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**PROFESSIONAL ARTICLE:** From Paper Trails to DNA Barcodes: Enhancing Traceability in Forest and Fishery Certification

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**LEXISNEXIS SUMMARY:**

... Many third-party certification processes have developed in areas such as forestry, fisheries, and for many agricultural products to provide this information to consumers and regulators. ... While these techniques, like any other, are open to misuse in handling and processing material samples, we draw on case studies of forestry and fishery certification practices to argue this is a much less significant risk than found in many present day certification systems. ... The risk of fraud remains high--both as a real phenomenon and as a public or industry perception--potentially undermining confidence in existing schemes and processes. ... Recent developments in biotechnology provide several means for overcoming many issues with existing certification processes. ... Examples of success in this area include DNA barcoding traceability work of Amazonian fish by analyzing catch being sold as Acara" and of other species in Brazilian fish markets, for American catfish stocks, and other seafood products. ... But these technologies will greatly simplify the task of inspecting and monitoring production processes and supply chains for many products, enhancing the reliability of, and confidence of consumers in, resource certification systems.

**HIGHLIGHT:** Governments and industries are familiar with private sector or third-party driven natural resource and agriculture certification schemes, like the Forest Stewardship Council (FSC) process. These schemes affect products including organics, fair trade coffee, fisheries, olive oil, cheese, milk, herbs and many more. In practice these schemes attempt to control attributes of final retail products through supply chain verification of a specific product, or process

qualities that involve consumer product labeling and certification of chain of custody product and process control procedures. All are difficult and costly to administer. It is necessary to monitor and inspect each step of lengthy supply chains. These schemes ensure the quality and purity of final products in the face of omnipresent dangers and incentives for producers to evade quality standards and adulterate products or processes. Many schemes operate more or less on a self-regulatory basis where producers agree to honor third-party certification of supply chain operators who, typically, are infrequently inspected. This system periodically gives rise to various forms of product and process quality scandals. New technologies linked to genomics, proteomics, metabolomics and transcriptomics that involve cellular level identifiers in specific products show promise in improving both the quality and cost of regulatory oversight of many certification efforts. They enable rapid, low-cost confirmation of the origins and purity of many goods often without the need for intermediate supply-chain monitoring and inspection. This article describes the state-of-the-art of 'omics<sup>n1</sup> technologies and discusses the advantages and limitations of these techniques in the areas of natural resource and agricultural certifications.

ABSTRACT

**TEXT:**

**[\*422] I INTRODUCTION: TRACEABILITY, THE ACHILLES HEEL OF EXISTING AGRICULTURAL AND NATURAL RESOURCE CERTIFICATION PROCEDURES**

Product certification generally involves following that product from the point of production or collection, to the point of consumption. Certificates of quality are typically delivered by a third-party. Two important areas dealing with certification are: (i) the type of minimum standards that the product must meet, and; (ii) the trust that consumers can place in the ability of the certification body to deliver both unbiased, and technically valid results. Certification can be helpful to both the producers and the consumers of a product, and can serve a variety of societal and environmental goals. These include the development of sustainable production methods, the control of the quality of both production processes and final products, and the protection of human and animal health. A complete tracing process ensures that every important step between harvesting a resource and that resource's consumption is tracked. For example, tracking seafood begins with recording fish catches at the moment of capture, and continues when the product is landed and sold to a distributor. When the fish arrives at the processing centre, another step is recorded and is followed by data regarding the now-processed product (fish fillets for example) being sold to a retailer, its transportation and arrival.

