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Abstract: Madagascar has always held a special place on the bioprospecting map. Designated as one of the world's "hottest" biodiversity hotspots, scientists believe the extremely high flora and faunal endemism contain unique potential for the commercialization of natural products. Years of collections by bioprospectors in Madagascar are beginning to pay off, not necessarily from drug discovery, but through the biodata from their botanical collections. In the paper, we highlight the links between labour and value over time to illustrate the historical process of collecting inventories of biodata and calculating biodiversity metrics. As we demonstrate, biodata originally used for the purposes of drug discovery and scientific exploration are now being repurposed in biodiversity offsetting programs for multinational mining operations in Madagascar. This project of "re-mining" biodata has reinforced the power of select research institutions which now service their expertise for biodiversity offsetting initiatives. In sum, botanical agencies are far from apolitical actors in these new iterations of market-conservation but active participants in a new age of green grabbing.

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Madagascar has always held a special place on the bioprospecting map. Designated as one of the world's "hottest" biodiversity hotspots, scientists believe the extremely high flora and faunal endemism contain unique potential for the commercialization of natural products. Years of collections by bioprospectors in Madagascar are beginning to pay off, not necessarily from drug discovery, but through the biodata from their botanical collections. In the paper, we highlight the links between labour and value over time to illustrate the historical process of collecting inventories of biodata and calculating biodiversity metrics. As we demonstrate, biodata originally used for the purposes of drug discovery and scientific exploration are now being repurposed in biodiversity offsetting programs for multinational mining operations in Madagascar. This project of "re-mining" biodata has reinforced the power of select research institutions which now service their expertise for biodiversity offsetting initiatives.In sum, botanical agencies are far from apolitical actors in these new iterations of market-conservation but active participants in a new age of green grabbing.

Keywords: Labour; Scientific Institutions; Political Ecology; Green Grabbing; Bioprospecting; Biodiversity Offsets; Madagascar; Africa

1. Introduction

For more than thirty years conservation scientists have been engaged in a massive global effort to collect, catalogue and chemically screen the world's biodiversity for drug discovery(known as bioprospecting). Since early days of conservation, nothing captured the imagination of the public more than the iconic image of the barefoot doctor seeking to cure humanity's ills under the canopy of the rainforests (Brosius, 1997; Voeks, 2004).[1] As Voeks remarks, "…the myth that pristine forest represents the primary repository of nature's medicinal providence" has provided the motivation and the funding necessary for conservationprograms worldwide (Voeks, 2004: 868; see Reid et al., 1993). Bioprospecting was a shining example of the widely touted Integrated Conservation and Development Projects (ICDPs) at the 1992 Earth Summit in Rio (Neimark, 2012a).[2] To the scientific community at the time, bioprospecting

[1]All attempts were made to protect the confidentiality of the participants of this research and information is reported anonymously. All names of research participants that do appear are pseudonyms.
[2]Most noteworthy were mass bioprospecting agreements between the Costa Rican Biodiversity Research Institute

opened opportunities to finance plant collection on an unforeseen scale; the perfect melding of conservation and capitalism (Brockington and Duffy, 2010). The discovery of new species, proponent's argued, not only increased the chances to unlock natures' chemical treasures, it also would lead to the revaluation of nature unleashing a global conservation effort that would protect these treasures for years to come.The conservation logic behind this "taxonomic call to arms" was to rapidly and efficiently create a biodiversity inventory before a crisis of massive deforestation and species extinction wiped out the world's biodiversity (Hayden, 2003: 57). Following suit, the capitalist logic held that any species not chemically screened was a lost opportunity to find a blockbuster drug.

For three decades, Madagascar has held a special place on the bioprospecting map. As one of the world's "hottest" biodiversity hotspots, scientists believed the extremely high flora and faunal endemismcontained unique potential for drug discovery. For instance, the primary directive one of Madagascar's longest running bioprospecting projects, the International Cooperative Biodiversity Groups (ICBG 1998-2013)[3]was to amass large volumes of plant material for drug discovery screening.[4]Yet, the dream of a perfect long-term union between conservation and capitalism under the rubric of bioprospectingproved a relatively short marriage. Most large projects to finance species collection and identificationhave tapered offfrom their peak in the early 2000s. Indeed the ICBG agreement itself came to a close in 2013.This raises a series of questions to which this paper seeks to respond. What happened to all the plant material collected for drug discovery? How is it now being used? And what is the future of biodiversity

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(INBio) and Merck and Co., and the US federally funded, International Cooperative Biodiversity Groups (ICBG).

[3]ICBG- Madagascar represents an eclectic mix of high-tech US laboratories such as the National Institutes of Health and Virginia-Tech, commercial partners, Dow AgroSciences, environmental NGOs Conservation International (CI) and Missouri Botanical Gardens (MBG), and Malagasy national laboratories, such as the NationalCentreforApplied Pharmaceutical Research (CNARP).

[4] Marine and micro-organisms were also collected.

conservation in the absence of the drug discovery narrative?

In what follows we revisit what Parry (2000) has called “the fate of the collections.”As Parry argued, “[c]ollecting is often perceived as being a one-off appropriation and transference of individual objects” rather than “the first acts in a complex process…that entails not only the acquisition but also the concentration, disciplining, circulation and regulation of flows of material” (2000: 375). The “danger,” wrote Parry, was “focusing myopically on the point of collection and fixating on the specifics of particular compensatory agreements”while losing sight “of the much larger and far more significant questions surrounding the ownership, potential value, and future usage of the collections” (Parry, 2000:376).

As we illustrate through more than a decade of field research on bioprospecting in Madagascar, the fate ofbiological data inventories (henceforth, biodata), including thousands of digitized and material floral herbarium specimens, once collected for the purposes of drug discovery arenow being repurposed in biodiversity offsetting programs for multinational mining operations. In search of a way to revalue the large biodata inventories created during the era of bioprospecting, botanical gardens and other “centres of calculation” (Parry, 2000) that once transformed *in situ* nature into leaves, stems, and molecules for drug discovery are now servicing these *ex situ*collections and scientific expertise to help produce biodiversity offsets.

Biodiversity offsetting is the practice of reducing the net loss of biodiversity caused by intensive mining through the protection and mitigation of intact ecosystems. Biodiversity offsetting, particularly for large-scale mining projects, has become a key conservation strategy in Madagascar where corporate mining interests such as Sherritt and Rio Tinto seek to reshape their image as environmental stewards both locally and globally. There is a cruel irony here. Thousands of digitized and floral specimens that were once collected and transferred from

Madagascar to inventories in the global North under a previous cycle of so-called “low-impact” bioprospectingcollection are now being re-mined and transferred back to establish criteria and certify very “high-impact” mineral extraction.

