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Horses as Sources of Proprietary Information: Commercialization, Conservation, and Compensation Pursuant to the Convention on Biological Diversity

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Horses indigenous to East and Southeast (E/SE) Asia, including native, landrace, feral, and wild populations, embody valuable genetic diversity. Conservation efforts for animals have largely been driven by humane altruism, with little consideration for the information value of genomes. Yet, if horses are viewed as archives of information as well as objects of affection, their conservation shifts to a market-based paradigm. Horse genetic resources (GR) likely contain significant value to the lucrative global horse industry, including veterinary applications such as diagnostics, therapeutics, genetic markers, gene therapies, and cloning technologies. As biotechnology becomes increasingly sophisticated, mining of horse GR will accelerate, thus facilitating identification, inventorying, bioprospecting, and commercialization of genetic information. Yet, establishing a value chain that balances equitable compensation for commercial applications while promoting conservation of horse populations remains a challenge. Recommendations presented here include establishing regional and national human resource and institutional capacity (competent national authorities), that catalog eco-geographical inventories of horse GR; monitor, manage, market and direct equitable value chains from horse to genetic information to commercial products; and ensure revenue flow back to support conservation. This system will foster market incentives to build capacity for sustainable conservation of the diverse horse populations of E/SE Asia.

Key words: access and benefit sharing, biodiversity, biotechnology, bioprospecting, capacity building, developing countries, Convention on Biological Diversity (CBD), genetic resources, horse, intellectual property, Przewalski's horse.

Introduction

The global horse industry is a multibillion-dollar global concern. In the United States alone, the total economic impact of the horse market, including racing, showing, and recreation, was \$102 billion in 2005, providing jobs and products for breeding, training, and maintenance (American Horse Council, 2005). However, because of stringent breeding practices, many horse breeds have lost genetic diversity, accumulated genetic mutations (Petersen et al., 2013a, 2013b), and are afflicted by genetic diseases (Finno, Spier, & Valberg, 2009; see Table 1). Indigenous horse populations of East and Southeast Asia (E/SE Asia; native, landrace, feral, and wild; see Table 2) are genetically diverse. This includes the only surviving wild population, the Przewalski's Horse (Lau et al., 2008; Figure 1). As such, they are a potentially valuable resource for the global commercial horse industry.

The Convention on Biological Diversity (CBD)—“whose entry into force in 1993 contributed to ... establishing state sovereignty over biological and

genetic resources” (Vezzani, 2010, p. 678)—seeks to conserve genetic resources (GRs) via an access- and benefit-sharing (ABS) regime that envisions a systematic, equitable, and workable balance between conservation and use of GRs, including commercialization of products flowing from GRs. ABS should ideally facilitate developed countries' access to developing countries' GRs, including fair compensation with monetary and non-monetary benefits, thereby encouraging conservation (ten Kate & Laird, 1999). However, few E/SE Asian countries, albeit parties to the CBD, have implemented ABS measures, largely due to insufficient infrastructure and lack of financial and human resources (Vivas-Eugui, 2012).

While most GRs bioprospected from developing countries have been from microorganisms and plants, biotechnological advances now enable similar applied utilization of animal GRs for research and development of commercial applications (Gollin & Evenson, 2003; ten Kate & Laird, 1999). The fundamental principles of

Table 1. Genetic diseases of the horse.

Genetic disease	Breeds affected	Gene name	Inheritance pattern	Population affected	Population of carriers
HYPP	Quarter horse	SCN4A	Semi-dominant	4%	56%
HERDA	Quarter horse	PPIB	Recessive	Unknown	Cutting lineages 28%
GBED	Quarter horse	GBE1	Recessive	Causes foal death	8.30%
	American paint horse				7.10%
LWFS	American paint horse	EDNRB	Semi-dominant	Causes foal death	Tobiano 94%
	Quarter horse				Other paint stock 21%
SCID	Arabian	PRKDC	Recessive	0.18%	8.40%
JEB	Belgians	LAMC2	Recessive	Causes foal death	17-27%
	Other draft breeds				
CSBB	Appaloosas	TRMP1	Recessive		
PSSM	Quarter horse	GYS1	Recessive	Unknown	6%
	Belgians				36%

Sources: Finno et al. (2009); McCue et al. (2012); Horse Genome Project (2011)

Table 2. Representative horse breeds in East and Southeast Asia.

Country of origin	Horse breed	Scientific taxonomy	Wild/feral/native
China	JinJiang horse	<i>E. caballus</i>	Native
	Lichuan horse	<i>E. caballus</i>	Native
	Debao pony	<i>E. caballus</i>	Native
	Baise horse	<i>E. caballus</i>	Native
	Guizhou horse	<i>E. caballus</i>	Native
	Luoping horse	<i>E. caballus</i>	Native
	Yili	<i>E. caballus</i>	Native
Japan	Misaki horse	<i>E. caballus</i>	Feral
	Miyako pony	<i>E. caballus</i>	Native
	Noma pony	<i>E. caballus</i>	Native
	Hokkaido pony	<i>E. caballus</i>	Native
	Yonaguin horse	<i>E. caballus</i>	Native
	Takora horse	<i>E. caballus</i>	Native
	Kiso horse	<i>E. caballus</i>	Native
Mongolia	Przewalski's horse	<i>E. przewalskii</i>	Wild
	Mongol horse	<i>E. caballus</i>	Native
Cambodia	Cambodia pony	<i>E. caballus</i>	Native
Indonesia	Timor pony	<i>E. caballus</i>	Native
	Batak pony	<i>E. caballus</i>	Native
	Bali pony	<i>E. caballus</i>	Native
	Gayoe	<i>E. caballus</i>	Native
	Deli pony	<i>E. caballus</i>	Native
	Java pony	<i>E. caballus</i>	Native
Thailand	Lampang pony	<i>E. caballus</i>	Landrace
Vietnam	Vietnamese	<i>E. caballus</i>	Native
	hmong horse		
Eurasia	Tarpan	<i>E. ferus</i>	Extinct wild horse

Sources: Miller (2009); International Museum of Horses (2010); Ling et al. (2010); Obata et al. (1994); Lampang Pony Welfare Foundation (n.d.); Jansen et al. (2002)

plant GRs are applicable to animals. Development of research and data are needed, however, to facilitate and manage value in animal GRs (Gollin & Evenson, 2003). Over the past decade, this concept has been reiterated:

“a critical component of agricultural biodiversity is knowledge, including ... scientific knowledge. This aspect of ... livestock biodiversity has not been raised, most likely because there is little applied work on the topic. Economics concepts could be applied to investigate the value of information about genetic resources and their diversity” (Drucker, Smale, & Zambrano, 2005, p. 59).