Product and process certification has become an important addition to natural resource and agricultural regulation. Consumers and citizens have demanded product process attributes--like sustainability, and ethical treatment of workers and animals--in addition to earlier concerns for product quality and purity.<sup>n2</sup> Consumers increasingly expect access to mounting product and process information to make their purchasing decisions. [\*423] Many third-party certification processes have developed in areas such as forestry, fisheries, and for many agricultural products to provide this information to consumers and regulators.<sup>n3</sup>

Such schemes targeting quality, adulteration, and purity are very common in the food and agricultural sectors.<sup>n4</sup> They also exist in a variety of other food areas, including organic food standards and genetically modified food labeling. These schemes extend to non-food areas as well, such as natural resource products. These schemes also extend to concerns such as the preservation of old-growth and tropical timber harvesting, or rare animal or plant species exploitation.<sup>n5</sup>

In addition to concerns for preventing environmental degradation and health risks, there are concerns for the transparency of certification processes. Product and process fraud have arisen.<sup>n6</sup> Increasing the amount of accurate information on consumer products through certification is by no means an automatic or unproblematic process.<sup>n7</sup> Most certification schemes are difficult and costly to administer because of the manner in which--using existing goods-testing technologies--each step in lengthy, ambiguous product supply-chains must be monitored and inspected to ensure final products retain their original characteristics, and are not altered, blended or substituted at different points in the chain<sup>n8</sup> It is extremely complex to administer such systems, and it is difficult to ensure that 'certified' standards are actually met in practice.<sup>n9</sup> It is also difficult to establish the credibility of the many certifying entities.<sup>n10</sup>

[\*424] A critical issue for many natural resource and agriculture product and process certification schemes is the capacity of certifying agencies to trace the origins of products, and product components, accurately through the many steps required to get a product to market in a modern industrial production process. <sup>n11</sup> Because production and supply chains often cross multiple national and administrative borders on various continents, it is very difficult to trace a product or its components. In many instances, certifiers lack the ability to track product contents and processes back to their origins; the opportunities for error or fraud are many. <sup>n12</sup> While systems, such as Hazard Analysis and Critical Control Point (HACCP) regulation, are broadly used to prevent the contamination of food and pharmaceutical products--by biological, chemical, and physical hazards--they can do little to prevent intentional misrepresentation and are not designed to account for environmental product process concerns. <sup>n13</sup>

"Traceability" is thus a critical weak link in the entire certification process. <sup>n14</sup> Traceability is also an issue in areas like the trade in endangered [\*425] species or the prevention of deforestation. <sup>n15</sup> Heavily processed products--fish filets, meat cuts, or wood planks--typically appear on store shelves or factory lots where certified and uncertified products are indistinguishable from each other save for a nominal certification label. <sup>n16</sup> Given the price premiums often adhering to such a label, this situation could easily lead to fraud or misrepresentation; a situation for which, until recently, both consumers and regulators had little recourse. The recent discovery that purportedly Marine Stewardship Council (MSC) certified Chilean sea bass were, in fact, not that fish, coupled with the finding that 15 percent of the actual Chilean sea bass samples had been fished outside of certified areas, demonstrates the vulnerability of current certification schemes. <sup>n17</sup>

Recent advances in genomic science offer a series of tools, which can help provide a safeguard against attempts to circumvent certification safeguards. This article focuses on the potential use of such techniques-- notably 'DNA barcoding' and other kinds of 'marker' technologies--in supply chain certification efforts, to expand the latter's existing capacity. <sup>n18</sup> While these techniques, like any other, are open to misuse in handling and processing material samples, we draw on case studies of forestry and fishery certification practices to argue this is a much less [\*426] significant risk than found in many present day certification systems. Their use will result in substantial improvements in reliability in many natural resource and agricultural product areas.

This article examines the potential traceability benefits of DNA barcoding through a discussion of the general limitations on traceability in existing certification programs. Part II and III examine the limitations of existing certification schemes in the forestry and fisheries sectors. Part IV briefly discusses of the development of DNA barcoding and other cellular level identifiers. Part V describes how these new technologies may be applied to natural resources such as forest products or fisheries. Finally, Part VI concludes with a discussion of the promise that these developing technologies hold for enhancing the reliability of market driven certification programs.

