Journal of Applied Ecology 2004
41, 181–187

FORUM

Setting up tropical biodiversity for conservation through non-damaging use: participation by parataxonomists

DANIEL H. JANZEN
Department of Biology, University of Pennsylvania, Philadelphia, PA 19104, USA

Summary

1. A parataxonomist is a resident, field-based, biodiversity inventory specialist who is largely on-the-job trained out of the rural work force and makes a career of providing specimens and their natural history information to the taxasphere, and therefore to a multitude of users across society.
2. Any large inventory effort will benefit from a team of parataxonomists, not only through the large quantity of material and information they will gather and process, but through its among-year and within-season continuity.
3. Parataxonomists' accuracy increases substantially with pride of workplace ownership, experience, and detail and continuity of iterative feedback from users of specimens and information.
4. Being drawn from the pool of rural workers into activities that are normally the privilege of university-educated citizens, parataxonomists require continuous mentoring and encouragement to compensate for their potential social isolation from their former peer groups and the defensive disdain with which they may be treated by more elevated social classes.
5. *Synthesis and applications.* Parataxonomists are a key element in setting up wild biodiversity for non-damaging sustainable development, not only through finding and making biodiversity available, but also by being employed locally by its development. The parataxonomist is to the neighbouring forest as both a literate person and a reference librarian are to a library.

Key-words: Area de Conservación Guanacaste, biodiversity development, Costa Rica, INBio, inventory, rural sociology.

Journal of Applied Ecology (2004) **41**, 181–187

Introduction

Visiting collectors, taxonomists, biodiversity prospectors, photographers, bird-watchers, ecologists, behaviourists and other forms of biodiversity explorers have long enlisted or hired residents in tropical locations to assist with getting samples and information of wild biodiversity. In the late 1980s, Costa Rica's Instituto Nacional de Biodiversidad (INBio) was formed with the mission of conducting and facilitating a national biodiversity inventory: roughly, to set up Costa Rica's wildland biodiversity for its conservation through non-damaging use (Gámez 1991a,b, 1999; Janzen 1991; Sandlund 1991). A central concept was that in order to use biodiversity resources non-destructively, they needed to be found and identified, and their natural history understood. Who was to carry out this very labour-intensive task in a hot, wet, unfriendly tropical rural environment? It was immediately obvious that the enormous task of inventorying 4% of the world's terrestrial biodiversity would take many centuries if the task was left to the usual process of haphazard visitation by national, international and highly urbanized biologists with their multitude of agendas and brief time on the ground. Additionally, neither funds, inclination nor time were available to generate an entire in-country PhD-based and field-orientated science establishment for the task of what boiled down to interminable field work and laboratory effort in very rustic circumstances.

The formal parataxonomist was thus born as the resident, field-based, biodiversity inventory specialist

Correspondence: D. H. Janzen, Department of Biology, University of Pennsylvania, Philadelphia, PA 19104, USA (e-mail djanzen@sas.upenn.edu).

mining in the headwaters of the information stream that courses through the value-adding and organizational process of the taxasphere – the aggregate of museums, taxonomists and their collective knowledge – and thence outward into a multitude of users, including repeated iterations into the taxasphere itself (Janzen 1991, 1992, 1993; Janzen *et al*. 1993; Basset *et al*. 2000, 2004; Goldstein 2004). The parataxonomist, like the paramedic, the nurse, the teaching assistant and the paralegal in their respective institutions, practices a career with the potential to be a key element in the institution of national biodiversity development, when conducted for the purpose of national conservation and sustainable development.

What do parataxonomists do?

From the outset, the parataxonomist is at heart a full-time collector and processor of specimens and natural history information for the inventory site in which he or she is resident and specialized (Janzen *et al*. 1993; Longino & Colwell 1997; Basset *et al*. 2000; http://janzen.sas.upenn.edu; http://www.entu.cas.cz/png/index.html; http://viceroy.eeb.uconn.edu/alas/alas.html). The parataxonomist is an extension of the museum-based taxonomist back to the source of what museums and the taxonomic literature are full of, and 'expeditions' bring home. A parataxonomist is doing what many a taxonomist wishes he or she had the social freedom and budget to do full time. The structure of the collecting, and the formats into which the collateral information is decanted and moulded by the parataxonomist, is highly dependent on the nature of the downstream recipients and their feedback. However, the nature and availability of the particular biodiversity and facilities of the inventory site, as well as the cleverness and perception of the inventory by the parataxonomist, also strongly influence the product.