To examine the concept of animal GR utilization pursuant to the goals of the CBD, an ideal model system that exemplifies and illustrates conservation, commercial value, and informational assets is the horse.

We propose here an ABS system for coordinated utilization and conservation of horse GRs from E/SE Asia, a concept that can be extended to other animal GRs. This ABS system includes building human resource and institutional capacity (e.g., competent national authorities [CNAs]) that catalog eco-geographical inventories of horse GRs. CNAs can also monitor, manage, market, and direct equitable value chains from horse to genetic information to commercial products, and certify revenue flow back to support conservation. An important aspect of the proposed management system is consistent maintenance and tracking of proprietary rights to the genetic information that the horse embodies. As such, this conservation scheme considers the horse as a repository of proprietary information that imparts value and promotes

conservation, as distinguished from conservation paradigms motivated by humane sentimentality and altruism, e.g., giant pandas in China.

The Horse

There are approximately 500 breeds of domestic horses. Selection and concentration of desired traits in horses fulfill specific requirements: work, sport, or companionship (Petersen et al., 2013a, 2013b). These can easily be visualized in breeds such as the Friesian, whose size and strength allowed knights in heavy armor to be carried easily but also contained the fine bone structure required for speed; this is contrasted with the Shetland Pony, whose small but hardy frame was required to pull carts through mine tunnels (The Friesian Horse Society, n.d.; Johnson & Johnson, 2008). Five thousand years of artificial selection has redefined, focused, and narrowed the equine genome. To perfect and maintain the purity breed, most breed associations restrict registry to only those animals that meet requirements and prohibit admixture from breeds outside their registry. Such selection pressure has led to polarities of genetic diversity (McCue et al., 2012).

As a whole, the global horse population retains genetic diversity, but this varies depending upon geographic origin as well as how recent a new breed was cleaved from its ancestors (Petersen et al., 2013a, 2013b). Within many breeds, centuries of heavy selection pressure has decreased genetic diversity (Petersen et al., 2013a, 2013b). For example the Thoroughbred, which descended from 30 horses (27 sires and 3 dams) has lost 16.3% heterozygosity (McCue et al., 2012; Thiruvankadan, Kandasamy, & Panneerselvam, 2009). Ironically, inbreeding, although exerting high selection pressure for speed for over 300 years, has not yielded a significant increase in overall speed (Thiruvankadan et al., 2009). However, heavy and relentless selection pressure has affected many horse breeds' ability to survive a bottleneck event, decreased fertility, and attenuated viability (Juras, Cothran, & Klimas, 2003).

Originally domesticated 5,000 to 6,000 years ago, wild horse populations once roamed much of the Eurasian steppes (Petersen et al., 2013a, 2013b; Warmuth et al., 2011). E/SE Asian indigenous horses are repositories of valuable genetic diversity. Numerous traits have been exploited to develop many of the world's 500 unique breeds. Founding horse populations contained a wealth of genetic diversity. However, because of artificial selection and loss of most of the wild populations, this pool of diversity is disappearing (McCue et al., 2012),



Figure 1. Przewalski's horse (*Equus przewalskii*, also known as Mongolian ass, Asian wild horse, Mongolian wild horse, and takhi) is the last remaining true wild horse. Several reintroduced herds survive in Mongolia.

Photograph courtesy of Geoff Simpson/NaturePictureLibrary.

with a concomitant loss of potential value to the global horse industry. For example, surviving horse GRs include the wild Przewalski's Horse (*Equus przewalskii*; Figure 1), which has been conserved; there are more than 1,500 animals worldwide and 300 reintroduced into its natural habitat, Mongolia (Lau et al., 2008). Despite its two additional chromosomes, it is closely related enough to the domestic horse (*Equus caballus*) to produce fertile offspring. However, the extinct wild horse of Eurasia, the Tarpan (the last Tarpan died in 1909), is a source of genetic diversity that has been permanently lost (Jansen et al., 2002).

The domestic horse falls into three genetically distinct breed categories—native, feral, and landrace (Petersen et al., 2013a, 2013b). Native breeds are designated according to origination from a specific region (e.g., the Yili, a relatively recent breed known for speed and endurance, was developed in China in the early 1900s by crossing Russian stock with other Chinese native breeds; Ling et al., 2010). Feral breeds can trace their lineage to domestic horses that escaped or were released; whereas propagated via natural selection, they retain specific traits (Csurhes, Paroz, & Markula, 2009). Little is known genetically about the native and feral horses of E/SE Asia, possibly due to poor access to samples (Miller, 2009). The only known feral breed in E/SE Asia is the Misaki Pony found in Japan, which originated from Chinese horses released in Japan almost 2,000 years ago (Obata, Takeda, & Oishi, 1994). Landrace breeds have high genetic diversity as well as a series of traits that enable them to survive varying conditions (McCue et al., 2012). The Lampang Pony of Thailand is a landrace breed that, despite being in an

environment where communicable diseases abound, suffers little infection. Genetic testing suggests Przewalski's Horse may be an ancestor of some landrace breeds (Carleton, 2008).