This research contributes to critical studies of market-conservation (Arsel and Büscher, 2012; Brockington et al., 2008; Roth and Dressler, 2012) and the production and appropriation of nature in an age of “green grabbing” (Cavanagh and Benjaminsen, 2014; Corson et al., 2013; Fairhead et al., 2012; McDonald and Corson, 2012). The biodiversity inventories described below are the product of the quintessential green grab – bioprospecting (Neimark, 2012a). However, in the important literature on green grabbing, there isless emphasis on the role of labour in the production of conservation value (for exceptions see Büscher, 2014; Lansing, 2012; Neimark, 2012a; Sodikoff, 2012; 2009West 2006).[5]Reflecting on past bioprospecting research (Brosius, 1997; Hayden, 2003; Neimark, 2012b; Parry, 2004) we show how biodiversity inventories are produced through labour processes that combine both conservationist and capitalist logics (Lowe, 2006; Sodikoff, 2012; Waterton et al., 2013).Building on Marx’s (1976) treatise on commodity fetishism, we demonstrate how herbarium collections first used in drug discovery and then in offsetting schemes concealed the labour processes that brought them into being.We show that it takes hard work to produce biodiversity into a form of value through which capital can recognize it (Robertson, 2006). We argue alongside Sodikoff (2012) and others (Lowe, 2006; Waterton et al., 2013) that it is critical to account for the hard work of local scientists and manual labourers associated with collection. Reliable biodata inventories must be produced through a scientific division of labour that is organized around forms of knowledge and expertise that make biodiversity legible in ways that “conform(s) to the virtual reality defined by

[5]Sodikoff's(2012) in her excellent study of forest labour, aptly demonstrates the paradox of development and conservation project’s workers which are undervalued and underpaid and thus remain reliant on destructive slash-and-burn (tavy) cultivation.

important Western models of society and nature" (West and Carrier, 2004: 485). The virtual reality of biodata inventories is ultimately dependent upon the material reality of collecting, preserving and transporting specimens.Our focus on labour demonstrates how uneven international divisions of labour are reproduced into low-wage manual and scientific labourers in the South, and high wage, knowledge professionals in the North. This attention on labour, we hold, is an important analytical contribution which can be used to critically examine a wave of new market-conservation interventions throughout the global south (Corson et al. 2013; Fairhead et al. 2012).

In the remaining parts of the paper we return to the process of bioprospecting collection to locate biodiversity offsetting within its historical context in Madagascar. First, we frame the practice of biodiversity offsetting as an example of market-conservation and suggest that it exemplifies the "audit culture"(or the systematic accounting of biodiversity) in market-conservation and echoes the spatial dynamics and power relations associated with historical and contemporary forms of green grabbing (Fairhead et al., 2012). However, we also argue that biodiversity offsetting fetishizes the scientific labour of collection that built the inventories through which green audits and reclamation efforts are designed. In section three we lay out the historical context of two ICBG collection institutions with very dissimilar development trajectories – the privately-funded US Missouri Botanical Gardens (MBG) and the Malagasy Pharmacological Laboratory (CNARP). We highlight the marginalization of CNARP in the post-bioprospecting context and how MBG has repositioned itself as the authoritative body within anemerging green "certification economy."This economy is deeply reliant on an emerging group of technical experts andprofessional consultants whose job it has become to define and approve of biodiversity offsets for mining in the global south.This is supported by the next section which provides a detailed ethnographic account of labour processes for both plant collection and chemical extracts used in bioprospecting. In section five, weexplain how biodiversity is produced for offsetting using the metrics from herbarium indexing and the mass collections achieved under bioprospecting for drug discovery. We affirmthat the practice of green auditing constitutes for offsetting a “double fetishization” (Goodman, 2004) of nature through a narrative around the production of offset spaces to mitigate the effects of extensive mining by multinational corporations such as Rio Tinto and Sherritt International. In our conclusion, we raise critical justice questions surrounding botanical gardens (re)emergence as tropical biodiversity currency traders and new corporate certifiers in an age of green grabbing.

This paper is based on 14-months of intensive ethnographic fieldwork by the first author, including over 110 semi-structured interviews and participant observation, carried out in 2005 and 2006 in Madagascar. During this time, two successive bioprospecting trips were made in Madagascar. Interviews were conducted with botanists, field guides, wage workers, and local participants of bioprospecting. Follow-up interviews were carried out with, and economic data collected from, project managers, university and independent scientists and researchers, and administrators in local, regional and national offices of the Malagasy government. One of the purposes of this paper is to update the research conducted in 2005/6 with current work on re-mining the biodata for contemporary market-conservation.

2. Fate of the Collections Revisited: From Bioprospecting to Biodiversity Offsetting

Since the 1980s, advocates for bioprospecting claimed the best way to address the global environmental crises −including species extinction and deforestation − was conservation schemes which linked world markets and rural economies. Bioprospecting could employ people living closest to the resources to identify and collect distinctive flora and fauna and, in return, be provided compensation for their medicinal knowledge and participation. Advocates claimed that since nature offered a repository of genetic information and unique chemical compounds, “locals” would provide frontline protection offering a “win-win” solution to the crisis. The initial round of funding for bioprospecting missions in the 1990s enabled private botanical agencies to recruit and train scientists from poor countries in taxonomy and herbarium collecting, locally known in some countries as “para-taxonomists,” and gave logistical and material support for source-country research institutions (Janzen, 1991).[6] Far from sold on the returns from individual bioprospecting missions, pharmaceutical companies were lured in to participate for two reasons. First, source-countries established a critical mass of capable scientific labour that could facilitate the drug discovery research. Second, advancements in technology such as robotics, high-throughput screens, and digital libraries of compounds, made it easier, faster, and cheaper to screen and identify bioactivity. These two developments, scientific labour and technological advances, enabled a complete shift in the way bioprospecting worked. Rather than depending local ethnobotanical knowledge of medicinal plants, a process which many saw as slow and “less scientific,” well-trained para-taxonomists could facilitate bulk collection to run through high-throughput mass screens, and establish access and control over the corresponding herbarium specimens for the baseline inventory (Hayden, 2003; Neimark, 2012a). For the bioprospecting industry, this meant less risk as they could amass libraries of natural compounds, all without having to leave their home institution.