## II. THE LIMITATIONS OF EXISTING TRACEABILITY SYSTEMS

Most current traceability systems are paper or electronic-based. They typically rely on physical barcodes attached to products and databases ostensibly tracing the products from stage to stage of the production process. <sup>n19</sup> Currently, many records are stored by transcribing information into a computer file, a hard copy, or a Personal Digital Assistant (PDA). Many schemes use bar codes, or Radio Frequency Identification Devices (RFID), in which an observer must read the tag or brand and record the number, which is then passed along to the next step in the chain. Each system offers a way to trace products through records kept on the producing site. These systems record changes of ownership during processing and distribution in order to try to ensure a proper chain of custody from field to store.

Each such step, however, provides potential "error points" where the integrity of the traceability trail is only as reliable as the reading and transcription of the data. These systems are subject to tampering, and the insertion of counterfeit goods in place of certified ones, which can be difficult to detect. RFID, for example, allows an electronic reader to upload and update information from a chip implanted in a tag, placed under an animal's skin or introduced into the gut in a protective bolus. Plans exist to extend this technology by linking it to Global Positioning Systems, which could then be used to pinpoint the exact whereabouts of a product in real time. Yet present day RFIDs do not produce a

strong enough signal to do this without intermediate transmitters. Smart chips can also incorporate constant monitoring of temperature and humidity. [\*427] This technology has already been used in a variety of ways. For example the UK-based company, Historic Futures, have used smart chips to trace product history in areas such as clothing. <sup>n20</sup> However, any such devices could be removed and re-planted into non-certified animals or products. Furthermore, data can be manipulated: databases, for example, trace barcodes rather than specific products, allowing products to be substituted by simply swapping barcodes. The process of making RFID tamper-proof is itself recent. While it promises to be very secure, it still is too expensive for large areas of the world and other methods--like standard grocery store-style product barcodes that can be too easily scratched, damaged, or altered. <sup>n21</sup>

Given the difficulties and costs associated with inspections and monitoring, it is currently very common for many schemes to operate on a largely honorary or self-regulatory system. Despite their technologically sophisticated overlay, producers, distributors, and retailers largely rely on agreements to honor third-party certificates provided by supply chain operators. <sup>n22</sup> These actors are typically subject to only infrequent or annual audits and inspections by the certifying body, which are often linked to the design of certification processes rather than to actual product tests <sup>n23</sup>

### **III. EXISTING CERTIFICATION EFFORTS IN NATURAL RESOURCE REGIMES: PROBLEMS WITH TRACEABILITY IN FISHERY AND FOREST PROCESSES**

Over the last several decades, both the fisheries and the forestry sectors developed numerous certification schemes as fish and forest stocks have become unsustainably exploited. With 80 percent of fish stocks overfished in 2008, <sup>n24</sup> and forest lands under similar environmental pressure due to destructive overharvesting, <sup>n25</sup> consumer campaigns led [\*428] both governments and retailers to implement certification processes to assure consumers of specific product quality. Certification processes have sought to demonstrate attributes, such as the use of sustainable forest practices in harvesting forest products or, the assurance that rare species or habitats have not been exploited or destroyed. Two certification bodies are predominate in these areas: the Forest Stewardship Council (FSC) and the Marine Stewardship Council (MSC). <sup>n26</sup>

As forestry certification schemes develop, and are increasingly adopted by companies and governments, the role of non-governmental actors in this area has increased. <sup>n27</sup> In the process, certification organizations have sought wider acceptance through the use of scientific tools in their certification and by stressing transparency. <sup>n28</sup>

The various certification bodies have different principles, with which they test these forestry operations. For example, the FSC follows ten principles when certifying companies. Companies must comply with: (i) the laws and FSC principles. Companies must respect (ii) tenure, use rights, and responsibilities; (iii) indigenous peoples' rights; (iv) and community relations and workers' rights. Furthermore, (v) benefits from the forest must be equitably used and shared; and the (vi) environmental impact; (vii) management plan; (viii) monitoring and assessment must be properly conducted at all times. Finally, companies must (ix) engage in the maintenance of high conservation value forests, and; (x) of their plantations. <sup>n29</sup> The FSC principles are aimed at "locking in" a process of increased efficiency in implementing the basic notions of forestry protection, and at creating a set of basic processes that are highly amenable to tracing. For example, the monitoring and assessment principle is [\*429] designed to overlap all phases of harvesting, and can be used both as a tool by the forestry companies and as a choice and information tool by consumers that desire more sustainable products. In this sense, tracing is embedded in the final certification in more than one way. These advances are significant but the scheme still requires an efficient and tamper-proof traceability system in order to achieve its goals.

