DNA barcoding: the social frontier

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DNA barcoding has been promoted as the holy grail of biodiversity conservation. Its proponents envision a time when anyone will be able to use a portable Life Barcoder to identify a fragment of an organism to the species level within seconds. While several critics have questioned whether DNA barcoding will work technically, claims about its social benefits have not been scrutinized. Here, I focus on two prevalent assumptions about the Life Barcoder: that it will democratize access to biodiversity and that it will increase appreciation for it. I argue that neither of these assumptions is well supported, since a Life Barcoder will prioritize one way of knowing over others, and create a technological distance between people and organisms. Consequently, DNA barcoding may not benefit conservation as much as its proponents assume.

Front Ecol Environ 2007; 5(8): 437–442, doi:10.1890/060128.01

Several biologists have recently proposed a new vision for the conservation of biodiversity, DNA barcoding (see BOLD Systems [2006]), which they compare in importance to the invention of airplanes (Hebert and Barrett 2005) and the printing press (Janzen cited in Holloway 2006). DNA barcoding seeks to standardize taxonomy by using a single, short DNA sequence, such as part of the conserved mitochondrial gene COI, to discriminate between species. If this works, DNA barcoding could lead to the development of the Life Barcoder, a device similar to Star Trek's "tricorder", which would allow people to identify species (Janzen 2004; Figure 1). By simply removing a leaf from a plant, a leg from a mosquito, or a scale from a fish and placing it inside the Life Barcoder, one could quickly identify an organism to species. DNA barcoding proponents claim that this would allow anyone instant access to species' identifications, increasing appreciation for biodiversity and thereby providing greater impetus for conservation. In an online pamphlet, for example, the Consortium for the Barcode of Life (2004) promotes "the promise of a schoolchild with a barcoder in hand learning to read wild biodiversity".

However, we know little about the implications of this technology and, thus, whether it is a good idea in the first place. Yet, curiously, there has been little apparent reflection on such issues, despite the estimated $1–2 billion price tag (Hebert *et al.* 2003; Hebert and Gregory 2005). Instead, critics and proponents alike have focused on the technical question of whether or not DNA barcoding will discriminate among species (eg Cognato *et al.* 2006). This assumes that the Life Barcoder would be a neutral "tool" for conservation, thereby sidelining social and ethical questions about how its very existence might affect our respect for, and interactions with, biodiversity (Figure 2).

It is possible to raise such issues as a conservationist rather than as a technophobe. DNA barcoding could undoubtedly have practical benefits; nonetheless, it is important to consider its socio-ethical dimensions now, because it is at these early stages of development of the technology that we have the greatest flexibility in determining its form (Winner 1986). Social scientists have criticized early claims about other large-scale technological proposals, including the Human Genome Project (Kevles and Hood 1993), and some of their doubts about a resulting "biotech revolution" have since been validated (eg Nightingale and Martin 2004). To date, there has been only limited consideration of whether the proposed Life Barcoder will fulfill claims about its benefits, largely in the context of critiques of whether it will work (Scotland *et al.* 2003; Godfray and Knapp 2004; Ebach and Holdrege 2005; Prendini 2005; Holloway 2006; Rubinoff 2006). Here, I question whether the proposed benefits are warranted in light of potential social costs, in the hope that this will promote a dialogue about the best way to obtain the outcomes we seek.

In a nutshell:

- DNA barcoding could have diverse benefits, but it is not a conservation panacea
- The Life Barcoder could limit access to biodiversity, potentially constraining people to a costly, high-tech way of identifying species
- The Life Barcoder could decrease appreciation for biodiversity by limiting sensory interactions with organisms themselves, which is one of the sources of people's concern for biodiversity

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Assumed social benefits

The Consortium for the Barcode of Life's online pamphlet (2004) lists ten benefits of DNA barcoding that apply mostly to scientists seeking to inventory biodiversity. Such benefits might then apply to humans as a whole, to the extent that knowledge of biodiversity will

Courtesy of HMS Creative Productions

Figure 1. *The Life Barcoder could have practical benefits akin to those of the "Star Trek's" tricorder, shown here. The tricorder was mainly used to identify organisms on exotic planets, however, so it provides little insight into how the Life Barcoder would affect our everyday interactions with biodiversity.*

aid conservation. The Life Barcoder could also have other important practical applications; for instance, customs agents will be able to more quickly and reliably screen organisms to detect whether they are endangered species or potentially invasive.