The advent of bulk collection and of corporate funding led to a boom period during which botanical institutions created innovative ways of cataloguing and analysing the biodata in herbariums in the US and Europe and also digitized databases online (Waterton et al., 2013). The

[6] The term “para-taxonomist” is not widely used in the Madagascar ICBG. Instead they are referred to as local collector.

virtual databases afforded botanical repositories significant advantages as huge amounts of plant material could be compressed into digital formats opening up new potentials for its future redeployment as informational portals and other commercial options. Bronwyn Parry (2000: 375) argues we must look past traditional notions of collecting as apolitical and “benign.” Rather, for Parry, collecting must be seen as "…a process that enables individuals or groups to alienate (both territorially and epistemologically) particular bodies of material for their exclusive use.” Building on Parry’s conception of alienating nature, Hayden states that bioprospecting was a way in which the pharmaceutical industry could engage nature through “…pegging the ‘value’ of nature into quantifiable measures of industrial worth (2003: 57).” As she notes, “[o]ne of the key aspects of this articulation of biodiversity as a field of potential loss is the formulation of a storehouse of information *not yet catalogued* and thus with a value that can *only* be imagined” (2003: 57). Underlining the rhetorical power of the capture and control of biodata is a prize conservation opportunity through the market of finding a lucrative drug. It is as Hayden puts it, “the potential for transforming plants into information, and information into a patentable product, that allows proponents to label bioprospecting a form of sustainable – ecological friendly— economic development” (2003: 58-9).

Yet, since its introductionto the conservation community roughly 30 years ago, bioprospecting has failed to deliver on its primary directives of finding a blockbuster drug. This led to many large pharmaceutical companies to shut down their natural products divisions and seek out new methods to drug discovery which seemed somehow “more scientific” such as computer-generated molecules(Neimark, forthcoming).In the wake of this bioprospecting “bust,” botanical agencies began to look elsewhere as their collected material began to recede in valuewithout flow of commercial funding from pharmaceutical firms. Ultimately, this downturn in bioprospecting activity has led them to seek out new opportunities in market-conservation.[7]

Today biodata isn't only about drug discovery. Indeed, biodata is vital to a range of market-conservation initiatives, most notably biodiversity offsetting (McAfee and Shapiro, 2010; Robertson, 2011). Biodiversity offsetting is a practice which enables nature to be traded under what Fairhead et al., call, the "economy of repair" (2012: 241). Offsetting signals a shift in the way localized environmental externalities of market transactions are remediated through the production of an environmental good or service removed both spatially and temporally from the "affected" or degraded nature. It has recently been described by Sullivan as a way, "to incorporate environmental harm into development activity and thereby turn conservation strategies into profitable enterprise…" (2013a: 81). Offsetting programs are promoted by a consortium of firms, financial institutions, government agencies and NGOs under the umbrella group Business and Biodiversity Offsets Programme (BBOP) whose "mitigation hierarchy (avoid, minimize, restore, offset)" has become an industry standard "to achieve no net loss or a net gain of biodiversity."[8] These exchanges, according to Sullivan, "require the presence of measurable conservation and/or ecological restoration indicators associated with material nature, including threatened species, biodiversity, and carbon sequestered in the biomass of forests or soils" (2013b: 82-3). New offset spaces (including conservation enclosures and repaired sites) are intentionally designated and designed based on biodiversity thresholds and metrics created by experts who have created, maintained and mined the rich biodata produced through earlier iterations of collection(Seagle, 2012; see also Benabou, 2014). In offsetting programs, nature's

[7]Neves, K. 2014. "Reproducing Empire, Subverting Hegemony? Botanic Gardens in Biodiversity Conservation." EnviroSociety. 4 December. www.envirosociety.org/2014/12/ reproducing-empire-subverting-hegemony-botanic-gardens-in-biodiversity-conservation

[8] Business and Biodiversity Offsets Programme (BBOP) Accessed on November 20 2014 at: http://bbop.forest-trends.org/

valuation is carefully monitored by auditing institutions and paid for by multinationals increasingly concerned with maintaining a green reputation (Mutersbaugh, 2004). This "socially necessary abstraction" commonly presents biodiversity value as intrinsic (assumed a priori value in nature, or nature fetishized)(Robertson, 2011: 389).

In this paper, we demonstrate that the production of abstract nature is not a new phenomenon, but is actually dependent upon historical process of previous highly coordinated and iterative expeditions designed to collect, classify and inventory the island's biodiversity for drug discovery. As we illustrate, the biodata inventories used for offsetting metrics in Madagascar ultimately privilege those who controlled the collection; those who made decisions over their application, and those with the power to use them for the purposes of accumulation or governance (Parry, 2004; Turnhout et al., 2014). As Parry clearly explains, "[t]he collector's power derives from his or her ability to acquire materials of interest…and to then recirculate them (or not) within the marketplace to strategic advantage (2004: 251). We historicize the production ofbiodata, highlighting the power and authority of select research institutions to provide a green stamp of approval for multinational mining operations. Our point here is not to show the success or failures of biodiversity offsetting (see Seagle, 2012), but to render visible the historical process that has brought about the seemly uncontested and unchallenged production of biodiversity (Lowe, 2006).

3. Historicising bioprospecting institutions in Madagascar

To understand the relationship between biodiversity offsetting and bioprospecting in Madagascar, it is necessary to consider a longer history of botanical collection agencies. In Europe, pre-colonial expeditions set out across the globe for valuable flora and fauna yielding a bounty of useful medicinal and industrial plants. The collections vaulted the prestige of European botanical centres and repositories, such as London's Kew and the HortusBotanicus Leiden (Brockway, 1979;Grove, 1995; Parry, 2004; Schiebinger, 2007). Local knowledge brought back alongside the plants helped scientists to isolate valuable medicinal treatments. Two prime examples include quinine from cinchona bark (*Cinchona officinalis* L.) to treat malaria and ipecacuanha root (*Cephaelisipecacuanha*) for amoebic dysentery (Sneader, 2005). Other botanical gems like teak, rubber and sugar, were also taken to European collections for breeding germ-stock *in situ* (Grove, 1995). During the colonial period, institutes across Africa, including the French *L'Office de la RechercheScientifiqueet Technique Outre-Mer* (ORSTOM) and the British Tropical Development and Research Institute (TDRI), also began to set up experimental gardens with newly acquired exotic and introduced species (Gaillard, 1990).