Nascent parataxonomists are carefully selected from the community that is resident and near the target wildlands. They are chosen for the same traits that are used in the choice of graduate students and other candidates for positions requiring high individual responsibility, self-motivation, long-term dedication, on-the-job growth and curiosity. Owing to the rural geographical and social source of parataxonomists, however, they tend to have minimal formal education, be adults already in the work force, be tightly bound to the community where they are found, and view the position as a vocation rather than as an ephemeral step on a ladder to some geographically or socially distant post. They are resident biologists on the edge of a wilderness. The training and formation of parataxonomists is a highly pragmatic combination of formal 'classes' that have been created site-specifically for the purpose of inventory and all that entails (including such diverse things as how to build a database, drive and care for a car, and use a chain saw), apprenticeship to other parataxonomists, professional scientists and science administrators, and continuous on-the-job training. The latter develops as part of the feedback from other parts of the taxasphere and other users of the parataxonomists' products, and because the technology and philosophy of biodiversity inventory for biodiversity development is evolving rapidly. In less than two decades, the Costa Rican parataxonomists have moved from horseback and specimen preservation over campfires to cell-phones, e-mail dialogues and sampling for DNA sequencing.

It cannot be overemphasized that parataxonomists cannot operate in isolation from a larger process that is designed to receive their products, reward them for it, and provide frequent intellectual feedback. My first questions to the planners who comment on how they would like to have parataxonomists in their management scheme include the following. Who is going to provide them with their mentor–apprentice feedback over the years? Who is going to receive appreciatively the fruits of their labour in the rain and the mud? Who is going to reward them for abandoning their rural microsociety to become larval scientists with little chance for metamorphosis? Parataxonomists are not free-agent PhD students hoping to be rewarded by prizes from the global community or tenure in a major university. Rather, they become middle-class workers in biodiversity who will only survive in a guiding structure that values specimens and accurate information rather than fishing-boat labour, bean-picking sweat, and pounding laundry on a rock in a river.

The parataxonomist and multitaxa inventory of large areas

If the goal is to find most of the species in a particular narrow taxon in a particular site, and then move on to gather similar information from other distant sites, this may sometimes be achieved quite efficiently through targeted visits by knowledgeable non-resident collectors or taxonomists, as well as through long-term efforts by resident parataxonomists. However, there are two major caveats. First, if the user can afford to wait for the information to emerge from a multitaxa inventory of the ecosystem by parataxonomists (assuming there is one in process), the properly guided inventory is guaranteed to yield nearly as good a data set, or a much better one in some cases, than will the targeted visit. For example, the slow inventory of Hesperiidae of the Area de Conservación Guanacaste (ACG) in northwestern Costa Rica by parataxonomists finding and rearing their caterpillars (Burns & Janzen 1999, 2001) is locating tens of species that are yet to be seen as adults. Secondly, if there is a body of parataxonomists working at a site, the visiting collector will obtain his or her desired material far faster by teaming temporarily with the resident parataxonomists than by surveying alone (and the parataxonomists will receive yet more feedback from the taxasphere, almost guaranteeing surprising findings for that taxon at the site in the future). Additionally, there are special within-society cases where it

can be highly productive to 'borrow' parataxonomists from a major inventory to conduct a targeted strike on another biodiverse area.

I know of no methodology that surpasses a large team of experienced and guided parataxonomists in conducting a biodiversity inventory of a large complex site. Guided both by information and collecting interchange among them, and by feedback from taxon-specific interested users of the specimens and the information, the resident parataxonomist generates incredible arrays of information simply by being there all the time and through the among-year variations, by being able to follow up on seasonal biological processes, and by viewing information and specimen gathering as an elegant job. There is no description of the light in the eyes of a 40-year-old third year parataxonomist the first time she digitally captures a 9-mm caterpillar spinning a cocoon more complex than the finest sweater she has ever knitted.