The application of these principles is generally nuanced according to the country, and the environmental and climate requirements of local forests. The acid test for forestry certification will be employed not only (or predominantly) in relatively open and transparent forestry operations in North America and Europe, but in highly exploited areas like Brazil and Indonesia, where governments may oppose certification, and corruption and malfeasance in timber licensing and management are pervasive. <sup>n30</sup> While developed countries represent the largest majority of FSC certified areas, there is still enormous difficulty in extending the principles of the scheme to developing countries. This

has meant that the scheme, originally presented in the early 1990s as a way to reduce the alarming rate of deforestation in developing countries, has remained mostly a promising option. <sup>n31</sup> Furthermore, Non-Governmental Organizations allege that some companies--while holding FSC certification--are actually acting outside of the scheme's boundaries, as in the case of SODEFOR in the Republic of Congo. <sup>n32</sup> Such circumstances often allow species and location standards to be evaded, or for uncertified products to be substituted for certified ones, at various points in production supply chains.

In the fisheries sector, the MSC is the most important certification body. <sup>n33</sup> Fisheries certifications, like many forestry ones, often promote [\*430] eco-labeling of final consumer products. There is little doubt that this has increasingly become an important part of the marketing process in response to consumer demand. <sup>n34</sup> MSC has brought together various constituencies from both the public interest sphere--academia, environmental NGOs, and public interest groups--and the commercial sphere--retail, fishermen, and Multinational Corporations (MNCs)--to develop such arrangements. <sup>n35</sup> Much like the forestry certification bodies that we have seen above, MSC works on the basis of a broad-spectrum alliance, and has cultivated connections with large fish processing corporations that have been central in demanding certification for the products that they process and sell. <sup>n36</sup> The inclusion of the major players in these certification schemes carries both positive and negative connotations. On the positive side, many of these actors are interested in developing at least a sustainable market for higher priced products. This in and of itself is a positive--a demand-driven mechanism that would appear to bode well for environmental conservation and the abatement of health risks. On the other hand, the actual effects on conservation and sustainability have not been nearly as pronounced as they were expected to be. <sup>n37</sup> The risk of fraud remains high--both as a real phenomenon and as a public or industry perception--potentially undermining confidence in existing schemes and processes. The chief executive of the MSC, Rupert Howes, stated that

as the momentum behind the MSC programme increases and market demand for MSC-certified products grows, so too does the incentive for fraudulent use of the MSC ecolabel. DNA testing helps build public confidence in product sourcing and labeling claims. Traceability is an essential business requirement and the MSC will continue to develop systems that help protect our partners' investment, markets and reputation. <sup>n38</sup>

Certification in fisheries is more complex than in the forest sector; oceans and rivers within which fish move are typically more difficult to control and monitor. Ownership and management of fish stocks are, therefore, targeted by certifying "a combination of site, species, and fishing [\*431] gear, making its object of governance a fluid hybrid of cartography, ecological taxonomy and technology." <sup>n39</sup> Thus, the result is the certification of a fishery rather than of a geographical space. Sometimes within such a space, we can find various certified fisheries. These differences play a critical role in the MSC approach, and therefore "the precise assessment of a fishery will vary with the nature of the species, the capture method used, the ecology of the fishery, etc." <sup>n40</sup>