Seeking to sever its colonial ties with France, Madagascar's First Republic (1958-75) invested in independent National Research Institutes (NRI) to furnish the young state with the scientific capacity to continue research in agricultural and forestry sciences and develop new industrial products. It was at this time, in 1976, that the national pharmacological centre – CNARP −was created to develop affordable medicines and herbal products for the Malagasy people.[9] Financial support for CNARP was garnered from the newly-formed, yet fragile government. Nevertheless, as time wore on, state funding needed to be supplemented with loans from multilateral institutions, such as the World Bank and the International Monetary Fund. By the mid-1980s, Madagascar as with other countries in Africa was beginning to feel the crippling effects of debt and subsequent structural adjustment from these loans. For CNARP, the new austerity measures slashed budgets, thereby starving it of equipment, support staff, and training

[9]Created on 1 October 1976 by Decree No. 76334, National Research Centre Pharmaceutical was reorganized and renamed the National Centre for Pharmaceutical Research Application in 1992.

in new research techniques.

Eventually in the mid 1990's, international donors did bring some relief. However, in order to obtain funds, states were pressured to adopt a host of "green conditionalities" − market-based conservation strategies, such as debt swaps and other biodiversity conservation interventions − which aligned with the newly established sustainable development objectives of donor institutions (McAfee, 1999; Schroeder and Neumann, 1999). The influx of these funds, particularly in the 1990s, fostered a subsequent "conservation boom," in Madagascar and elsewhere in Africa (Corson, 2010; Duffy, 2006; Kull, 1996). This money was quite significant, with some estimates for donors' contributionsbeing approximately $450 million for the three 5-year National Environmental Action Programs (NEAP I, II and III - 1991-2008), and the US contribution alone totalling $120 million (Freudenberger, 2010:9). Needless to say, this money opened a window to build collaborative links with environmental NGOs and big donor projects. Furthermore at this time, research institutes were under pressure to generate revenue through commercial opportunities (Stads and Randriamanamisa, 2010). This push for commercialisation was particularly the case under the ICBG, as civil society organisations and private research institutes, like the Missouri Botanical Garden (MBG), quickly stepped in to supplement an increasing portion of CNARP funding. As noted by a researcher with connections to the ICBG:

> We are a public institution, but the government doesn't give us anything. By the time the money from the ministry filters down to our laboratory we receive just chalk…chalk, paper and one litre of solvent…this is why it is really vital to collaborate with outside institutions. [10]

The ICBG was tailor made for national institutions like CNARP to tap into international funding,

[10] Anonymous interview (March 1, 2006).

under the condition that they would facilitate drug discovery of Malagasy plant material.[11] In return, the ICBG kept the institution afloat through training on plant collecting and basic herbarium and extraction equipment (Neimark, 2012a).[12] Yet, these benefits pale in comparison to influence and power as a principal institution in Madagascar, and, CNARP role as a redundant labour force.

The Madagascar collections boast rough estimates of 203, 984 herbarium specimens housed in digital catalogues.[13]The expeditions by 2006 had collected up to 4,000 chemical extracts subsequently exported for drug discovery, a number which was estimated to triple by the end of the project in 2013.[14] These collections are a significant source of pride for the teams and are symbolic of the dual mandate of the project– to discover natural products and seek out new species for identification (Neimark, 2012a). However, it also speaks to the immense amount of work that teams of para-taxonomists and others have contributed to amass such collections. Without these teams, MBG would find it much harder to claim its "stellar" and almost quasi-diplomatic status in the country. As noted by a leading PI in Madagascar:

> We have had twenty to twenty-five year reputation that is sterling. We have become a valued partner, when the government wants information about plants in a particular area they come to us. So it is a lot easier for us to do our work here.

He went on to say:

> …originally we based our work on research, systematic botany, we built such a strong basis of knowledge of Malagasy plants, that we have become the authority of Malagasy plants. Knowledge is power and right now, and for quite some time MBG has that power[15]

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[11]This follows the CBD mandate that states must facilitate access if proper benefit-sharing agreements (ABS) are place (Neimark and Tilghman, 2014).
[12]Anonymous interview (March 5, 2006).
[13]MBG has worked in Madagascar for over twenty-five years. Fourteen of those years were under the ICBG project. MBGs herbarium Africa collections total approximately 650,000 with roughly 150,000 being added each year. Accessed on 1 May 2014 at: http://www.missouribotanicalgarden.org/plant-science/plant-science/africa.aspx
[14] Anonymous interview (March 5, 2005).
[15] Anonymous interview (March 11, 2005).

Yet, MBG scientists do not see themselves or their power as particularly “political” or easily compromised in any way, a leading botanist:

> We don’t want to become a Conservation International or World Wildlife Fund, where their research already has a pre-determined results…we want to be seen as an organisation that has remained objective. For a long time MBG was doing quality science that is lived under the naive guise that we really have an effect [on conservation]…but in reality, the research we do ends up in peer-reviewed journals. It was relevant data, but not being used.[16]

One way it is now being used is to support new collection technologies and online herbarium collections databases, such as MBG’s *tropicos* network. Here, scientists are able to place “locally” collected material and knowledge found in the most remote areas of Madagascar and *fix* it into packaged information of “global” networks of exchange (Parry, 2004).[17] The *tropicos* database has become one of the world’s leading online herbarium collection sites − a global standard. The benefits that comefrom controlling access to such databases exceeds the work of drug discovery; however, as scientists’ placement of plant species taxa in digital formats can be now recast for the market-conservation – vital since the end of programs. In digital formats, herbarium samples are translatable into the exact diversity baselines and audit calculations (discrete calculations of nature either lost or gained) needed for mining offsetting programs. MBG and other botanical scientists are in effect, defining and thus producing biodiversity through herbarium indexing.

