general, has been transformed from a mainly descriptive science to a fully hypothetico-deductive science contributing to community at several levels. Insect collections will find still more of their justification through their contributions to science and less through their value as reference collections for producing species identifications. In line with the citation of Sydhoff (1995) referred to above, research institutions housing insect collections will earn their credits by the quality of their scientific output - ideas and renewal in a scientific context. Incidentally, this stronger emphasis on scientific excellence has increased the gap between academia and the amateur societies. To the loss of both, I should say. The amateur entomologists in many European countries greatly outnumber the professionals. Dedicated amateurs often build up considerable species-level expertise, and amateurs may possess authoritative knowledge on local insect faunas. That expertise, I think, may (and should) be utilized much better through reclaiming the close association between amateurs and professionals. This may be done through that broad interface of ours - the insect collections.

Today, we have very large insect collections especially in the natural history museums of Paris, London, New York

Fig. 2: Low temperature freezers and tissue banking contribute to excellence in science by making ‚live' specimens readily available. *(Photo: T. Pape)*

and Washington, DC (Tab. 1). These institutions together have vast collections, they are well funded and have large staff, and they will most probably prosper even further in the future. Runners-up to those in pole position are museums like the Naturhistorisches Museum (Vienna), Australian National Insect Collection (Canberra), Museum of Comparative Zoology (Cambridge, USA), Museum für Naturkunde (Berlin), Canadian National Collection of Insects (Ottawa), Field Museum (Chicago), Bishop Museum (Honolulu), Zoological Museum (Copenhagen), and Swedish Museum of Natural History (Stockholm). These institutions (and several others not listed) have the potential for continued growth, yet government funding shows signs of decrease, and maintaining staff is often a severe administrative struggle.

Many much smaller insect collections exist, and a natural question would be: What is the lower limit? Investment bankers have a tough rule of survival for business companies: Being number one is the only acceptable position; being number 2 is still manageable; but to be number 3 means crisis. Should you get even below that, it is recommended to close down or sell out! If natural history museums are seen as enterprises producing natural history collections, one could say that the institutions in the lower end need some good arguments to maintain the funding for their collections. I should hasten to say that there might be such arguments, and I will repeat my earlier point that the collections *per se* represent the databanks from which the real products - our science, our ideas and renewals - are produced. Smaller collections may, for example, be very strong in their local fauna: INBio in Santo Domingo, CR certainly is the institution of choice when it comes to the insect fauna of Costa Rica. Just as the Zoological Museum in Oslo is the prime location to study Norwegian insects. For obvious reasons. What is not evident from a mere count of specimens is that the entomological research institution in Costa Rica is of a considerable size in terms of manpower, and through innovative research contributes to ex-

cellence in science. Furthermore, INBio is a young institution, and, through an efficient sampling program and front end collection management, collections are rapidly growing. The Swedish Museum of Natural History in Stockholm, one would think, would be the place to study Swedish insects. It is, but only to some extent. The best collections of Swedish insects are not found in Stockholm but at the University of Lund, the southernmost university of Sweden. The museum in Stockholm has always had admirably high ambitions of covering global biodiversity, and for that reason the collections contain more exotic and relatively less Swedish material. The early global focus, on the other hand, is behind the very large number of name bearing types. Having many old types is a credit, and we take pride in this, but old types in themselves are not enough. Types are reference specimens and will in themselves bring few new ideas and little renewal.

NHM (London):	57.500 species
USNM (Washington, DC):	51.843 species
AMNH (New York):	50.000 species (?)
MNHN (Paris):	50.000 species (?)
NHMW (Wien):	32.000 species
CNC (Ottawa):	18.000 species
ZMH (Helsinki):	12.000 species
BPBM (Honolulu):	10.000 species
ZMUC (Copenhagen):	10.000 species
ANIC (Canberra):	8.000 species (?)
NRM (Stockholm):	6.726 species
ZMO (Oslo):	3.500 species
INBio (Sto Domingo, CR):	1.775 species

Tab. 1: Holdings of identified Diptera in selected museums based on information from local Diptera curators. Question marks are given where curators indicated especially crude estimates.

So, the point remains: We need good reasons to maintain small collections, and small collections have to be more than just bleak and fragmentary shadows of the bigger ones. Many European museums are government funded, and we are already seeing an increasing need for good arguments to convince these governments that they should pay for the continued growth of collections. I am anxious that any government in a longer perspective would be reluctant to fund a museum trying to do what other museums are doing much better. University-based collections are even more under pressure as universities depend still more on external (i.e., non-governmental) funding often coming directly from industry and other private enterprises. Universities may, for that reason, be more dependent on internal flexibility in research strategies; a flexibility that does not match the importance of continuity for large insect collections. Perhaps for this very reason, systematic entomology in Sweden has shrunk from its Linnaean heydays in the 18th century, with entomological locomotives in Lund, Stockholm and Uppsala, to its present state where active entomological research collections and substantial collection-based entomological research are found mainly at the Swedish Museum of Natural History, which is a government-funded institution residing under the Ministry of Culture.

Collection size and quality of collection-based research merge in a potentially synergetic relationship, in that excellence in science is facilitated by the presence of large collections - and large collections will grow out of excellence in science. Virtual collections are emerging for the benefit of the scientific community, but collection-based research will still see the specimen as the ultimate source of primary information. Museums are to some extent evaluated (and evaluate themselves) based on the size of their holdings of real specimens because more specimens means more potential in information retrieval and more potential for scientific results. As discussed by Kristensen (1994), the statement that 'small is beautiful' just does not hold for collection-based research institutions. It is on the contrary: the bigger the better. The Linnaean enterprise of documenting Life on Earth - of which insects make up the lion's share - is by its very nature truly international and requires research institutions and research collections of considerable size, and with the necessary funding.