Strict breed regulations through registration and breed associations' efforts to "breed true" have likely decreased genetic diversity (McCue et al., 2012) and increased population frequencies of detrimental alleles. It has also contributed to genetic disease expression (Bannasch, 2008; Barakat, 2013; Finno et al., 2009) such as hyperkalemic periodic paralysis (HYPP), severe combined immunodeficiency (SCID), lethal white foal syndrome (LWFS), congenital stationary night blindness (CSNB), junctional epidermolysis bullosa (JEB), glycogen branching enzyme deficiency (GBED), hereditary equine regional dermal asthenia (HERDA), and polysaccharide storage myopathy (PSSM).

Horses as a Genetic Resource

Due to the lower biological and physical requirements for bioprospecting, sample collection, and subsequent processing, most GR access and utilization has focused on plants and microorganisms (Deke, 2001; Gollin & Evenison, 2003). However, as with the pharmaceutical, botanicals, and agricultural industries, the potential application of GR-derived biotechnology to the horse industry is linked to the underlying value proposition (e.g., see Kesling, 2013). This value proposition is driven by advances in biotechnology that facilitate cost-effective mining of the horse genome.

Genetic research on horse populations is ongoing and increasing in sophistication—in Canada, the Native Mountain, Moorland, and Nordic pony populations (Juras et al., 2003), and in Italy and Brazil for equine diversity (DeAssis et al., 2009; Stasio, Perrotta, Blasi, & Lisa, 2008). Subsets of horse breeds have been genetically tested to determine diversity of the species and within specific breeds (McCue et al., 2012), along with genome-wide analysis of breeds (Petersen et al., 2013a, 2013b). Analysis of complex genomes has become economically feasible (Service, 2006). The Horse Genome Project has mapped the Thoroughbred genome and identified specific genes (e.g., speed capability), thereby providing a research tool for a multitude of ailments as well as other applications that could directly influence the horse market (e.g., cloning of polo ponies; Adelson, 2012; Horse Genome Project, 2011). The Horse Genome Project has facilitated an equine single-nucleotide polymorphism genotyping array, which identifies genes for health, performance traits, genetic diversity,

origins of the domestic horse, and equine evolutionary patterns (McCue et al., 2012). There has been a corresponding increase in genomic patents relating to equines, e.g., identification of grey alleles (associated with side effects including increased susceptibility to skin cancer; US Patent No. 8278043) and screening for CSNB, a congenital disease that is linked to the leopard appaloosa coat pattern gene (US Patent App. No. 20130112152A1).

Indigenous E/SE Asian horse populations are a likely unutilized source of GRs that could provide benefits to the country of origin, researchers and the global commercial horse industry. As the tools of genetic analysis and biotechnology advance, the feasibility of utilizing these untapped GRs increases, for example, cloning and genetic modification of domesticated breeds (e.g., genetic engineering of Przewalski's horse genes into polo pony clones; Adelson, 2012). Hence, as horse genome research advances, accessing, developing, and commercializing GRs from indigenous horses could become an economically viable enterprise with broad and equitable benefits, but only if effectively managed and regulated. Over a decade ago, Deke (2001) predicted such a convergence of factors, i.e., that

“the scarcity of genetic resources is rising as demand for them increases due to current advances in biotechnology, while at the same time availability decreases as genetically diverse organism become increasingly extinct. In this circumstances, a linkage between commercialization and the conservation of biodiversity as proposed by the Convention of Biodiversity may succeed ... [that] commercialization of genetic resources may ... represent a means to create incentives for withholding natural areas from conversion” (pp. 24, 26).

The Convention on Biological Diversity

The CBD provides the policy and practical basis for equitably balancing conservation and commercialization of horse GRs. Article 15 of the CBD provides guidelines to signatories on ABS of GRs, i.e., a system where host countries facilitate appropriate access to GRs to other actors and in return receive some benefit (Montreal Ministry of Sustainable Development, Environment and Parks, Centre for International Sustainable Development Law, 2008; ten Kate & Laird, 1999). Ideally, ABS operates as a quasi *quid pro quo* system, where the developing, primarily tropical, mega-biodiversity coun-

tries provide GRs to the developed countries which then transform the GRs—via biotechnology and other technical inputs—into commercial products (Lesser, 2000); this system should entail reciprocal protection of property rights and equitable sharing of value derived from GRs. However, in practice ABS has not been readily implemented; developing countries face many challenges, such as weak government infrastructure, inadequate investment in capacity building, and lack of awareness relating to GR value and management (Thornstrom, 2007). Perhaps this is ironic, as this need has been echoed and reechoed. Indeed, nearly two decades ago, Lesser (1998, p. 196) noted that “[v]irtually all knowledgeable observers from inside and outside the CBD, governments, companies, and the NGO community recognize the need for *capacity building and funding*.”

Adopted in 2002 as a non-legally binding addition to the CBD, the Bonn Guidelines on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising out of Their Utilization (Bonn Guidelines) are intended to establish ABS goals and requirements, encourage conservation, promote capacity building, and bridge the gap between nations that provide and those that bioprospect and utilize GRs (Thornstrom, 2007; Tully, 2003). Three components are necessary for an effective ABS system: prior informed consent (PIC), mutually agreed terms (MATs), and a material transfer agreement (MTA). PIC, the contract that articulates what the research project entails, is signed by all stakeholders (e.g., government agencies, owners of private property, and indigenous people) and ensures that all parties understand the scope of the agreement. MATs ensure fair and equitable sharing of benefits (Thornstrom & Bjork, 2007), including provisions of user and provider states, type and quantity of the GRs, limitations on use, access by third parties, and what provisions or benefits (monetary and non-monetary) might be shared if there is valuable utilization or derivatization of the GRs (Tully, 2003). MTAs include a definition of the material to be transferred, why it is being transferred, restrictions on how it can be used, cost of transport, start and termination dates, and mechanisms and procedures to address any breach of the agreement (Thornstrom & Bjork, 2007). As a progression of the Bonn Guidelines, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the CBD (Nagoya Protocol) was created and opened for signature in 2011; the Nagoya Protocol makes many of the provisions of the Bonn Guidelines legally enforceable, i.e., beyond the aspirational charac-

ter of much of the CBD (Kamau, Fedder, & Winter, 2010; Oliva, 2011).