4. Producing Biodiversity: Labouring in the Forest and the Lab

But where does biodiversity indexing begin? To understand how herbarium specimens

[16] Anonymous interview (April 14, 2006).
[17] Accessed on March 1, 2013 at: http://www.tropicos.org/projectwebportal.aspx?pagename=Milestones&projectid=17

are transformed into biodiversity offsets we must begin with bioprospecting collection. It was in late April 2005 when a team of Malagasy bioprospectors finally arrived in Sambava, a remote town located in the heart of Madagascar's "vanilla triangle."[18] The team was holed up in a hotel room among hundreds of cotton sacs overflowing with recently collected plant material. The sacs were laid across the floor as emanating odours filled the room with an almost toxic smell. One of the head collectors, Philippe, stood on the balcony of the hotel room, surveying the success of the trip, "as you can see, there were no exceptions; we took everything we could with a fruit and flower," continuing he said, "…for us, it is actually *all* about collection."[19]

Philippe wanted to make it clear he was not on a "cloak and dagger" enterprise sent to pillage forest communities of their medicinal knowledge and resources. As with many of the researchers in the ICBG, they did not see themselves as doing anything beyond the work they were trained to do. On the trip they very rarely ever spoke of commercialization or even drug discovery.[20]Although this disconnect seems stark, it is easy to understand given that for the research team their individual tasks constitutes just one small node in a much larger commodity chain. Adding to his disconnect are the realities of drug discovery itself, the collecting sites in remote forests are thousands of miles from the high-tech laboratories in the US and the lengthy process it takes to bring a drug to market (approx. 15 years). In an attempt to bridge these temporal and spatial gaps, not just for the workers but for the communities who are set to receive benefits from commercialization, the ICBG has developed a figure (shown below) to describe the bioprospecting collection process.

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[18]The north western coastal towns of Sambava, Antalaha, Vohemar and Andapa (SAVA) are centre of vanilla-production.

[19] Anonymous interview (March 5 2005).

[20] This observation included multiple interviews in 2005-6, with ICBG researchers and collectors.

Figure 1: ICBG image describing the work done in the bioprospecting commodity chain[21]

The figure provides examples of how individual labour contributes to the dual-mandated outcomes of the team – the collection of bioprospecting samples (depicted by the upper end of the figure) and herbarium specimens (lower part).

In general, collecting herbarium specimens for science is not seen as an activity bound up in the same politics and sticky intellectual property issues as bioprospecting for drug discovery. Yet, the systematic collection of herbarium specimens for inventory is quite political nonetheless (Parry, 2000). In fact, one must go beyond the standard definitions of scientific collections to see it as a complex labour process which allows benefits to accrue for the recipients of the material. Herbarium collections have given botanical agencies, such as MBG, the political power and global brand recognition which have opened servicing opportunities not available to their Malagasy partners in the ICBG (see section 6).

Given how vital the collections have become to the enduring vision of botanical agencies, it is easy to understand the energy that is put into organizing the bioprospecting teams. The group selection itself is a product of calculated choices by project administrative staff and selection is thereby based on maximising efficiency. The key is to complete directed work and seamlessly move on to the next collection. Even before plants are located and the first sample taken, individuals on the team− from the head collector down to the local porter− are informed of individual tasks, including anything from the climbing of trees to collect fruit and flowers to digging out roots. In the end, the collections are, in fact, a product of work, done by an assemblage of skilled and unskilled trained Malagasy labourers.

[21] This figure was generously provided with permission by the director of CNARP in 2005. Also accessed on May 14, 2011 at: http://www.abs-initiative.info/antsiranana_11-08_040.html

To guarantee success in very remote locations in Madagascar, the assembled team must race against time once a plant part is excised it begins process of decomposition where traces of rot could ruin whole samples. As such, these work teams can be organized even without the watchful presence of an ICBG administrator. Rather low-skilled and locally-hired collectors are deployed from regional botanical centres to carry out mass collection. Nothing encapsulates how disciplined the work teams are, more than these trained para-taxonomists (see also Waterton et al., 2013). The locally-hired collectors are mobile and extremely efficient labourers who, at low cost, are trained in plant collection and sufficient botanical knowledge to identify and collect true herbarium specimens at a rapid pace.

Table 1 about here

Although not a large collection team relative to other scientific or commercial expeditions, what it lacks in numbers it makes up for in efficiency and optimisation of local skills and experience. For example, the collection of flowers on larger trees can entail a dangerous 12-metre climb. The local-hired collector, Floris, is usually charged with the job. He described how he became skilful at climbing trees, "[I]... used to work at a *rum-coco* factory. Normally we put grooves in the tree to make it easier to climb, but if you make grooves then people will steal, so I had to learn how to climb without them."[22] Essential as well in this regard are the large number of porters hired to transport fresh material from the forest to the main road and base camp, eventually making their way to regional herbariums or to the capital for drying. "To be a porter you must be mature and strong, so you can handle the work of carrying and guarding the material…"[23] To make sure no time is wasted; porters are selected and given their directives way in advance of collection. For

[22] Anonymous interview (March 4, 2006).
[23] Anonymous interview (March 4, 2006).

the most part, they are hired for their ability to carry the material. Although sometimes questions do arise as to the names and locations of particular species, their knowledge has become secondary to their main task keeping the material moving toward the drying stations at CNARP where they will be made into chemical extracts for export.

The team's specialised division of labour is quite important to achieve this goal. As the manual workers assume the hard physical labour tasks, the para-taxonomists and taxonomists focus on specialized herbarium identification and collection, thus increasing the overall value of the mission. With each bioprospecting sample collected (1 kg. of each: bark, roots, wood, leaves, fruit/flowers) five "true" voucher specimenswith all of the morphological parts of the plant represented are also taken and prepared on site. Each specimen is sent to each of the botanical repositories' herbariums, including the National Museum in Paris and to MBG's headquarters in the US. This highly specialised task, once reserved for the lead botanist, is now also conducted by localised trained para-taxonomists. This important task satisfies two functions for the ICBG, it identifies a species so that if bioactivity is later found, scientist can identify species and thus avoid any of the very costly mistake of replication (identifying compounds already discovered), and secondly, it helps the ICBG find new species and build up their systematic botanical collection databases, the biodiversity inventory.

One day, Robert, a head Malagasy chemist in CNARP, was speaking about his bioprospecting samples collected up north. Sitting in his laboratory surrounded by outdated glassware, centrifuges, flow-hoods, and chromatography machines, Robert walked over to a refrigerator, lifted the cover, and pulled out six four-inch glass tubes filled with a dark brown and deep-green grainy liquid. "Here, these may be them. These are the extracts made from the plants which are now ready to ship to laboratories in the US"[24] When asked about how the material would be sent to the US, he pointed to a cardboard box with the distinctive marking of a global courier company and said, "it's actually quite easy." He went on to explain that since these chemical extracts are not subject to the same strict rules of phytosanitation as other biological material, such as live plants, the ICBG can ship thousands of extracts at a fraction of the cost.