Problems

Why is the tropical world then not clothed with a light layer of parataxonomists, bunched up here and there on this or that regional or national biodiversity inventory? First and foremost, it is still an extremely rare event for a tropical country, institute or other unified process to attempt a multitaxon long-term biodiversity inventory of a large area complete with a resident rural community, some members of which can be guided into being parataxonomists as a career. Parataxonomists are not formed *in vacuo* with the anticipation that some use for them may appear. This is because no one will finance that, and vocations tend to answer a demand rather than produce one. Rather, parataxonomists are formed in a site-specific manner that takes into account the ecosystem traits, the social traits and the overall goals of the institutional structure that desires a biodiversity inventory. While it may be easy to generalize about routine actions of rearing insects and identifying plants, for example, the parataxonomist in Papua/New Guinea or Guyana is moulded by and for that place and project (Basset *et al*. 2000), as is the parataxonomist working in the ACG (e.g. see the Methodology in http://janzen.sas.upenn.edu) or for Costa Rica's INBio (Janzen *et al*. 1993; Gámez 1999). As the USA national park service sets out to find everything in its national parks (Janzen 2002a), it will find its own kinds of parataxonomists drawn from the very different kinds of communities surrounding those national parks and will have a heavy 'volunteer' (better termed 'apprentice') flavour. It will unsurprising if Sweden's anticipated national biodiversity inventory (F. Ronquist, personal communication) ends up depending heavily on school children as microparataxonomists. As large-scale inventory projects, for the purpose of setting up massive amounts of biodiversity for all kinds of users, increase in number, so will the number, kind and distribution of parataxonomists.

Secondly, and much more daunting, the formation and maintenance of a body of many tens of parataxonomists at a site requires both major long-term secure budgetary commitments and a dedicated personnel management system. These traits have not been widespread among field inventory efforts in the past. Developing and obtaining a quality return from a large body of parataxonomists is a marriage, not a one-night stand. Parataxonomists leave their careers as farm labourers, forest inspectors, housewives, truck drivers, etc., to enter another career, and those with enough courage and skill to be good parataxonomists do not do this without assurances of job security.

Simultaneously, the training and formation time invested by the scientific community, both in-country and international, to move someone from digging ditches to unsupervised and high-quality collection of tapeworms, microbeetles and caterpillars, and processing their associated data, is a major investment that takes years and mega-inventory to pay back. It is equally relevant to note that it is not commonplace to find in one project manager the skills to be simultaneously a major professor, database reviewer, labour organizer, vocational skills instructor, long-distance supervisor and friend, all in a foreign language, to a very diverse group of adults with at best grade-school education living on the margins of primitive conditions and viewed by their peers, relatives and neighbours as moving off to another planet.

Thirdly, the established social and academic structure of many tropical countries does not automatically embrace the parataxonomist. To take a farm labourer or village housewife and empower that person to carry the same kind of technical and emotional responsibility expected of a good university graduate student can involve a major shift in class and social structure. Given that intellectually rewarding and remunerative employment is a resource in short supply in tropical countries, and especially in the biodiverse ones, the creation of parataxonomists increases the competition among those who already have equivalent positions by virtue of birth, urbanization or academic credentials. Equally, the person who moves from being in charge of a machete or dishtowel to being able to manage a computer and databases, understand the scientific process, have global acquaintances (in the taxasphere and other user communities) and manage their own resources, represents the movement of political and economic power from the national centres to rural bases. Decentralization is a process not always embraced by those whose power is being decentralized, which can mean virtually all of the 'educated' portion of a biodiversity-rich tropical country.