The CBD stresses capacity building as a priority for ABS implementation. In this regard, the Bonn Guidelines encourage provider countries to create CNAs that coordinate and manage ABS (Tully, 2003) in order to incentivize conservation of GRs in a sustainable manner by equitably facilitating commercial access. However, for this to occur, developing countries must invest in ABS capacity building. This will enable equal bargaining power with reciprocal benefits proportional to GR that are bioprospected and developed commercially. In addition, countries that have such capacity will be better positioned to identify and manage intellectual property rights (IPRs), further enabling access to a greater share of potential value and benefits (ten Kate & Laird, 2000).

CBD ABS Systemic Challenges

Although outlined in the CBD and elucidated in the Bonn Guidelines (and legally strengthened in the Nagoya Protocol on ABS), the chronically unresolved issue for the CBD (and resultant intellectual property [IP]) is coherent ABS capacity building towards successful and sustainable simultaneous use and conservation of GRs (Oliva, 2011; Tully, 2003). Most countries have not attempted to implement ABS obligations, and where implementation appears to have been pursued, actual operational efficacy is, at best, questionable (Wynberg & Laird, 2009). Indeed, despite 193 party states having ratified the CBD, only about 60 have any form of ABS measures in place, and fewer have coherent policy implementation (Vivas-Eugui, 2012). ABS system implementation becomes even more critical when considering potential downstream IPR (Tully, 2003); IPR might be either an impediment or incentive to effective and equitable ABS depending on management capacity and capability. Hence, a preoccupation with litigation of IP related to GRs (e.g., via attempts to invalidate patents that allegedly embody biopirated GRs or other unsustainable GR “management practices,” such as expensive legal actions to pursue biopirates) should be balanced with a workable system that uses IP management as a tool for lowering the transaction costs of ABS. In other words, use IP as a means to facilitate transfer, development, and commercialization in addition to being a mechanism for legal action. However, the ABS system has been largely stymied by an “absence of adequate national regulatory clarity and institutional capacity” (Harvey & Gericke, 2011, p. 333), thus per-

petuating onerous transaction costs leading to market failure.

Since its signature by 150 government leaders at the 1992 Rio Earth Summit, steps to implement the CBD's ABS provisions via establishment of CNAs have been overshadowed, indeed smothered, by two decades of largely politicized, misinformed, dis-informed, and useless high-level policy symposia and summits that have been filled with discussions, but with little tangible capacity building. Forums have become platforms for divisive issues, distracting attention from ABS implementation and instead fomenting confusion and estrangement (Wynberg & Laird, 2009). As Lesser (2000, p. 49) observed over a decade ago, "four Conferences of the Parties of the CBD appear to have made little progress, and frustration appears to be increasing." Perhaps this is a paradigm problem, so that the issue needs to be recast. The esoteric policy dimension of previous discussions deflates when the CBD's ABS provisions are conceptualized as a process. The mundane business of establishing a workable system remains, and as with any system (e.g., plumbing, electrical, or transportation) a series of hubs, conduits, and connections need to be established in order to facilitate efficiency. However, as it currently exists, the CBD ABS system interfaces are riddled with gaps—science policy, knowledge, knowledge systems, assessments, communication, ownership, and capacity (Chabason & Van Den Hove, 2009).

In E/SE Asia, ABS implementation largely remains a work in progress. Among the first countries to have laws regarding biological resource access, the Philippines stands out in the E/SE Asian region with an implemented ABS system. MAT regulations are also quite developed (e.g., the minimum terms of an agreement on bioprospecting). Provisions include not only PIC but also royalty payments (CBD, 2013b). Japan's ABS measures are consistent with the CBD and Bonn Guidelines (Ministry of Economy, Trade and Industry, Japan & Japan Bioindustry Association, 2006). Aside from the Philippines (and to a lesser extent, Singapore, Korea and Japan), most countries of E/SE Asia are deficient as to implementation of ABS capabilities. China, a signatory to the CBD, has a rudimentary ABS system. Despite an apparent plethora of ABS somewhat specific policies, and related laws and regulations, there is little evidence that any substantial implementation has occurred (CBD, 2013a; State Council of the People's Republic of China, 2008). Preliminary CBD ABS measures in Malaysia, Thailand, and Vietnam—albeit encouraging—illustrate that there appears to be little effort to establish func-

tional ABS systems in this region, and implementation is (at best) still nascent (Southeast Asia Regional Capacity Building on Access and Benefit Sharing, n.d.).

Genetic Resources and the Value Chain

Strategic ABS systemization for GRs can overcome market failure by establishing "a market for biological diversity conservation that internalizes into a market transaction all the costs of the impacts of biological diversity destruction and decline" (Lawson, 2006, p. 138). As applied to this study, this suggests that assignment of value, property rights, and eventual commercialization of connected assets arising from horse GRs creates incentives for conservation of indigenous horses of E/SE Asia. The mechanism to facilitate this is the establishment and management of a system of property rights, clearly delineated, which extend from the tangible material of the horse to the final IP (e.g., invention) derived from there. In this way, the richness of information embodied in the horse, whether it is protein, nucleic acid-based, or other, can be accessed, valued, and utilized with compensatory benefits derived for all parties along the value chain. Furthermore, the GR must be conceptualized as both tangible material and the intangible information embedded therein. Hence, two forms of property rights are applicable—tangible (chattel) and intellectual (information). For example, tangible property rights can be applied to chattel (e.g., to blood, tissue samples, embryos); IP rights can be applied as trade secrets (genetic information protected as proprietary business information; Kowalski, 2007) or patented inventions (e.g., use of the nucleotide sequence of a gene).