However, these tubes were quite distinctive in other ways. Each held a mixed alphanumeric code which was a new identifier of the plant material. The codes, Robert explained, provided a way for ICBG administrators to communicate without divulging any information about the plant material which could be by anyone in the email chain for individual commercial gains. This shroud of secrecy, very common in the practice of bioprospecting, reflects how far abstracted the plant material has become from both the forest site it was collected and those scientists who collected it. The codified chemical extracts help to standardise biodiversity so that economic metrics can be calculated and decontextualized from any "untidy" cultural or social attachments to collection locations (Parry, 2004: 388).

These samples are not devoid of conservation politics, however. They are, in fact, relics of the hard work that went into making them. After trained chemists package the extracts for shipment, they must wait to receive results from the labs in the US. Malagasy scientists who, without the proper materials (i.e., chemicals, stable electricity or lights and/or heavy spectrometry equipment), remain at times literally, "in the dark," (due to electricity shortages) and effectively in subordinate positions as support staff to their US counterparts. A leading Malagasy chemist in the ICBG:

> …for the time being, our laboratory is not able to identify molecules, so we need to send the extract to Virginia-Tech and they do the identification. It has always been like that.

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[24] Anonymous interview (April 10, 2007).

> So for now, this [the ICBG] is the only way to get funding and also to reinforce our capacity to do research.[25]

Robert, who is a leading medicinal chemist in Madagascar, was transformed into a low-wage laboratory technician whose main purpose was to fabricate and ship-off chemical extracts to high-tech screening labs in the US. Because of this, other Malagasy scientists accused him of "selling out" the country's biodiversity (Neimark, 2012a).[26]Indeed, in many ways Robert and other Malagasy scientists did just that. They rewarded foreign groups' access to their forests with control over massive amounts of biodata. Through the coordination of scientific labour funded through bioprospecting dollars for chemical extracts, MBG piggy-backed onto the process and green grabbed highly-valuable taxonomic data that it could use, not only in publications, but also to produce metrics that establish biodiversity offsets for multi-national extractive industries.

5. (Re)mining the Biodata: Indexing, Baselines, and Auditing

While the majority of the literature surrounding the practice of bioprospecting and market conservation hasweighed heavily on the politics of benefit-sharing indrug discovery, much less focus has been placed on the collection of herbarium specimens.[27]As we demonstrate in this section, herbarium samples collected and controlled by MBG's access to vital knowledge, technical expertise, and the authoritative cloutto transform the organization into a significant "third party" green auditor and a major player in the emerging voluntary certification economy associated with biodiversity offsetting (Banabou, 2014).

A vivid example of MBG's scientific authority and green certification power includes its repurposing of biodata to build biodiversity indexes, baselines and audits for two large mining

[25] Anonymous interview (Jan. 19, 2006).
[26]Anonymous interview (Sept. 8, 2006).
[27] Exceptions see: Parry's 2000; Waterton et al., 2013.

projects: 1) the Rio Tinto/QMM ilmenite mining project in Southern Madagascar; and 2) the Sherritt nickel and cobalt mine in Eastern Madagascar called Ambatovy. To illustrate their commitment to conservation through net positive impacts, Rio Tinto commissioned MBG and other groups, such as the Smithsonian, to create an inventory of the southern littoral region, entitled, *Biodiversity, ecology and conservation of littoral ecosystems in Southeastern Madagascar, Tolagnaro* (*Fort Dauphin*) and the supplemental publication, *Forecasting the path towards a net positive impact*.[28] The aim of establishing these offset baselines is to eventually promote their high extractive work as having "no net loss" and, preferably, a "net gain" on any biodiversity measured prior to mining operations (BBOP, 2012). MBG developed plant baseline studies for both projects drawing on their vast herbarium databases and scientific authority status helped create the currencies needed to demonstrate "net positive impact." For these mining companies and their conservation partners, fixed metrics of biodiversity can be counted and audited as offset currencies, and species not accounted for translated into potential currency lost. According to the BBOP literature, currency is defined as:

> … the unitary measures of biodiversity lost, gained or exchanged. This varies from very basic measures such as area, to sophisticated quantitative indices of multiple biodiversity components which may be variously weighted….[29]

To develop legitimacy, biodiversity offsetting schemesrequire teams of scientific "experts,"renowned in their field, who can measure the impacts (Banabou, 2014). For example, MBG's role, alongside international and in-house scientists in the Ambatovy site, is to identify "priority species," or "species of distinct classification due to taxonomic interest, rarity, or possible endangerment" which can be held up as a direct example of the "development of taxa-

[28] All of this sustainable action follows the standards set by the Business and Biodiversity Offsetting Program (BBOP, 2012a).
[29] BBOP 2012b accessed on October 12, 2013 at www.foresttrends.org/biodiversityoffsetprogram/guidelines/glossary.pdf

specific mitigation measures" (BBOP, 2012: 31). The most evident examples of such mitigation under mining offsets is MBG's work on the baseline listing of "species of concern" or selected flora targeted for mitigation. MBG and their scientific labour teams are charged with auditing the current inventories, and setting them alongside previous species baselines (many of which have been done over the past twenty five years of operations).[30] Without these specialized inventories, and more importantly MBG brand's "stamp of approval" as the leading botanical scientific and now essentially auditing team, the mining company's offsets run the risk of legitimacy and could potentially have their mining permits pulled by government ministries without being monitored and observed for environmental impact. Rio Tinto and Sherritt's access to these sites is dependent on partnerships with such entities as MBG, as the Malagasy government requires environmental impact assessments to be conducted around mining sites (Freudenberger, 2010; Henkeles, 2001).[31] MBG's authoritative status, other scientific agencies, helps to provide this assurance to the Malagasy state and that of the wider conservation community.One can witness the certification process in speculative descriptions of restoration and creation of newlyreforested sites at Sherritt's Ambatovy (see Table 2):

> The mine restoration programme includes progressive footprint rehabilitation through erosion control, reforestation with targeted species and facilitated secondary successions. The aim is to produce a multifunctional replacement forest with biodiversity values that can be included in the offset calculation (by reducing the residual impact on biodiversity that will require offsetting)…

As we described earlier, MBG's abilityto produce and certifybiodiversitywas actually originally established on the historical labour of Malagasy scientists at national research agencies, such as CNARP. Because the Malagasy state agencies, in previous and iterative scientific expeditions,

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[30]Another prime example of MBG and Kew servicing their expertise can be seen in Rio Tinto's Mitigation handbook, "Forecasting the path towards a Net Positive Impact on biodiversity for Rio Tinto QMM" (Temple et al., 2012).
[31]Ambatovy's EIS was approved in 2006.

only served as a coordinator of scientific labour for the collection and processing of biodiversity, they did not maintain full control over the biodiversity inventory conducted within its territory. MBG's control over the inventoryenables it to certify(approve or disapprove) Rio Tinto and Sherritt's actions.[32]Moreover, through this process, they alongside other certifiers effectively produce a new language of biodiversity, including some of the concepts shown above: "progressive footprint rehabilitation" (returning nature to a "native" state) "facilitated secondary successions," (enabling the establishment of new flora and fauna communities) "multifunctional replacement forest" (mixed forest tree reforestation). In other words, new abstract conceptualizations of biodiversity and the repairs made through offsets fetishizethe economic value extracted by MBG and mining companies(Goodman, 2004).