Within this scheme some marketing practices are condoned, such as the re-branding of less desirable species. This has led to outcomes such as consumers thinking they are eating a type of sea bass when they order Chilean sea bass, but are really having Patagonian Toothfish. **While re-branding can be harmless to consumers' health and safety, if not necessarily to fish-stocks, the mislabeling of fish products is a more serious practice that can lead to a variety of wide-ranging consequences; it is typically illegal in most countries.** <sup>n41</sup> These consequences--including health risks associated with allergies, food borne illnesses, and high levels of mercury <sup>n42</sup> or pesticides, <sup>n43</sup> associated with illegal product substitution--are more worrisome byproducts of product fraud and adulteration. In extreme cases--as with the 2007 poisonings due to the presence of mislabeled puffer fish toxins--consumers' lives may be endangered. <sup>n44</sup>

[\*432] The existing international regulatory and certification system does not help in the process of tackling shortcomings, such as those associated with product substitution. <sup>n45</sup> For example, while the Codex Alimentarius <sup>n46</sup> of the Food and Agriculture Organization (FAO) sets clear standards for labeling, individual countries are often less open with their practices. <sup>n47</sup> Furthermore, while labeling regulation tends to apply to the wholesale end of business, the retailers and restaurants are much less regulated and are capable of substituting inexpensive items for expensive

certified menu items. Despite the presence of certification systems, this leaves consumers in a conundrum regarding the source, and therefore the potential health and environmental risks, associated with purchasing or consuming certain products. <sup>n48</sup>

Thus, in both the forestry and fishery cases, traceability is key to determining that the final product sold in stores is the one that was certified in the field. This is especially important where certified products enjoy a price premium over non-certified products in stores--a financial incentive for fraud and mislabeling through the substitution of non-certified goods for certified ones.

#### IV. ENHANCED TRACEABILITY THROUGH DNA BARCODING

As recent scandals in areas such as dairy and beef products, in a wide variety of countries and settings have shown, existing natural resource and agricultural certification systems remain prone to failure. <sup>n49</sup> Until recently, the only way to bolster the efficacy of such schemes was to increase the number and frequency of inspections, placing a great deal of stress on the administrative capacity of certifying bodies and increasing the cost of certification substantially, often beyond the price advantage a certified good might enjoy. Such efforts are often viewed as counter-productive, undermining consumer, producer, and retailer support for such schemes, as well as the trust relationships that underpin most existing certification systems. <sup>n50</sup>

[\*433] Recent developments in biotechnology provide several means for overcoming many issues with existing certification processes. Molecular DNA technology in particular has developed rapidly over the last decade, and applied genomics has developed a series of transformative technologies for product and process regulation. <sup>n51</sup> These are similar to the well-known advancements in forensic DNA analysis, which have provided a range of new tools to criminal investigation agencies and have enhanced their ability to identify and apprehend criminals. <sup>n52</sup> Much of the process is based on genotyping: determining the differences in the genetic make-up of an individual sample by comparing it to reference, or "base-line," background data that is collected from specific plants and animals in specific regions or locales. It is now possible to use molecular markers to trace the origin of many imported products, such as timber, fish, coffee, palm oil, organic foods, GMO foods, meat, and other products. This enhanced traceability can clarify a potential illegal origin, or illegal production practice, for various products--like meat or fish "from farm to store." <sup>n53</sup> Additionally, recent events, like the emergence of bovine spongiform encephalopathy (BSE), have fostered the emergence of stricter or more widespread traceability measures. <sup>n54</sup>

Legislation and market-based initiatives from around the world have increasingly aimed at ensuring a better, and more uniform, control of the journey that products undertake in increasingly globalized production and consumption chains. These efforts are generally aimed at ensuring that consumer choices correspond to consumer expectations, and attempt to maximize a consumer's ability to influence product content, origins, and production processes. However, maximizing the benefits of these choices requires a better definition of food chain traceability, improved enforcement of attendant regulations and standards, and harmonizing [\*434] the practices involved in all of these steps. <sup>n55</sup> Increasing interest in the survival of endangered species, <sup>n56</sup> combating food fraud, <sup>n57</sup> and expanding our taxonomic horizons, <sup>n58</sup> has led to a strong interest in promoting traceability through genetic markers. But until very recently, the regulatory landscape favored a more on-demand approach--in the case of Europe--or even a voluntary one--in the case of the United States.