Fourthly, biodiversity inventory, for whatever purpose, is traditionally the domain of universities, government agencies and large companies. The reward and motivational systems long-established in these social units are highly ritualized and played out in highly structured arenas. There are two consequences for the

'country bumpkin' formed into a parataxonomist, a parataxonomist who is now abandoning the world of his and her neighbours to become a dependent part of an international community of seekers and users. First, many of the traditional rewards, authorships of research papers, prestige at meetings and other territorial symbols, tenure, curriculum vitae, reputation to granting agencies, publicity in the media, patents, etc., may be quite meaningless to the parataxonomist. Secondly, the parataxonomist may well be marching to an international drumbeat encoded in the Convention of Biological Diversity and centuries of academic biological query, but he or she has to survive largely in the social milieu of a village resident on the margin of the fearful wilderness called a national park or other kind of conservation area. For example, the thrill of finding a new species, for the parataxonomist, comes largely through observing and building on the thrill expressed by his or her new employers (and the attendant trickle down through that line of security), rather than in the form of enthusiasm by parents or neighbours who, first, could not care less (a new species does not put bread on the table for them) and, second, have probably been squashing that new species underfoot for generations. All this means that the project heavily peopled with parataxonomists has to move strongly away from a familiar academic reward structure into one that really pays in the currency of the local situation. Parataxonomists are not graduate students being 'paid' by the contacts and learnings that they will use to earn their way through another social structure, but rather they are employees producing and paying their bills now.

What can parataxonomists produce if they are embedded in a scientifically and administratively nurturing social structure?

My personal direct experience with parataxonomists is limited to those working in the on-going inventory of the ACG, all of whom I, Winnie Hallwachs and others formed *in situ*, and those working in INBio's national biodiversity inventory, many of whom we and others trained in the ACG before they went off to their respective field sites in other Costa Rican conservation areas (Janzen *et al*. 1993). They work in the context of a loosely knit administrative structure with important elements, especially the government research-permitting system and INBio's curatorial posts, being occupied by former parataxonomists who have moved on (upwards). In total, 22 parataxonomists with 10–17 years of experience each, and another four with 2–5 years of experience, are currently conducting a total inventory of the ACG plants (*c.* 7000 species), parasites of the *c.* 1000 species of vertebrates (*c.* 10 000 species), assorted nematodes and fungi, and Lepidoptera (*c.* 8000 species of macrocaterpillars, and their food plants, parasitoids and gut microbes). They link to the taxasphere through a diverse network of national and international institutions, mentors and administrations. These parataxonomists sparsely populate and reflect a dormant plan for an All Taxa Biodiversity Inventory (ATBI) once planned for the ACG (Langreth 1994; Janzen 1996a,b), a plan that would have involved hundreds of parataxonomists.

I will only briefly mention the product from those contributing to the ACG caterpillar inventory Web site at http://janzen.sas.upenn.edu. Fourteen parataxonomists ('gusaneros' in the vernacular) earn a salary equivalent to being a manager of a filling station, tractor driver for a large farm, running the local social security office, or owning a small but well-positioned grocery store. They maintain five caterpillar-rearing centres spread through 110 000 ha of ACG dry forest, cloud forest and rain forest, where their wild-caught caterpillars (and their parasitoids) are reared, processed, database, frozen (adults), mounted, boxed and pooled for later movement out to the museums and taxonomists sprinkled through the taxasphere. All the information is destined for traditional publications (Gauld & Janzen 1994; Janzen & Gauld 1997; Miller, Janzen & Franclemont 1997; Janzen, Sharkey & Burns 1998; Burns & Janzen 1999, 2001; Schauff & Janzen 2001) and the above-mentioned public Web site. Informally, I should be viewed as the 15th parataxonomist, as I am not a taxonomist and do the same things that the parataxonomists do, in addition to serving as a major bridge to the taxasphere.

The parataxonomists live at the rearing barn in the forest or commute to their homes in villages adjacent to the ACG. Six are married within the group, and 12 have families and children. The caterpillars and newly eclosed adults are cared for 365 days of the year, and there are 1000–3000 feeding on any given day among the five rearing barns. The project began in 1978 with one parataxonomist and has grown gradually until reaching its current size in 1997, with experienced people teaching the newcomers, in an explicitly apprenticeship tradition.