However, GR utilization as raw material for advanced innovation has been fraught with market failure (i.e., underutilization of GR as an asset due to an inadequate system of property rights, institutional capacity, human capital, and management). This, in turn, leads to under or over valuation and destructive depletion of GR: "the private cost of using the environment does not coincide with its social cost. This effectively favors those uses that are non-sustainable from an ecological point of view" (Deke, 2008, p. 2). For example, the components of an ecosystem are consumed instead of conserved due to an inability to assign value and property rights, i.e., the case of a forest being clear cut instead of sustainably harvested for pharmaceutical compounds. In addition, this situation is frustratingly exacerbated because the tools for collecting and assaying GRs are increasingly sophisticated (genomics, pro-

teomics, metabolomics; Fridman & Pichersky, 2005), such that efficient and economical bioprospecting becomes systematic. Since each species (e.g., horses) can be viewed as a finite gene pool (a discrete library of information), irreversible erosion and loss of this information might occur even as the tools to access it become more refined, thus creating a situation that is simultaneously urgent and ironic.

The market failure quandary can be addressed by building integrated systems of property rights, which promote stable markets, coherent management, and predictable transactions. As Deke (2008, p. 4) notes, “by laying down a framework of property rights in biodiverse areas and the GRs hosted therein, the holder of the rights can receive sufficient revenues to forgo alternative, biodiversity-degrading land use and maintain natural areas as biodiversity habitats,” e.g., the possible slaughter and extinction of horses in E/SE Asia, as had been the fate of the Tarpan a century ago. It is therefore important to not, “underestimate the costs of extractive (as opposed to sustainable) development. Great care must be taken ... because once a species is lost, it is gone forever, and ‘useful’ products cannot be harvested from an extinct species” (Gollin, 1993, p. 188).

What is needed is a balance of two institutional frameworks—public-sector administered allocation and private-sector market allocation of information embedded in GRs. This can facilitate efficient and sustainable GR resource access, benefit sharing, and eventual commercialization, thus affording equitable allocation of value and distribution of compensation coupled to sustainable conservation. In sum, when the institutional environment is defined, and the participants understand how to operate in the system, conservation and preservation of GRs and biodiversity can be enhanced, promoted, and sustained (Deke, 2008).

The CBD aspires to establish a working framework for sustainable conservation via a defined, regulated, and enforced system of benefit sharing; however, to achieve this, a clear chain of property rights management—from access to final commercialization—is sorely needed as the foundation to build this framework into a dynamic system. Compensatory benefits for all parties along the value chain will drive a systematic cycle, balancing use and conservation of GRs. Market demand, albeit crucial, is insufficient; an efficient system of clearly defined property rights is also equally important to facilitate a predictable, equitable, and balanced sequence of transactions (Deke, 2008; Frisvold & Day-Rubenstein, 2008). The major weak link in this value chain is a persistent lack of institutional capacity

in developing countries, which prohibitively increases transaction costs and stymies GR utilization and conservation. This is due largely to “a lack of political will on the part of the country hosting valuable biodiversity endowments and/or lack of national governance and institutional capacities” (Deke, 2008, pp. 27-28). Hence, capacity building in institutional infrastructure and human capital are key steps to create the connections needed for engaging in a global system that maximizes GR potential while simultaneously preserving it. For the conservation of horse populations of E/SE Asia, such a system would be of significant benefit to the horses, the countries of the region, and the global horse industry. What are the system components necessary to make this happen?

Recommendations

Global livestock biodiversity, including horses, is in a state of decline, with at least 28% of breeds extinct, endangered, or rare since the outbreak of the First World War (Roosen, Fadlaoui, & Bertaglia, 2005). As the global horse industry can be measured in the billions of dollars (American Horse Council, 2005), preservation of the horse gene pool is not only a humanitarian but also a serious economic concern. Conservation strategies will need to be driven by financial factors in addition to humane sentimentalities. Hence, although systems for identification and cataloguing, valuation, assignment of property rights, and subsequent management towards commercialization of animal GR assets still appear to be at a nascent stage (Deke, 2008), the rapid convergence of three factors—(1) the monetary value of the global horse industry (estimated in the billions of dollars), (2) the rapidly evolving analytical tools of biotechnology, and (3) the finite (and possibly precarious) state of the world horse genetic inventory—indicate that practical steps towards implementation of management systems are not only important, but urgent.

What is needed is a strategic plan for ABS implementation, which will simultaneously conserve and utilize horse GRs. In this respect, fundamental theoretical guidance on how to proceed has been provided:

“Viewed as inputs to the innovation process, genetic materials have the potential to become genuine resources in the context of a sufficiently rich set of complementary knowledge assets. The effective functioning of a market in GRs depends on these knowledge assets just as much as, if not more than, it relies on a sound system of IP rights

and a robust capital market. This suggests that attempts to estimate the value of GRs should focus attention on how researchers form and update their beliefs. It also suggests that the institutions regulating bioprospecting, including systems of IP rights, should reward the provision of helpful prior information, as well as the conservation of the base biological material” (Rausser & Small, 2000, p. 196).

The challenge is the implementation of theory into practice. How can capacity building in human capital, institutional infrastructure, and global networks provide a sustainable system for ABS that is efficient and equitable? The tools of biotechnology (e.g., genomics, proteomics, metabolomics [Fridman & Pichersky, 2005; Gollin & Evenson, 2003]) permit greater targeted bioprospecting with refinement and precision that is yet to be realized, further increasing marginal value to horse GRs. When used in conjunction with other knowledge sources (e.g., traditional, indigenous knowledge, and animal husbandry information on horse populations), the synergistic effect of combined information can further enhance potential value, as per Rausser and Small’s (2008) proposition. However, full utilization and sustainable conservation will depend on an integrated and stable system in which clearly delineated, managed, and enforced property rights are essential.