A critical moment in the process came in 2005, when the European Union and the United States implemented full traceability requirements in their food chains. <sup>n59</sup> In 2005, the European Union established a "farm to fork" traceability model. <sup>n60</sup> This regulation demands that, even in the absence of a consumer request, food and feed operators within the European Union must be able to establish a full traceable link for their products. This ended the consumer driven on-demand system and implemented a much stronger one. <sup>n61</sup>

In the United States, the traceability model was based on a voluntary system until 2005, when the enactment of the Bioterrorism Act made food and feed traceability the new standard. <sup>n62</sup> As the technology in the field of DNA

barcoding progresses, the options it offers increasingly match the requirements of the increased traceability. Finally, because of the increased reliability and scope of DNA barcoding, in October, 2011 the U.S. Food and Drug Administration (FDA) approved the use of this technology as a tool to prevent the importation of mislabeled seafood into the United States. <sup>n63</sup> These moves will encourage the use and dissemination of these technologies, and their integration into existing schemes as both a supplement and substitute for existing procedures and techniques.

[\*435] Biological markers can be used to trace an animal from farm to store. More significantly, for future traceability regimes, many products carry a built-in unique genetic identifier or "DNA barcode." <sup>n64</sup> This DNA barcode cannot be manipulated and can unequivocally establish a product's identity and origin, without the need for costly intermediate supply chain inspections and monitoring. Recently developed 'omics-based marker technologies provide a promising way to enhance the reliability and effectiveness of certification, at relatively little cost. <sup>n65</sup> These technologies, linked to genomics, proteomics, metabolomics, and transcriptomics all involve the use of cellular level identifiers in specific products, which can be used to confirm their, identity, origins, and purity. <sup>n66</sup> Because of the way DNA is inherited, it also offers a means of linking individual animals or plants to their parents or location of origin. <sup>n67</sup> When this is coupled with information about expressed traits--e.g., tenderness and marbling in meat--the parts of the DNA that are closely associated with the expressed variation, or even the specific genes controlling such traits, can be determined and certified. <sup>n68</sup> They enhance traceability in supply chain oversight in two ways: first, only an original and a final product sample would be required to test to adulteration and substitution, and; second, even where more detailed knowledge [\*436] is required in order to correct alterations--as would be the case with tainted food products--this is made simpler and more reliable.

The capacity of DNA barcoding to identify various types of alterations to food and timber, that may not be apparent to the naked eye when these products are processed, is an important advantage in the fight to enforce standards, properly trace products, and implement sustainable methods of resource extraction. Such alterations are very common--for example, when fish are processed into fishsticks, their appearance and identification is altered. Another example is when timber is used with veneers, or other materials, that disguise its appearance. DNA barcoding is thus superior to other techniques designed to enforce standards such as product purity, sustainability, and other factors, which are otherwise unrecognizable.

Wine and olive oil are other good examples. Genomics-based markers can be associated with particular types of olives and grapes, and terroirs <sup>n69</sup> can be used to check final products for adulteration using other species or the same species grown in other areas. <sup>n70</sup> The same logic and techniques can be applied to many other products. For example, to distinguish between fish raised in fish farms and on the open ocean, or--in the case of tropical timber smuggling--between timber taken from a specific type and location of tree. As one commentator has argued, as the common link in the "gate to plate" continuum, DNA barcoding is becoming a must-have management tool for the future to improve, authenticate, trace, and verify product quality and origin in both forward and reverse. <sup>n71</sup> DNA barcoding links both the current handler, and the future one, in the production or retail chain in one continuous, seamless traceability process. <sup>n72</sup> This is most often understood as the "one step forward, one step back" model where product information is collected both by the shipping company and by the receiving one. <sup>n73</sup>

While the costs of genetic analysis and sampling were once too high to contemplate their large-scale use, costs of DNA sequencing and [\*437] other techniques have dropped dramatically in recent years. This promises much more widespread use to enhance certification accuracy and trust, and eliminate fraud and misrepresentation. <sup>n74</sup>

## V. THE POTENTIAL IN THE FISH AND FORESTRY SECTOR

Some of the applications for DNA barcoding to date have included quarantine processes, <sup>n75</sup> the identification of invasive species, <sup>n76</sup> trees, <sup>n77</sup> fish, <sup>n78</sup> endangered species, <sup>n79</sup> and food, among others. <sup>n80</sup> DNA [\*438] barcoding holds great promise in forestry and fishery management because it allows both for the control of products in regulatory terms--i.e., enabling the reduction of fraud and mislabeling--and for the insertion of higher levels of consumer choice in the process.