Table 2 about here

Today, the MBG is arguably the leading player in a large consortium of world-renowned international scientific groups, such as the Flora and Fauna International and Kew Botanical Gardens.[33]For MBG to arrive as the authoritative body on Malagasy biodiversity (see table 3), however, was by no means an easy task. It was created through hard work. Yet, as we argue, these labour processes, and the previous accumulation strategies that they served (i.e. bioprospecting) are quickly disappearing into the rear-view mirror as trends in conservation

[32]While MBGs consultancy work is not public, an estimated cost structure of Offset Process Costs was made by the Ambatovy BBOP Pilot Project which estimated that the average operational costs are estimated within the range of $250 – 300,000 per year for activities, including technical peer-review, conducting benchmarks and ecological assessments (BBOP, 2013).

[33]While research offsetting in Madagascar is beginning to emerge (Banabou, 2014; Seagle, 2012) up to this point little work has been done on the comparison of scientific institutions role in the certification economy. Our focus here has mainly been on MBG due to their historical importance in bioprospecting and plant collecting, however, there are other institutions which warrant similar investigation and comparative analysis to see generalizability of surplus value appropriation strategies among other herbaria and/or botanical gardens in Europe and North America.

interventions scale-upto large-scale offsetting strategies (see also Ferguson, 2009).

Table 3 about here

Two big winners emerge with MBG's ownership of the biodiversity inventory. One is the multinational who is able to package their work as "sustainable" under the supervision of high-quality science conducted by the most-well respected researchers in the field. Beyond the more obvious benefits of positive public relations and enhanced investment portfolios, having the world's leading scientists as partners provides mining corporations in Madagascar with the necessary "green" cover to gain, maintain, and control access to resources. A second big winner is the contracted non-profit research institution, like MBG, is provided ample funding to maintain a research presence. Private research institutes are now able to tap into the extra funding as entrepreneurs in their approach to scientific research. What is less spoken about are the losers in this process, how the state, most namely its national research institutions such as CNARP and the many scientific labourers which helped to build the inventories themselves, are generally left out of the process of green certification. CNARP has become, for all intents and purposes, a low-wage and low-skilled processing unit for the ICBG, rather than a national research centre managing the biodiversity inventories, chemical analysis and conducting certification of its own biodiversity.

6. Conclusion: Selling Expertise, Servicing Industry in the New Certification Economy

If biodiversity conservation in the tropics began with the iconic image of barefoot doctor finding miracle drugs from plants in the rainforest, then a new image of market-conservation might be that that of botanical gardens as new biodiversity currency traders in the green economy.As this paper shows, plant collection is hardly a benign activity of scientific exploration; rather it is a commercially-led scientific practice which produces highly politicised ecological and social spaces (Parry, 2004).Proponents of market-based conservation initiatives hold that nature is a repository of inestimable value that must be transformed into usable metrics for market exchange if we are going to have any chance to protect it from ecological destruction. Biodiversity's value is, as Sullivan sees it, "...built on increasing the visibility of nature to capitalism" (2013b). As we have demonstrated in this paper, scientific and non-scientific labour and knowledge is critical in this regard (Sodikoff, 2012).This labour is funded, in large part, for processing chemical extracts used in drug discovery. Many of those involved see their work as apolitical scientific metrics and measurements, used for the greater good of biodiversity conservation. However, this scienceof producing biodiversity is done in a context of highly unequal political-economic relations.The biodiversity inventory that is controlled by MBG and which gives the private institution its quasi-diplomatic status is, we argue, a product of the labour of scientific teams composed of skilled and unskilled labourers from porters to lab technicians. These labour assemblages, which worked towards for drug discovery and biodiversity inventories simultaneously, have now been subsumed into MBG's authoritative status as a green economy certifier. The paradox here is that under bioprospecting, collection work was originally conducted under the guise of sustainable "low impact" plant collecting it is now being repurposed for certifying highly extractive mining operations.

MBG is not alone. A host of other collection institutions have accumulated biodiversity inventories through iterative market-based conservation strategies in which private research institutions, NGOs and multinational corporations forge strategic partnerships (Corson, 2011). The valuable species diversity generated by the hard work of rural labourers and Malagasy scientists in collecting and processing the material in biodiversity inventories is ultimately appropriated and transferred elsewhere. As multinational corporations like Sherritt and Rio Tinto pursue extractive investments in Madagascar, they continually turn to MBG and other foreign institutionsto lend them their green authority. This raises a host of critical questions about the "double fetishization" (Goodman, 2004) of plant material and the justice questions behind the veils of biodiversity offsets. From the beginning, bioprospecting has been bombarded with questions of distributive within benefit-sharing agreements (Hayden, 2003; Neimark and Tilghman, 2014). Yet, there is little accountability for their re-use under offsetting. Whose job isthen to certify the certifiers?

Moving forward, we argue that political ecologists and critical geographers remain well positioned to challenge the rise of biodiversity offsetting (Banabou, 2014; Seagle, 2012). Political ecology's concerns of variegated forms of power and contestation over resource access and control, and attention to international institutions of environmental governance has provided scholars with an important lens through which to expose the circulation of nature for profit in market-conservation (Büscher, 2014; Sullivan 2013a). Our focus on the production of biodiversitycontributes to recent studies on political ecology and green grabbing and can be used as a model to critically analyse other market interventions, includingReducing Emissions from Deforestation and Forest Degradation(REDD+), and payments for ecosystem services. It is through such empirical studiesthat scholars can continue to do the important work of identifyingthe role of scientists as powerful political actors in creating market-conservation metrics and better understand the historical and structural power relations within and among scientific institutions.