However, the pamphlet suggests there will be much wider benefits. First, it claims that DNA barcoding will "democratize access" to biodiversity by "empower[ing] many more people to call by name the species around them" (see also Janzen [2004]; Hebert and Gregory [2005]; and Cognato *et al.* [2006]). Second, it claims that DNA barcoding will increase appreciation for biodiversity both locally and globally (see also Stoeckle [2003]; Janzen [2004]; and Savolainen *et al.* [2005]). Much of the hype about DNA barcoding appears to be based on these proposed benefits for the general public. Consequently, these claims require careful scrutiny, especially if they are being used to justify large-scale funding appeals in the public domain. Here, I raise the following questions about the Life Barcoder:

- Is it likely to be affordable and therefore accessible?
- Will it facilitate respect for other ways of knowing biodiversity?
- Will it engender appreciation for biodiversity?

Democratizing access or restricting it?

It may seem obvious that DNA barcoding will increase access to biodiversity, since a Life Barcoder would allow anyone to easily identify species. As Bowker and Star (1999) observe in their book on the consequences of classification, however, "Each standard and each category valorizes some point of view and silences another. This is not inherently a bad thing – indeed it is inescapable. But it is an ethical choice, and as such it is dangerous – not bad, but dangerous."

As an example, DNA barcoding has received some of its strongest criticisms from taxonomists concerned that it is a clandestine attempt to prioritize a single character (the COI sequence) for identifying organisms (Will *et al.* 2005). Even setting aside this somewhat cynical view, there is a compelling circularity in DNA barcoding because its proponents simultaneously define what biodiversity is and provide the only way to measure it. Kay (1996) describes a similar process in the way that molecular biologists have defined life itself through technology. DNA barcoding would provide the technological funnel through which biodiversity would have to be assessed in the future. While this might be acceptable if DNA barcoding were the "correct" way to identify species, this technique does not solve intractable problems about how to define species and which species concept we should use (Meyer and Paulay 2005; Fitzhugh 2006; Rubinoff 2006). The concern therefore is that the technology may drive decisions about the species concept. Consequently, we still need to question who benefits and who loses from the implementation of DNA barcoding.

The Life Barcoder will only broaden access if it is affordable. At present, however, DNA technology is too expensive for most of the world's people. Given the history of technology, it seems unlikely that a Life Barcoder will eventually be widely affordable, let alone "a free gadget" (Janzen 2004). Janzen points to the cell phone as a model, but cell phones are still by no means free, as any user will attest. It is therefore just as probable that DNA barcoding will restrict access to biodiversity to relatively wealthy organizations (and possibly individuals), who can afford the requisite technology (cf Dunn 2003). Similarly, Janzen's (2004) proposal that one penny be given to conservation with each name provided by a Life Barcoder raises the issue of how many species people could afford to identify. Underprivileged people, who generally live in regions with the most species, will be the least able to afford to identify their species, perhaps artificially lowering estimates of local richness. While one might counter these arguments by remarking upon the expense of taxonomic manuals – not to mention their

unwieldiness – people can learn from them and apply this knowledge to commonly encountered species, which would be less likely for a Life Barcoder (see below).

Regardless of the intention to broaden access, it appears that DNA barcoding is being developed with little input from, or collaboration with, those who deal with conservation issues on the ground. Recent conferences on DNA barcoding have focused almost entirely on technical issues, suggesting that the development of the Life Barcoder is a top-down initiative rather than a grassroots one. Diverse studies have shown that such efforts are ineffective for conservation compared to those that encourage people to engage with local issues (Borgerhoff Mulder and Coppolillo 2005). While there have been attempts to include more stakeholders in discussions about DNA barcoding, these have, to date, still reflected the interests of biodiversity scientists, government agencies, and high-tech start-up firms.