As of the end of 2002, the project had accumulated approximately 185 000 individual event-based caterpillar rearing records on the Web site, accompanied by 20 000+ digitized images of those caterpillars (selected from 80 000+ slides) and 42 000+ pinned voucher specimens deposited in major museums or headed that way. The team now produces approximately 25 000 new rearing records per year and all costs average about $350 000 per year (thanks to the USA National Science Foundation and the USA taxpayer). This $15·56 per rearing record includes the costs of sorting the specimens, getting them to the team of about 35 active taxonomists working with them around the world, publication costs, digitizing and Web-site maintenance. In the end, the project cost per species 'done' is about $1000 per species. This does not, however, include the nearly equal cost of contributed time and facilities by the taxasphere for the actual first-time identification of species, their subsequent description in the case of new species, and retention/archiving of vouchers. The project has no on-site supervisor; all parataxonomists manage themselves, and it is commonplace for me to have no direct contact

with them for 1–2 months. They do, however, live and work within the social milieu of the 95+ ACG staff carrying out a variety of biodiversity development activities throughout the ACG (Janzen 2000a,b, 2001a,b, 2002b; Janzen & Gámez 1997). No graduate students or post-doctoral researchers are directly supported by this project at the field site, although some have contributed specimens. The project does, however, annually absorb 2–4 international undergraduates for a 2–3-month field research experience.

My role is feedback on specimen quality, locating database errors, photography of some caterpillars, decisions as to which frozen adult Lepidoptera to pin, suggesting new search methods and places, imposing taxon-specific stop rules, resolving social problems, moving specimens and data to members of the taxasphere, and getting the photographs and information onto the Web site (which is constructed and maintained by Dr Winnie Hallwachs as her parataxonomist contribution). I carry out these activities at erratic intervals over the Internet and during visits of 2–3-week duration spread throughout the year, intermingled with my other responsibilities as a full-time professor at the University of Pennsylvania, USA, and conservation activities (Janzen 2000a,b, 2001a,b, 2002a,b; http://janzen.sas.upenn.edu/RR/rincon_rainforest.htm).

About 1/2000 acts of database entry/recording (into laptop computers at the rearing barns) are an unrecoverable error. Examples of recoverable errors, which are 50 times as frequent, are spelling errors, placing a species in the wrong family, voucher number inversions, reading a voucher number wrongly off of its rearing bag or date reversals. To date, the project has photographed and identified approximately 2600 species of non-leaf miner caterpillars (about 60% of which have unambiguous scientific names while the remainder labour under interim taxonomies). This is about 37% of the total non-leaf miner Lepidoptera in the ACG (dry forest, rain forest, cloud forest), as based on a decade of intensive inventory of adults in the 1980s. At current rates of inventory, the non-leaf miner caterpillars of the ACG will be completed in the coming 15 years. Despite the very intensive inventory of large and visible Costa Rican Lepidoptera over the past two centuries, the thorough combing of the ACG ecosystems by this team has located hundreds of species of non-leaf miner Lepidoptera new to Costa Rica and Central America, many of which are undescribed.

To carry out this project with traditional visiting university-based undergraduates, graduate students and PhDs would simply be impossible, even with a much larger budget. The on-site continuity, diligence of long-experience-based caterpillar seeking, large sample sizes, patience with extremely isolated social circumstances, and pride of workmanship in seeking and rearing offered by this team of parataxonomists is the only thing that makes it even remotely possible to conduct the complex biodiversity inventory of this large place.

Can projects such as that described above be combined with other megainventory projects?

There is no doubt that a cross-taxon biodiversity inventory of a large complex tropical area can be conducted with a large team of parataxonomists co-ordinated and integrated through both their vertical contacts with the taxasphere and on-site integration of trapping, sorting, processing and information/specimen export. The economies of scale, both in intellect and budgets, will be huge. These economies emerge when parataxonomists share labour among taxonomic sectors during times of peak activity, when there is an intellectual critical mass, and when inventory actions for any given major taxon generate substantial collateral information that can and will be gathered by an adjacent project. When the on-site intertaxon synergies among the taxasphere itself are included, truly spectacular things happen in rates of discovery, novelty of interpretation, and stimulus to push the sampling envelope. However, it will not happen by accident nor through the simple pooling of different projects by their accidental sympatry. There does have to be an explicit process of creating parataxonomists and their teamwork, rather than expecting it to emerge from the simple hiring of field assistants.