Developing countries, which comprise the bulk of mega-biodiversity (Deke, 2008), need to prioritize strategic and focused capacity building so as to engage in and profit from this system, moving away from being passive bystanders complaining about biopiracy. Although many countries have acceded to the CBD, with ABS provisions apparently planned, the number of countries actually implementing ABS is small. In many cases, CBD ABS “implementation” is under the authority of environment ministries functioning as bureaucratic gatekeepers, with a subsequent lack of promotion, and even outright deterrence, of possible value-added bioprospecting towards commercialization and conservation of GRs. In addition, much of the bioprospecting “pursuant” to the ABS provisions of the CBD in developing countries has been undertaken by foreign organizations, with little proactive participation by the bioprospected country itself. In order to connect to a global innovation market where the information assets of GRs can be licensed, the mega-biodiverse countries must implement practical measures toward a more proactive strategy aimed at promoting sustainable development of GRs (Artuso, 2002; Rausser & Small, 2000).

Developing countries, therefore, need to carefully consider whether to practically implement the ABS provision of the CBD via establishment of CNAs that actually manage GRs. In the case of the indigenous horse populations of E/SE Asia, this would necessarily include the countries of the region wherein horses (or perhaps more precisely, the genetic information which the horses embody) are domiciled, i.e., as the sovereign GR and biodiversity of those countries.

What steps need to be taken? Five prescriptive recommendations include to

1. establish human resource and institutional capacity (CNAs);
2. catalog eco-geographical inventories of horse GRs throughout the E/SE Asia region;
3. market horse GR inventories via a web-based, globally networked resource;
4. monitor, track, manage, and direct equitable, leak-proof proprietary value chains from horse to genetic information to commercial products; and
5. ensure revenue flow back to support conservation.

1) CNAs that Manage Horse GRs

To effectuate the CBD ABS provisions, as per the Bonn guidelines, practical and predictable procedures need to be established in developing countries, including clearly identifiable centralized CNAs that administer these procedures in a competent coherent, professional, and efficient manner. In many cases this will require investment in building human capital and institutional infrastructure (e.g., staffing with professionals fully capable of understanding, negotiating, and granting access to GRs and subsequent contracts governing use and benefits). Crucially, the developing countries themselves must contribute significantly to this process and not expect international donors to lead the initiative (Juma, 1993). Such CNAs with sufficient capacity, in turn, would facilitate systematic and sensible regulation of ABS of biodiversity and GRs (Thornstrom, 2007), with enhanced abilities to acquire technology, access information, and foster global networks (Gollin, 1993). Template agreements regulating ABS might include, but are not necessarily limited to, letters of intent, research permits, PIC, MAT, MTAs, confidentiality agreements (Laird & Wynberg, 2008; Thornstrom & Bjork, 2007), as well as license agreements with provisions (e.g., options and grant-backs) that ensure revenue and/or other compensatory value flows back to the sources of the biodiversity and GRs.

In order to coordinate horse inventory management with ABS strategic implementation, national and regional focal points for inventory management of horse GRs could partner or consolidate with CNAs. This arrangement could catalyze establishment and implementation of a sustainable conservation/utilization system for horse GRs and “further develop [global] information sharing and technical cooperation, training, and research” (Food and Agriculture Organization of the United Nations [FAO], 2007, p. 36). Longer-term goals and benefits should also include specific priority areas that enhance and build inventory and horse GR management (e.g., technical development, technology transfer, collaborative programs, and associated education, capacity building, and information networks; FAO, 2007). The CNA, as a focal point for managing regional and national horse GRs, will then be the base of operations for the recommendations below (i.e., implementation).

2) Eco-geographical Inventories

To increase efficiency of E/SE Asian horse GR inventory management, eco-geographical mapping as a tool to inventory horse populations needs to be a priority. A comprehensive compilation of data—including climatic, ecological, geographical with cross-indexing to phenotypic, and genotypic information as available (Parra-Quijano, Iriondo, Torres, & Rosa, 2011)—eco-geographical mapping is particularly applicable to locally adapted populations of organisms. Although it has been done predominantly with plants (Parra-Quijano, Iriondo, & Torres, 2012), it has also been successfully applied to animal populations (e.g., guanaco [*Lama guanicoe*] in the Andean region of South America; González, Palma, Zapata, & Marín, 2006). Compiled information can be catalogued into a database and mined for efficient identification of horse GRs (e.g., disease resistance, bone density, endurance, or heat tolerance). Eco-geographical mapping therefore provides *a priori* information that increases bioprospecting efficiency, facilitates decision-making, and thereby lowers transaction costs. This is consistent with general theoretical principles of efficient inventory management and business-cost containment (Burja & Burja, 2010). Furthermore, there is a strong likelihood of geographical genetic migration and local adaptation of E/SE Asian horse populations (with possible gene flow from wild to native populations; Ishida, Oyunsuren, Mashima, Mukoyama, & Saitou, 1995; Kavar & Dovč, 2008; Lippold, Matzke, Reissmann, & Hofreiter, 2011; Warmuth et al., 2011). Mapping infor-

mation can be a tool to more precisely predict and then identify potentially valuable horse GRs, with commercial applications.

In addition, cataloging inventories of horse GR is consistent with the pioneering theoretical work of Deke (2008, p. 62) that *a priori* information can “reduce ex ante uncertainty ... knowledge of specific GRs [serving] as an indicator of promising information.” In other words, information confers value on the GR such that conservation is incentivized over wholesale obliterative exploitation—the so-called tragedy of the commons (Gollin, 1993). Thus, information builds to incrementally reduce uncertainty, decrease attendant risk, and impart marginal value. This, in turn, facilitates greater efficiency in bioprospecting and subsequent research, development, and commercial application of GR-derived innovation.