Discussions about DNA barcoding have also ignored indigenous ways of knowing biodiversity. Many indigenous cultures have developed well-honed, practically-oriented taxonomic systems that contribute to their ability to manage local biodiversity over time (Figure 3). It is unclear how the proposal to barcode life would affect preservation of this knowledge. There is a risk that it would contribute to its loss, since it implicitly imposes an "objective" view of species that is meant to apply everywhere, in contrast to intimate indigenous experiences with, and stories about, local species (Nabhan and St Antoine 1995; Henderson 2000). While indigenous peoples may choose to accept or reject DNA barcoding, they may have limited opportunity to reject it if it becomes the "proper" way to identify species, enforced by the strong ties between institutional biology, commercial interests, and government agencies. Thus, their own knowledge systems may gradually be undermined.

Courtesy of D Macadam/Science News

Figure 2. *DNA barcoding will not literally "brand" species, but the symbolism of this cover image from* Science News *evokes questions about how it will affect our relationship with biodiversity.*

Engendering appreciation or disenchantment?

The literature on DNA barcoding claims that it will engender appreciation for biodiversity. This assumes that we need more scientific knowledge to inspire environmental values. Bocking (2004) instead argues that "Efforts to derive environmental values from science… miss the point, because they obstruct access to discussion about them by the very people – that is, the public – who have historically led in defining them". There is ample evidence to demonstrate that people appreciate and care about biodiversity; the impediments to conserving it are not so much taxonomic as economic and political. Furthermore, there is little evidence that simply putting a name to an organism leads one to care about it (cf Ebach and Holdrege 2005; Holloway 2006). Instead, one must care about nature enough to name species at all. Naming may therefore merely reinforce a pre-existing sense of caring. The lives of distinguished biologists suggest that this is the case. For example, EO Wilson (1994) states that "hands-on experience at the critical time, not systematic knowledge, is what counts in the making of a naturalist. Better to be an untutored savage for a while, not to know the names or anatomical detail. Better to spend long stretches of time just searching and dreaming".

Similarly, a recent study of children's perceptions of plant classification concluded that "emphasis…within science curricula on naming and classifying organisms may be at the expense of environmental understanding" (Tunnicliffe and Reiss 2000; Figure 4). In contrast, Janzen's (2004) vision includes "identification credits" for finding new locales for species, creating a competitive biodiversity game rather than joyful, child-like exploration. It may be that the quest to find new species and to identify them inspired many biologists to choose their careers, and that access to an easily available label might have undermined that exploration.

People develop an appreciation for life primarily through interactive experiences with organisms, and it is unclear how the Life Barcoder would facilitate such interactions. We desperately need people who have developed an intimate relationship with the natural world, and naming fulfills only a fraction of this need. Consequently, we must train the next generation of naturalists, rather than kids with Barcoders in their hands (Raven 2004). By

Figure 3. *The Kallawaya of Bolivia possess an exhaustive knowledge of Andean plants and their curative uses. Ilaryon Ramos Condori (pictured), an expert herbalist, is among fewer than 100 people who still know the rapidly disappearing Kallawaya language and its unique plant taxonomy (Harrison 2007).*

looking closely at an organism, one learns more than just its name: one learns how to observe – a very valuable scientific skill in its own right – and one learns something about this individual and this species. Over time, one also learns about the concept of variation, which is so critical to understanding biology, yet potentially veiled in DNA barcoding by the implication that species are fixed.

What are the consequences of having a machine as our intermediary with the natural world? There is a substantial difference between interacting with a screen and interacting with organisms themselves. Traditional taxonomy relies on characteristics that can be observed with the naked eye, perhaps assisted by magnification. This encourages people to interact directly with an organism and to look closely at it. In contrast, the Life Barcoder would discourage people from identifying organisms in this everyday manner. Although this is inescapable for microscopic taxa, the Life Barcoder would breed dependency with macro-scale species too, as people would become unable to identify them using their own sensory capacities, which would likely atrophy over time. In extreme cases, users would need to put every individual through their Life Barcoder, as they might have no other way of knowing whether visually similar individuals represented different "cryptic" species (Figure 5). This would be particularly problematic where DNA barcoding necessitates destructive or harmful sampling, a side-effect of the technology that has been absent from discussion.