It is immediately evident that parataxonomists, and the projects that they support, can be strongly boosted by personnel exchanges among projects. However, there are three major hindrances to such exchange. First, virtually all parataxonomists speak the language of their resident area, and thus communication between resident and visiting parataxonomists from other language bases will be marginal (though good things can happen with a quick mind and a good translator). Secondly, most parataxonomists are married with families and otherwise embedded in their communities. Trips of more than a few days duration away from these social circumstances generate severe problems, both for those left behind and for the inventory process that they are leaving untended. These difficulties are not insurmountable, but they are not those normally associated with the peripatetic community of students, faculty and other kinds of researchers who carry out many international biodiversity development projects. Thirdly, parataxonomists operate at an income level where often they would prefer that the travel and other dislocation costs be spent on increasing their own job and social security than on trips to other places, as personally attractive as these may be.

The parataxonomist's role in conservation

Despite this litany of cautionary commentary, there is no doubt that the parataxonomists, basically resident biodiversity managers hired and formed from the rural work force to be the backbone of a major biodiversity inventory project, are a key element in setting up wildland biodiversity for its conservation through

non-damaging use. To do this well, we have to find it, know where it is (and how to find it again), and know what it is (to store information about it and link this to other information). A small army of well-guided parataxonomists can carry out major portions of this multifaceted task for any large complex tropical wildland. I would argue that such inventory is the next step following designation of any large tropical area for conservation. The first act of raw conservation, critical as it is, in no way guarantees conservation into perpetuity unless the second act is integration of that wildland into the social and economic fabric of the resident, national and international community. Each of these communities has its own shopping list. But it is very hard to go shopping if the lights are out, there are no labels on the cans, there are no jobbers, and the cash register is not working. And it is harder yet if each time the sun sets, many of the cans reposition themselves on the shelves. Inventory well done sets up the supermarket for the user.

Being a parataxonomist during the basic inventory, and then for the subsequent research and development, and finally for the uses of a large conserved wildland, is an elegant and long-term job. Jobs mean votes. Jobs mean local economy, GNP and international relationships. Not many workers are inclined to take a chain saw to the factory that employs them and, when they do, we are in the realm of social relations that fit with other traditions and far beyond traditional biodiversity management.

When the tropical loggers cut down a forest they move on, and others create the fields and pastures, caring not a whit for the forest that once was. When the parataxonomist sets up a forest through inventory, those same parataxonomists are obvious high-quality candidates for the biodiversity development processes that follow. They have both economic roots (who better to hire to carry out a bioprospecting programme or guide ecotourists or monitor management impacts; Gámez 1992; Reid *et al*. 1993; Wille 1993; Bookbinder *et al*. 1998; Sittenfeld *et al*. 1999) and sociopsychological roots. It is not an accident that the neighbourhood I grew up in 50 years ago is still the most comfortable-feeling neighbourhood I have experienced anywhere in the world. The parataxonomist is a wildland gardener and potential champion of the persistence of that garden over the coming decades and centuries.

But being a parataxonomist is more than an income stream and good public relations for the interface between a forest and its neighbours. The parataxonomist is to the neighbouring forest as a literate person is to a library, and simultaneously as a reference librarian is to a library. and the parataxonomist is a middle-class role model for the children of the neighbourhood, a new kind of role model, one that sees the forest as a productive place in its own right. In this context, it should be recognized that an ecotourist guide, a biodiversity prospector, a biological control worker, a national park administrator, and many other analogues are all parataxonomists under another name. Each of these is one step closer to viewing and treating the conserved wildland as another kind of garden (Janzen 1998, 2000b, 2002b), rather than as something fearful to be removed so as to make way for human domesticates.

Acknowledgements

This essay was inspired by the All Taxa Biodiversity Inventory (ATBI) of the Great Smoky Mountains National Park (Janzen 2002a) and its positive effect on the US National Park Service, by the ongoing use of parataxonomists for biodiversity inventory in Papua New Guinea (Basset *et al*. 2000, 2004), and by the experiences of Costa Rica's INBio and ACG in depending on teams of parataxonomists to carry out their biodiversity inventory efforts. It was supported by NSF grant DEB 0072730 and by the administration of the ACG, and encouraged by Winnie Hallwachs, the co-conspirator for most of the thoughts expressed here.