The forestry field is an important area of application for traceability technologies--and potentially for DNA barcoding--because of the size of the industry, its impact on the environment, and the difficulties with earlier efforts at traceability. The development of DNA barcoding for plants lagged behind the establishment of the same technology for animals. <sup>n81</sup> In particular, the low rate of sequence evolution in plants' genome hindered the development of effective barcoding, since the range of easily observable variation was smaller. <sup>n82</sup> However, research has increasingly improved the capacity of the method in recent years. <sup>n83</sup>

Literature still differs, however, regarding the capacity of DNA technology to help in forestry traceability. In a study of Amazonian plants, DNA barcoding was helpful in the identification of juvenile plants and in recognizing errors in previous identification. However, it was rather less efficient for identifying collections; the study authors believed this to be a likely limiting factor in implementing DNA-based tropical plant biodiversity programs. <sup>n84</sup> In a different study of Panama forestry plots, however, the technology was found to have a higher than 98 percent success rate in identifying plants. <sup>n85</sup> While these studies have an important scientific resonance, the capacity of developing countries to enter and maintain a strong certification scheme that highlights sustainability is limited. On the other hand, the success of schemes--like the MSC--and the policies of some large retailers--like IKEA--to source sustainable products, demonstrate that consumer demand can have important effects on the industry.

In a related study, barcoding was used to identify ferns in U.S. nurseries where some plants were found to be non-native exotic species. <sup>n86</sup> [\*439] The University of Trieste used a panel of microsatellites to test the origins of 33 commercial cultivars of *C. Arabica*, and thirteen interspecific coffee hybrids collected in America, India and Africa with almost 100 percent success. With respect to timber, however, several experts have noted that DNA markers can be used to identify morphologically similar species, in order to prevent the illegal trade of species protected under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)--such as *Aquilaria* and *Cedrela* species. <sup>n87</sup> Barcoding in the North American solid wood sector, however, still has a large unexploited potential: recently it was only the third most used tracking method at 14.2 percent, behind paint daubs at 30.3 percent, and labels at 29.3 percent. <sup>n88</sup>

Molecular biology in general, and DNA barcoding in particular, also show a lot of promise in tackling problems in the fishery sector. <sup>n89</sup> Fish have been heavily classified in terms of barcoding through the FISH-BOL, <sup>n90</sup> and SHARK-BOL projects, <sup>n91</sup> and through a variety of regional research projects. <sup>n92</sup> In general, DNA tools have great potential in the fight against illegal, unreported and unregulated (IUU) fishing. <sup>n93</sup> The development of extensive gene mapping projects for tropical ornamental fishes, and for stocks managed for human consumption, has been the basis of implementing strong traceability and prevention measures to stop unsustainable practices. For example, the capacity to immediately identify non-compliant ornamental fish provides a critical tool for enforcement agencies to limit, or altogether eliminate, the potential profit that is often associated with IUU practices. At the same time, the capacity to identify shark species through DNA barcoding should be an important step in initiating checks on the flourishing, but unsustainable, shark fin market in Asian countries.