Figure 4. *Young children appreciate biodiversity without knowing the names of organisms. As they mature, they become more interested in taxonomy, but the Life Barcoder could stymie their exploration of the natural world and understanding of biology by providing the "right answer" too easily and too quickly.*

People interested in taxonomy formerly gained confidence in their abilities through their successful attempts to identify species. If they were unsuccessful, they would draw on the knowledge of other people by contacting an expert or interacting with a mentor. In this sense, DNA barcoding seems a long way from the hopes of parataxonomy (the training of non-experts by professional systematists so that they can then assist with the collection and documentation of biodiversity), which seeks to develop a conservation community rather than to erode it.

More generally, DNA barcoding epitomizes the belief that we need to identify all the biodiversity pieces in order to know how to conserve them. This may be understood as part of the "almost religious conviction that a widespread adoption of computers and communications systems along with easy access to electronic information will automatically produce a better world for human living" (Winner 1986). Edwards (1996) documents the extent to which this ideology has spread into modern society from the information technologies developed for the Cold War, which sought to provide "global technological oversight". Proponents simply assume that DNA barcoding can be properly extended to provide this oversight for biodiversity and its conservation. In reality, it may just exaggerate the problem of "taxonomic inflation", having more and more species that we don't know what to do with (Isaac *et al.* 2004).

Conclusions

While a Life Barcoder could have practical benefits for humanity, it does not stand up to claims that it will increase access to, and engender appreciation for, biodiversity. The program to develop this technology implies that, with more information, we will be able to solve the many social problems that stand in the way of effective conservation, including critical issues such as political and social inequality (Raven 2004). Despite its aspirations, however, the Life Barcoder will not necessarily lead to the conservation outcomes we desire. Sarewitz (1996) describes the general problem as follows: "If humanity is

unable or unwilling to make wise use of existing technical knowledge…is there any reason to believe that new knowledge will succeed where old knowledge has failed?"

Would it be wise to spend $1 billion or more to develop the Life Barcoder? This is clearly an insignificant amount relative to other global expenditures. However, we could use this funding to resolve more pressing social issues that limit conservation. For example, an initiative for global sustainable development recently requested a much smaller amount – $200 million over five years (Sachs and Reid 2006). In this context, $1 billion seems exorbitant and one has to wonder whether it is driven more by an image of "Big Science" than by careful attention to what we actually need (cf Rubinoff 2006). Impediments to conservation will remain even after completion of the DNA barcoding project, so shouldn't we focus on these social issues now rather than later?


Courtesy of J Kamstra

Figure 5. *Based on DNA barcoding, this common North American bird species, the raven, is comprised of two "overlooked" species (www.barcodeoflife.org/barcode/batsbirds). DNA taxonomy commonly detects cryptic species, but seeks to link them to traditional characteristics. In contrast, the Life Barcoder would create a dependency, as people would gradually lose the ability to identify species around them in other ways.*

DNA barcoding is not as harmful as some developments in contemporary biotechnology may be. Nonetheless, claims made by its proponents have not fully accounted for its possible effects. DNA barcoding could have many practical benefits, but in terms of biodiversity conservation, a cautious approach is necessary. We need to ensure that it helps people to understand the importance of biodiversity and of taxonomy, rather than substituting an empty technology. We also need to question whether widespread access to this technology would be appropriate, or whether the costs of such access may in some contexts outweigh its benefits. A Life Barcoder could forever change how people and their communities relate to biodiversity. It could reduce the diversity of life, which has inspired biologists, naturalists, poets, and everyday people for millennia, to just another video game. Now is the time to develop it with care.

Acknowledgements

I am grateful for comments from S Bocking, G Bowker, R Ellis, K James, S Murphy, and C Waterton, and for postdoctoral funding from the Biological Invasions IGERT at the University of California, Davis (NSF–DGE 0114432).

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