References

Basset, Y., Novotny, V., Miller, S.E. & Pyle, R. (2000) Quantifying biodiversity: experience with parataxonomists and digital photography in New Guinea and Guyana. *Bioscience*, **50**, 899–908.

Basset, Y., Novotny, V., Miller, S.E., Weiblin, G.D., Missa, O. & Steward, A.J.A. (2004) Conservation and biological monitoring of tropical forests: the role of parataxonomists. *Journal of Applied Ecology*, **41**, 163–174.

Bookbinder, M.P., Dinerstein, E., Rijal, A., Cauley, H. & Rajouria, A. (1998) Ecotourism's support of biodiversity conservation. *Conservation Biology*, **12**, 1399–1404.

Burns, J.M. & Janzen, D.H. (1999) *Drephalys*: division of this showy neotropical genus, plus a new species and the immatures and food plants of two species from Costa Rican dry forest (Hesperiidae: Pyrginae). *Journal of the Lepidopterist's Society*, **53**, 77–89.

Burns, J.M. & Janzen, D.H. (2001) Biodiversity of pyrrhopygine skipper butterflies (Hesperiidae) in the Area de Conservación Guanacaste, Costa Rica. *Journal of the Lepidopterist's Society*, **55**, 15–43.

Gámez, R. (1991a) Biodiversity conservation through facilitation of its sustainable use: Costa Rica's National Biodiversity Institute. *Trends in Ecology and Evolution*, **6**, 77–378.

Gámez, R. (1991b) El Instituto Nacional de Biodiversidad de Costa Rica: poniendo la biodiversidad a trabajar sostenidamente para la sociedad. *Biodiversity*, **7**, 86–88.

Goldstein, P.Z. (2004) Systematic collection data in north American invertebrate conservation and monitoring programmes. *Journal of Applied Ecology*, **41**, 175–180.

Gámez, R. (1992) Chemical prospecting: hope for vanishing ecosystems? *Science*, **256**, 1142–1143.

Gámez, R. (1999) *De biodiversidad, gentes y utopías: Reflexiones En Los 10 Años Del Inbio*. Instituto Nacional de Biodiversidad, Santo Domingo de Heredia, Costa Rica.

Gauld, I.D. & Janzen, D.H. (1994) The classification, evolution and biology of the Costa Rican species of *Cryptophion* (Hymenoptera: Ichneumonidae). *Zoological Journal of the Linnean Society*, **110**, 297–324.

Janzen, D.H. (1991) How to save tropical biodiversity. *American Entomologist*, **37**, 159–171.

Janzen, D.H. (1992) A south–north perspective on science in the management, use, and economic development of

biodiversity. *Conservation of Biodiversity for Sustainable Development* (eds O.T. Sandlund, K. Hindar & A.H.D. Brown), pp. 27–52. Scandinavian University Press, Oslo, Norway.

Janzen, D.H. (1993) Taxonomy: universal and essential infrastructure for development and management of tropical wildland biodiversity. *Proceedings of the Norway/UNEP Expert Conference on Biodiversity, Trondheim, Norway* (eds O.T. Sandlund & P.J. Schei), pp. 100–113. NINA, Trondheim, Norway.

Janzen, D.H. (1996a) On the importance of systematic biology in biodiversity development. *Association of Systematics Collection Newsletter*, **24**, 23–28.

Janzen, D.H. (1996b) Prioritization of major groups of taxa for the All Taxa Biodiversity Inventory (ATBI) of the Guanacaste Conservation Area in northwestern Costa Rica, a biodiversity development project. *Association of Systematics Collection Newsletter*, **26**, 45, 49–56.

Janzen, D.H. (1998) Gardenification of wildland nature and the human footprint. *Science*, **279**, 1312–1313.

Janzen, D.H. (2000a) Costa Rica's Area de Conservación Guanacaste: a long march to survival through non-damaging biodevelopment. *Biodiversity*, **1**, 7–20.

Janzen, D.H. (2000b) Wildlands as gardens. *National Parks Magazine*, **74**, 50–51.

Janzen, D.H. (2001a) Good fences make good neighbors. *PARKS*, **11**, 41–49.