3) Market Horse GR Inventories via a Web-based, Globally Networked Resource

Access to horse GRs and biodiversity data and information should be promoted via a dedicated web-based marketing portal. This concept has already been proposed, i.e., the Global Biodiversity Information Facility, a “data publishing framework as an environment conducive to ensure free and open access to the world’s biodiversity data” (Moritz et al., 2011, p. 1).

This is standard business operating practice, and the worldwide web now creates a global market portal that is ubiquitously accessible. The lack of such a market portal is a major limitation in the ABS system for horse GRs, which must overcome the following situation:

“It is also believed that the lack of knowledge as to what genetic resources are available, and which might be potentially useful, is a major limitation to industry being able to access genetic resources. Changing this situation to facilitate an increased demand for wild germplasm will require considerable effort from provider countries. Costa Rica, for example, has spent a lot of resources in developing an inventory and taxonomy of its biodiversity and ‘filling its shop window’ for potential customers [users] and this, believe some, is what other countries must do. Companies have noted the importance of ‘greater realism’ in terms of the potential opportunities of what is available and interesting. ‘If you don’t know what is available, and who has the rights to

provide it, it simply won't work” (Laird & Wynberg, 2008, quoting Dr. Steve Smith 2007, p. 17).

Laird and Wynberg (2008, p. 37) explain that marketing of GRs fits into an overall ABS, CNA-based comprehensive strategy: “Provider countries and institutions that actively build and market their biodiversity knowledge base and associated capacity, and enter into partnerships that help them to do this, receive greater benefits from their biodiversity, and support biodiversity conservation through these activities.”

4) Manage and Direct Equitable, Leak-proof, Proprietary Value Chains from Horse to Genetic Information to Commercial Products

The CBD recognizes that countries retain sovereignty (ownership), over GRs within their borders (Fidler, 2008). But in terms of property and proprietary rights, what are GRs? As articulated by Vezzani (2010, p. 678), “the CBD ... defines genetic resources as genetic *materials* (namely ‘any *material* of plant, animal, microbial, or other origin containing functional units of heredity’) of actual or potential value. It is acknowledged that this definition is broad enough to include viruses.” It is critical to note that the CBD does not articulate information; rather its focus is on materials, that is, tangible property. Although the GRs discussed in this article is horses, the best example of the loss of GR information (information “leaked” away), that was subsequently raw “material” for patenting, is found on a remotely distal branch of the tree of life—viruses.

Information “leakiness” has likely occurred with influenza virus samples shared through vaccine development networks (i.e., third-party use of viral genetic sequence data to develop and patent influenza-related vaccine inventions; Vezzani, 2010; World Intellectual Property Organization, 2011). In 2007, Indonesia decided to withhold access to pandemic influenza (H5N1) viral isolates, because viral materials could become subject matter for third-party patents, without equitable sharing or affordable access to the patented health-care innovations. As a possible solution, Indonesia sought implementation of MTAs on viral samples (Irwin, 2010; Laird & Wynberg, 2008). However, MTAs are legal instruments (contracts) that define terms for the transfer of *tangible biological materials*. “MTAs are bailments that transfer possession but not title: the party who transfers the materials retains full ownership; the party who receives the materials holds them in trust” (Bennett, Streit, & Gacel, 2007, p. 697). Hence, albeit

specifically articulated as key ABS legal instruments, MTAs do not *per se* address intangible property (i.e., information [IP] embedded in a bailed material). This needs to be addressed by another legal instrument (e.g., confidentiality or non-disclosure agreements, possibly pursuant to trade secret law; Gollin, 1993; Jorda, 2007).

Hence, Indonesia’s ad hoc attempts to “manage” access to and use of viral clades as materials, pursuant to the CBD and implemented by MTAs, might have been doomed from the start. Information leaks and third parties can then access and use it for research, development, invention, and patenting. This concept of GR information leakage has also been lucidly addressed by other respected authorities: “[T]he genomic content of samples should be covered in agreements ... intellectual property and other rights are much more difficult to manage for data compared with physical entities such as pieces of DNA or biological molecules” (Laird & Wynberg, 2008, p. 30). Since all earthly creatures—both great and small—contain genetic information, the same principles that are exemplified in the Indonesian case (Sedyaningsih, Isfandari, Soendoro, & Supari, 2008) must therefore motivate and stimulate investment by the developing countries themselves, in coherent capacity building for management of GRs from organism to commercial product. The viral sample case can be applied to the indigenous horse populations of E/SE Asia (i.e., controlling information leakage from GR).

5) Monitor, Track, Ensure Revenue Flow Back to Support Conservation

Compliance and tracking of GRs is a two-way street. Developed countries’ industries need certainty and continuity for ABS and subsequent product development. Developing, source countries desire equitable sharing of derived and future value of GRs (Laird & Wynberg, 2008). Weakness at this point in the system has led to reluctance on the part of developed country industries to bioprospect. From an intellectual standpoint, arms-length contractual ABS arrangements with upfront collection and downstream royalty revenue streams appear feasible. In reality, public-private partnerships (PPPs), built on both trust and contract, with value-added capacity-building investments (such as in-country screening) create perhaps a better, grounded, sound, and sustainable approach (Lesser & Krattiger, 2007).