[\*440] Examples of success in this area include DNA barcoding traceability work of Amazonian fish by analyzing catch being sold as Acara" and of other species in Brazilian fish markets, <sup>n94</sup> for American catfish stocks, <sup>n95</sup> and other seafood products. <sup>n96</sup> Fisheries that involve endangered species, or those that may rapidly become unsustainable--like the shark fishery--can benefit from DNA barcoding and DNA identification techniques in general. <sup>n97</sup> These benefits can accrue on a variety of levels. For example DNA barcoding can help classify endangered species to make management of fisheries more rational, <sup>n98</sup> to make it easier to track parts from protected species, <sup>n99</sup> and to make it easier to uncover potentially illegal trade. <sup>n100</sup> Several fisheries are already benefiting from these activities, from the identification of fins from protected shark species in the international market, to the development of more efficient stock management in Icelandic fisheries.

## VI. CONCLUSION: FROM PAPER TO DNA BARCODING

DNA barcoding, and other marker-related genomics techniques, are increasingly used in agricultural production to



trace individual cuts of meat, or to audit conventional meat traceability systems. The science [\*441] behind such techniques is now well known. The potential for their application to the natural resources sphere, however, is just now being recognized. Such applications in some cases require further technological advances--such as the development of hand-held or inexpensive field testing equipment. These advances await demand from regulatory agencies and certifiers in the impacted sectors like forestry and fisheries, <sup>n101</sup> or the development of appropriate geographic 'base-line' data on species' origins. <sup>n102</sup>

Within this context, a variety of technologies--including RFID, DNA fingerprinting, DNA barcoding, biochemical tools and others--are generally available and can be highly efficient in improving certification efforts, reducing costs, and improving the accuracy of certification schemes. Not every product is equally amenable to DNA barcoding. <sup>n103</sup> But where it is, it can help supply chain monitoring systems remain uncompromised over the many steps of the supply chain, and through many form changes, until a consumer purchases a product. It offers the possibility of a built-in traceability verification tool that cannot be removed like a paper barcode, and is not destroyed or altered by production processes.

Scientific work continues to accumulate relevant base-line data, and DNA technology has continued to improve in recent years, showing no sign of slowing down. The cost of equipment, and of taking a DNA sample, is declining rapidly; it is now frequently associated with existing management procedures, such as on farm procedures resulting in a sample of blood being available--e.g., ear tagging or some forms of tail docking. <sup>n104</sup> The cost of genotyping DNA samples is also declining rapidly as new genotyping tools come on-stream, and improved techniques provide an increasing amount of information from a single analysis. <sup>n105</sup> Such technologies are not foolproof, and the possibility of laboratory fraud or malfeasance is always present. But these technologies will greatly simplify the task of inspecting and monitoring production processes and supply chains for many products, enhancing the reliability of, and confidence of consumers in, resource certification systems.

### Legal Topics:

For related research and practice materials, see the following legal topics:

Environmental Law  
National Environmental Policy Act  
General Overview  
Governments  
Agriculture & Food  
General Overview  
Torts  
Strict Liability  
Harm Caused by Animals  
General Overview

### FOOTNOTES:

n1 "Omics" is the shorthand that is used in the field to describe the broad (albeit interconnected) field of proteomics, genomics, metabolomics, etc.

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n10 Graeme Auld & Lars H. Gulbrandsen, *Transparency in Nonstate Certification: Consequences for Accountability and Legitimacy*, 10 GLOBAL ENVTL. POL. 97 (2010); Magnus Boström, *How State-Dependent is a Non-State-Driven Rule-Making Project? The Case of Forest Certification in Sweden*, 5 J. ENVTL. POL'Y & PLANNING 165 (2003); MICHAEL DILLON & MICHAEL THOMPSON, *Developing and Implementing an Effective Traceability and Product Recall System*, in FOOD AUTHENTICITY AND TRACEABILITY 496-506 (2004).

n11 Auld & Gulbrandsen, *supra* note 10; Grant H. Shackell, *Traceability in the Meat Industry - The Farm to Plate Continuum*, 43 INT'L J. FOOD SCI. AND TECH. 2134 (2008).

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Laegreid & Lise Helleb Rykkja, *Regulation for Safe Food: A Comparison of Five European Countries*, 31 SCANDINAVIAN POL. STUDIES 125 (2008); Jahn, Schramm & Spiller, *supra* note 3, at 69.

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