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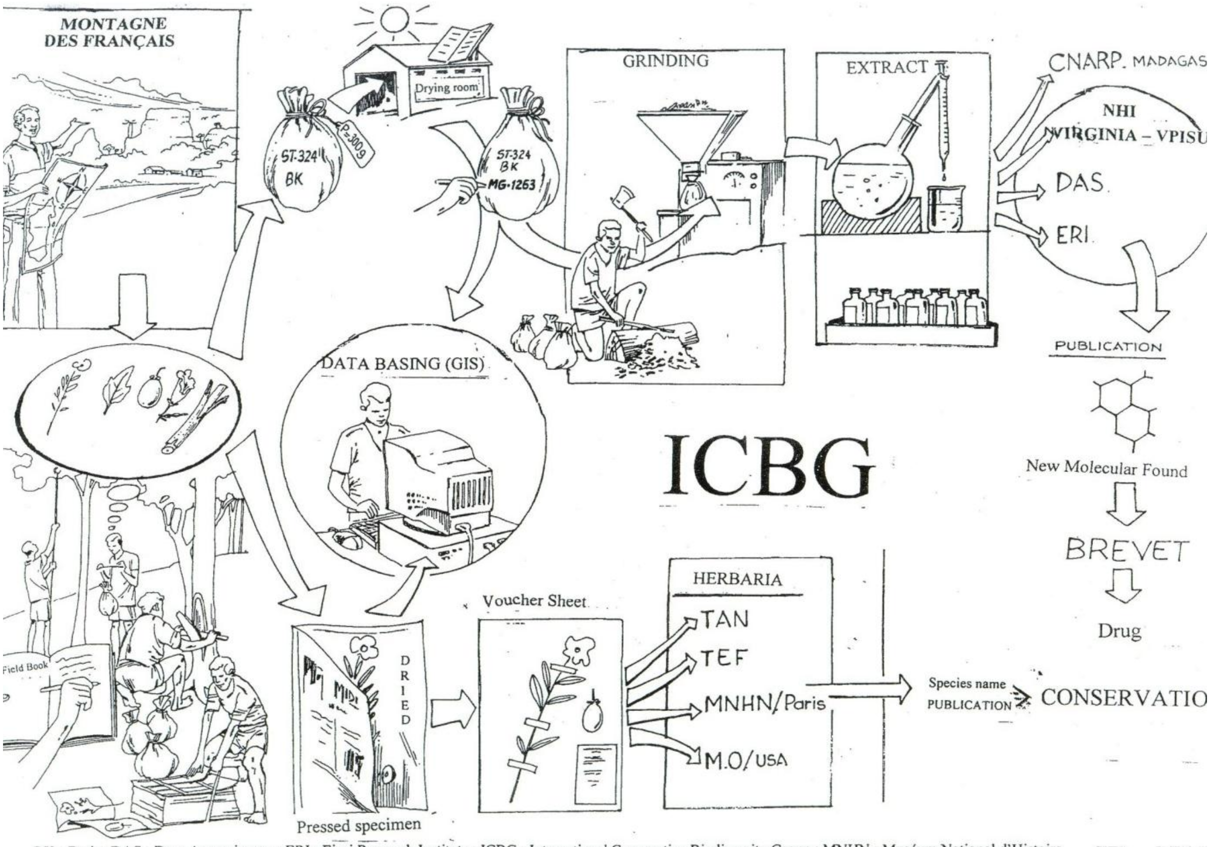
Figure

Table 1: Assembled labour force used in collection team[1]

Job title	*Number of individuals included*	*MBG;CNARP; Malagasy/foreign scientist/local hire*	*Main work tasks*
Systematic field botanist	2-3	MBG/CNARP	Directs the specialized collections of herbarium voucher specimens
Field botanist(s)	2	CNARP	Malagasy – tags/codes collection bags; collects location and ecological data - i.e., field pictures; ecological/location/GIS coordinates
Field specialist	1	CNARP	Tags/weighs collection bags
Specialist botanist	2	MBG	Charged with special collections – i.e., mosses, lichens, or recollections of specific taxa
Para-taxonomist	2-4	MBG	Tasked with organizing the bulk collection of herbarium specimen within a region
Local guide(s)	1-3	Local hire commune centre	Liaison between local communities
Cook/guard(s)	1-2	Local hire at village	Prepares meals and guards the base camp
Porters	6-8	Local hire at village	Carries bags to base camp and samples/specimens from collection site

[1] Data was collected on two successive bioprospecting field trips in 2005, and follow up interview with bioprospecting teams in 2006/7.

Figure 1: ICBG image describing the work done in the bioprospecting commodity chain



BK : Bark ; DAS : Dow Agrosciences ; ERI : Eisai Research Institute ; ICBG : International Cooperative Biodiversity Group ; MNHN : Muséum National d'Histoire Naturelle ; MO : Missouri ; NHI : National Health Institute ; TAN : Parc Botanique et Zoologique de Tsimbazaza ; TEF : Département des Recherches Forestières et Piscicoles ; VPISU : Virginia Polytechnic Institute and State University

Table 2: List of mining project conservation offsetting and rehabilitated sites

Mining project	***Conservation offsetting and rehabilitated sites***	***Total ha***
Sherritt Ambatovy[1]	Azonal forest	306
	Conservation Zone	3,338
	Total Ankeranaazonal and zonal forests	5,715
	Corridor Forestier Analamay-Mantadia (CFAM)	7,269
	Torotorofotsy forests	3,876
RioTinto QMM[2]	Avoidance Zones (Mandena, Petriky and Ste Luce)	624
	Rehabilitation and restoration	225
	Biodiversity conservation offset	6000

Source: [1] von Hase et al 2014; [2]Temple 2011

Table 3: Table of major offsetting programmes and scientific groups

Offset programme	***International Environmental Organization or Institution***	***Major mining company***	***In-house or contract scientific team***	***Knowledge adopted or constructed***
QMM Mine Biodiversity Strategy	Conservation International, Fauna and Flora International, Kew Royal Botanical Gardens, **Missouri Botanical Gardens**, World Conservation Society, World Wildlife Fund	RioTinto Int.	Contracted	Botanical and ecological inventories
Ambotovy Mine Offseting Program - BBOP	Conservation International, **Missouri Botanical Gardens**, World Conservation Society, Henry Doorly Zoo	Sherritt Int.	In-house & contracted outside	Botanical and ecological inventories

*Highlights

Research highlights

Critical historical analysis of bioprospecting and biodiversity offsetting.
A less studied output of bioprospecting are mass botanical herbarium collections.
We trace the bioprospecting collections now digitized for biodiversity offsetting metrics.
We examine labour in re-mining bioprospecting biodata for market legibility.
Scientific institutions develop unevenly under market-based conservation.

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