Janzen, D.H. (2001b) Lumpy integration of tropical wild biodiversity with its society. *A New Century of Biology* (eds W.J. Kress & G.W. Barrett), pp. 133–148. Smithsonian Institution Press, Washington, DC.

Janzen, D.H. (2002a) Biodiversity is us. *All Taxa Biodiversity Inventory (ATBI) Quarterly*, **3**, 3.

Janzen, D.H. (2002b) La sobrevivencia de las áreas silvestres de Costa Rica por medio de su jardinificación. *Manejo Comunitario de la Biodiversidad Biológica En Mesoamérica* (ed. F. Chapela), pp. 81–105. Universidad Iberoamericana, Puebla, Mexico.

Janzen, D.H. & Gámez (1997) Assessing information needs for sustainable use and conservation of biodiversity. *Biodiversity Information: Needs and Options* (eds D.L. Hawksworth, P.M. Kirk & S.D. Clarke), pp. 21–29. CAB International, Wallingford, UK.

Janzen, D.H. & Gauld, I.D. (1997) Patterns of use of large moth caterpillars (Lepidoptera: Saturniidae and Sphingidae) by ichneumonid parasitoids (Hymenoptera) in Costa Rican dry forest. *Forests and Insects* (eds A.D. Watt, N.E. Stork & M.D. Hunter), pp. 251–271. Chapman & Hall, London, UK.

Janzen, D.H., Hallwachs, W., Jimenez, J. & Gámez, R. (1993) The role of the parataxonomists, inventory managers and taxonomists in Costa Rica's national biodiversity inventory. *Biodiversity Prospecting* (eds W.V. Reid, S.A. Laird, C.A. Meyer, R. Gámez, A. Sittenfeld, D.H. Janzen, M.A. Gollin & C. Juma), pp. 223–254. World Resources Institute, Washington, DC.

Janzen, D.H., Sharkey, M.J. & Burns, J.M. (1998) Parasitization biology of a new species of Braconidae (Hymenoptera) feeding on larvae of Costa Rican dry forest skippers (Lepidoptera: Hesperiidae: Pyrginae). *Tropical Lepidoptera*, **9** (Supplement), 33–41.

Langreth, R. (1994) The world according to Dan Janzen. *Popular Science*, **245**, 78–82, 112–115.

Longino, J. & Colwell, R. (1997) Biodiversity assessment using structured inventory: capturing the ant fauna of a tropical rain forest. *Ecological Applications*, **7**, 263–1277.

Miller, J.S., Janzen, D.H. & Franclemont, J.G. (1997) New species of *Euhapigioides*, new genus, and *Hapigiodes* in Hapigiini, new tribe, from Costa Rica, with notes on their life history and immatures (Lepidoptera: Notodontidae). *Tropical Lepidoptera*, **8** (2), 81–99.

Reid, W.V., Laird, S.A., Gámez, R., Sittenfeld, A., Janzen, D.H., Gollin, M.A. & Juma, C. (1993) *Biodiversity Prospecting*. World Resources Institute, Washington, DC.

Sandlund, O.T. (1991) Costa Rica's INBio: towards sustainable use of natural biodiversity. *Norwegian Institute for Nature Research (NINA), Notat*, **007**, 1–25.

Schauff, M.E. & Janzen, D.H. (2001) Taxonomy and ecology of Costa Rican *Euplectrus* (Hymenoptera: Eulophidae), parasitoids of caterpillars (Lepidoptera). *Journal of Hymenoptera Research*, **10**, 181–230.

Sittenfeld, A., Tamayo, G., Nielsen, V., Jiménez, A., Hurtado, P., Chinchilla, M., Guerrero, O., Mora, M.A., Rojas, M., Blanco, R., Alvarado, E., Gutiérrez, J.M. & Janzen, D.H. (1999) Costa Rican international cooperative biodiversity group: using insects and other arthropods in biodiversity prospecting. *Pharmaceutical Biology*, **37** (Supplement), 55–68.

Wille, C. (1993) Riches from the rainforest. *Nature Conservancy*, January/February, 11–17.

Received 12 November 2002; final copy received 14 October 2003