PPPs are among the more coherently proposed and likely most easy to implement means for long-term monitoring, tracking, and overall compliance. As Laird and Wynberg (2008) have highlighted, PPPs have been

primarily employed for non-animal GR ABS arrangements. Seven cases are illustrative:

1. AstraZeneca and Griffith University in Queensland, Australia: Natural-product drug discovery partnership involving collections of terrestrial and marine biodiversity from Queensland; benefits accrued over time, with capacity building, technology transfer, information, and understanding for conservation planning and management.
2. Kenya Wildlife Service, International Centre for Insect Physiology and Ecology, and Novozymes and Diversa (now Verenum): Collection of microorganisms in protected areas; arrangements based on microorganism sourcing and ABS in the industrial biotechnology sector.
3. The Ethiopian Institute of Biodiversity Conservation, the Ethiopian Agricultural Research Organization, and the Dutch-based company Health and Performance Food International: The cereal crop *tef* (*Eragrostis tef*), a staple and among Ethiopia's most significant crop species, has gluten-free grain of interest to the food industry.
4. Ball Horticulture and the South African National Biodiversity Institute (SANBI): Select South African plants of horticultural interest for Ball; commercial products have been developed from this collaboration and it has yielded important experiences for the implementation of ABS.
5. Aveda Corporation, Mount Romance, and a range of community groups in Western Australia: Partnership based on sandalwood for personal care and cosmetic company; benefit-sharing through the supply of raw materials and agreements for the use in marketing of indigenous peoples' images and cultural property.
6. Natura and a range of community groups in Brazil: Sourcing of certified raw materials for the personal care and cosmetic sector; includes an agreement for commercial use of traditional knowledge. This case has affected Brazil's developing ABS policy framework.
7. Unilever, the British phytomedicine company Phytopharm, and the South African Council for Scientific and Industrial Research: Involves the succulent plant Hoodia, an appetite suppressant and a number of ABS agreements between the multinational consumer company, commercial Hoodia growers, and the indigenous San people of southern Africa.

A unifying principle from each case study is the value of building PPPs based on *both* trust and contract.

As eloquently elucidated by Lesser and Krattiger (2007, p. 873), "considerable trust in the integrity of the contracting company would seem to be critical, but ... checks should be included in the agreement." In other words, trust is the foundation for the sustainable system, which albeit including contracts and agreements, recognizes that no agreement can be structured to "permit verification of every aspect," i.e., cannot replace trust (Lesser, 1998, p. 182). This central maxim is reaffirmed by Laird and Wynberg (2008, pp. 29-30),

"A large element of trust and mutual respect—by-products of partnerships to a far greater extent than agreements solely for the supply of samples—is necessary to make these agreements work in practice. ... Material that gets utilized in a 'closed loop' [e.g., a PPP arrangement] faces fewer ... problems. For example, the licensing agreements to commercialize Hoodia have well-defined tracking mechanisms and all contracting parties have a responsibility to ensure material is used only for the purpose stipulated."

Hence, whether the GR is plants, algae, fungi, or botanicals, the principles appear to broadly apply and should be applicable to animal GRs such as horse populations of E/SE Asia. Key elements include trust, tracking, PPPs, and the capacity to engage in IP management, technology transfer, and related ABS activities. In short, what is needed are CNAs that are focal points for management of horse GRs, promoting "communication and collaboration, rather than suspicion and frustration" (Laird & Wynberg, 2008, p. 37).

Conclusion

In developing countries, building human-resource and institutional capacity that will enable active involvement in a systematic value chain—from horse to proprietary information which then flows back to the horse populations—will require a sequence of proprietary rights agreements governed and regulated by both tangible and intangible property regimes. A sequence of rights might include the horse as a tangible chattel, a blood sample, blood cells and DNA therein as tangible properties (transferred via MTAs), the genetic code as proprietary business information (protected as a trade secret), and/or the application of this information for "an innovative or creative and useful purpose", i.e., a patented invention (Lawson, 2006, p. 152). The value chain can be concep-

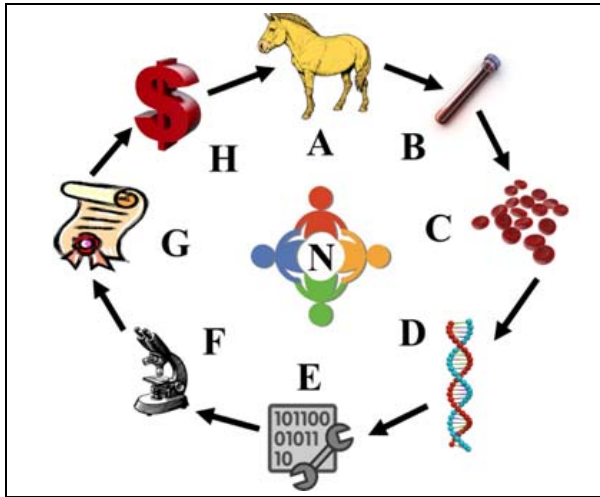


Figure 2. Proposed value chain to sustainably connect conservation of wild, native, landrace, and feral (indigenous) horse GR of E/SE Asia with commercialization of innovations arising therefrom. Each step in the system is connected via clearly delineated property rights and various licenses and/or agreements. Pursuant to the CBD, a developing country CNA (N) serves as the administrative hub coordinating and regulating equitable ABS. The steps in the value chain—with the property and attendant property rights—is indicated; tangible property (TP) and IP: A=horse/TP/chattel; B=blood/TP/chattel; C=blood cells/TP/chattel; D=nucleic acids/TP/chattel; E=business information contained in nucleic acids/IP/trade secret; F=research and development/IP/trade secret; G=invention/IP/patent; H=commercial applications and products (IP and TP) generate revenue completing cycle in system, with value returning to source.

tualized as a sustainable cycle, with an equitable distribution of value at all stages (Figure 2).

Hence, establishment of CNAs in developing countries that proactively manage horse GRs can simultaneously actualize this proprietary value chain, enable conservation, and drive commercialization, thus permitting horses to continue to roam free while the genetic information encoded in their cells is afforded protection as a property right that can be licensed and built into innovations for the benefit of all involved (Clements et al., 2010; Coase, 1960). The dilemma of market failure can be transformed into a dynamic system that conserves the indigenous horse populations of E/SE Asia based on the potential market value of the genetic information they embody. Conservation and innovation can thereby become mutually reinforcing factors.

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