I am not arguing for uncritical centralization of insect collections. Having everything located in a very few institutions would be absurd. This is not the way knowledge is generated. Yet having a modest number of exceptionally strong insect collections on every continent is good. Good for research in particular, but even for education and for public service. There is also a need for a second, much larger tier of insect collections, not quite as big but still with collections and staff of a size and quality sufficient for powerful research, teaching and outreach. The current distribution of such second-tier insect collections unfortunately is strongly skewed towards USA, Europe and Australia. Spreading vouchers in these museums will increase availability - more researchers will have a big collection at a not-too-expensive travel distance and more students may be stimulated to enrol in educational programs at graduate level. As a result, more research will be done. Spreading vouchers will even spread the risk that valuable, if not unreplaceable material is lost. Suddenly it seems that I am providing arguments that we should indeed have more institutions rather than fewer. This is not the case. There is still the concern about critical mass in staff to spur the necessary excellence in science, i.e., to create the ideas and renewal, and there is a concern for collections of a size enabling them to function as effective databanks for a multifacetted research. Smaller collections will be more constrained and may promote excellence by developing narrower research foci.

One way to expand without real physical growth is to team up with other institutions in consortium- or corporation-like constellations. The media are teeming with examples where already big private companies are fusing into even bigger ones. An approach to this concept is now being tried even for natural history museums. CETAF - the Consortium of European TAxonomic Facilities - which is a consortium of all the major European natural history museums and similar research institutions, was born some 5 years ago. It is still actively elaborating a suitable structure for launching major projects. Other ambitious European programs, like ENHSIN and BioCISE, to some extent emerge from the growing recognition that we need to team up, that big is better, and they are further spurred by the booming of the information technology on the one hand,

and the increasing European integration on the other. A lot of promising ideas and renewal, but perhaps with many of the participating institutions still trying to have a leg in too many of the projects, thereby creating a millipede - and as we know millipedes do not run very fast. A very interesting initiative is the Fauna Europaea (FaEu) just launched from a smaller number of European taxonomic facilities. It is interesting because it is a very well defined and very real project, with fixed milestones and deadlines for products. The Fauna Europaea project is a good example that a key word to major progress in our teaming-up is leadership. The European taxonomic team-building is in the form of consortiums, with individual institutions maintaining their full integrity and individuality. Europe is becoming still more aware of its potential through unification. While still under hectic debate and laden with emotional arguments, Europe is taking steps towards larger legislative cohesion. This most probably will spill into the way we manage scientific institutions. May I suggest that we look into the possibilities of taking the first step from consortiums into more corporation-like constellations, with the administrative structure necessary for supporting the high level leadership that we currently need.

Interoperability is a new keyword in the digital sphere. Programmes like CETAF, ENHSIN and BIOCISE may provide the infrastructural innovations and the interoperability we need at the institutional level within Europe. We need to functionally integrate our databases, not necessarily standardize them but to make them mutually operational. We should think in the same terms for our insect collections. Increased interoperability at the collection level means greater mobility of specimens. Insect collections represent one global resource, even if formal ownership of particular collections has a very local address. Increasing mobility, however, carries a number of problems relating to the 'hardcopy' nature of our collections: specimens cannot flow through wires, they cannot transform back and forth between digital and analogue signals, and they cannot easily be copied. For the simple reason that numbers of specimens count, as I have already mentioned, ownership matters and mobility of specimens become demanding in terms of administration. Keeping track of specimens from a multitude of loans is a well-known burden to many museums. A partial solution to this could be off-site enhancement deposition. Specimens are deposited on a long-term loan agreement where they are most profitable to our science. One measure of the strength of a collection is its coverage, but few collections have funds and personnel to maintain a very broad coverage at all levels, and museums often have small parts with a particular strength. Visiting researchers come to visit such specialized collections, and visiting researchers often take time curating and even adding duplicate specimens to the collection. Yet on a broader perspective such specialist collections would be more efficiently put to use in the institution of an active research-group. We need centres of excellence, and we need more of what I will here call Taxonomic Stewardship - the global responsibility for an entire taxon. At least one major museum is currently using an off-site enhancement strategy to increase the quality of particular parts of the collection and at the same time promote progress in taxonomy and systematics. As a positive side-effect, the extra burden of loan management within this particular taxon is simultaneously handed over to the receiving institution. In this way, part or all of entire taxa are deployed to other institutions with relevant leading experts, the taxonomic stewards of those particular taxa. Like an economic investment, a taxon is deployed at the relevant centre of excellence, and the enhancement through curation is the interest. The host, or taxonomic steward, in his turn, may increase his chances of attracting funding from the gain in research potential represented by the immediate availability of a much larger research collection. To the overall benefit of our science.

Especially for entomological collections, we may look to the other side of the Atlantic, where the US-based Entomological Collections Network has been the forum for many discussions and has stimulated developments in insect collection management. Each year the ECN has a meeting in connection with the traditional meeting in the Entomological Society of America. We certainly could use a European Entomological Collections Network as a stimulating forum for ideas and renewal and for the formalization of specific projects relating directly to our insect collections. A European Entomological Collections Network would be a proper forum for discussing more concerted efforts by European entomological research institutions to co-ordinate and develop efficient sampling programmes in parallel to the innovative IT-programmes already being implemented. While we certainly need to bring our insect collections online and produce virtual museums, we have a huge amount of field work before us, before we reach a satisfying coverage of the insects - for Europe as well as for the world at large. Never before have we had such opportunities of sampling the variety of life in the most remote places on earth, yet it is the last call for thousands of species, many of which will never be known. Let them be known at least as specimens in our insect collections, like *Thyreophora cynophila*.

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