

Institution: University of East Anglia		
Unit of Assessment: 5 – Biological Sciences		
Title of case study: NatureMetrics: a technology spin-out company using environmental DNA to provide cost-effective environmental impact assessment		
Period when the underpinning research was undertaken: 2012 - 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title)	Period(s) employed by submitting HEI:
Professor Douglas W. Yu	Professor of Ecology	2000 - present
Period when the claimed impact occurred: 2016 - 2020		
Is this case study continued from a case study submitted in 2014? No		
1. Summary of the impact		
<p>Yu has pioneered the use of environmental DNA samples to measure the compositions of ecological communities. In 2016, Yu co-founded NatureMetrics Ltd, the first commercial UK provider of DNA metabarcoding analyses to the global environmental impact assessment market. NatureMetrics enables clients to measure biodiversity with higher efficiency across the lifecycle of infrastructure projects, from pre-project baselines to post-project habitat restoration. NatureMetrics has grown very rapidly. By the end of the third full year of operation (2019), it had doubled gross profit. In 2019, a Series A investment funding round valued NatureMetrics at GBP7,500,000. Revenue in 2020 was GBP1,000,976, which exceeded 2019 revenue despite the COVID-19 pandemic. As of December 2020, the company had 33 employees, including 15 with PhDs. The company has also had substantial impacts via its clients. It has analysed over 8,000 environmental samples from more than 15 countries across the globe for over 90 clients, benefiting governments, corporations, NGOs and the environment.</p>		
2. Underpinning research		
<p>Governments, lenders, consumers and the public mandate that society monitor and mitigate the impact of human activities on biodiversity, and private businesses are increasingly pledging “No Net Loss” or even “Net Gain” in biodiversity as a result of business operations. To achieve these goals, practitioners must be able to measure biodiversity accurately. However, measuring biodiversity and change in biodiversity ("biomonitoring") is a labour-intensive, error-prone and costly process. For instance, conventional surveys of fish biodiversity require multiple rounds of electrofishing and netting and still fail to detect most fish species present.</p>		
<p>In 2012, Yu led one of the first experimental tests showing that "metabarcoding" of mass-trapped organisms (in this case, arthropods) could recover accurate estimates of species diversity and composition. Metabarcoding involves the use of the polymerase-chain reaction (PCR) to amplify gene fragments, followed by high-throughput DNA sequencing, allowing the many organisms present in a mass sample to be identified. This paper [R1] was included in the 2014 “Top Methods” issue of the journal <i>Methods in Ecology and Evolution</i>.</p>		
<p>In 2013 and 2014, Yu conducted follow-up studies [R2, R3] that compared metabarcoded mass-trapped arthropod samples (insect "soups") against gold-standard, morphology-based biodiversity datasets comprising tens of thousands of arthropod specimens and bird observations identified to species level by expert taxonomists using thousands of person-hours of effort. These studies</p>		



showed that the metabarcode datasets produced estimates of species diversities and compositions highly similar to those produced by morphological identification. Crucially, the studies also showed that the datasets produced similar management decisions for two conservation applications, namely restoration ecology and systematic conservation planning. Relative to the morphology datasets, the metabarcode datasets were documented to be many times quicker and cheaper to produce, while also being auditable by third parties and less reliant on scarce taxonomic expertise.

Yu's research [R1-R3] provided some of the earliest evidence that metabarcoding can be a reliable and efficient method for biomonitoring of animals, plants and fungi, with direct application to environmental impact assessment. These studies, plus research by Dr Catharine (Kat) Bruce in a PhD studentship supervised at UEA by **Yu** [Grant A] and published in [R2] and [R4], provided the justification, evidence and credibility that led to **Yu**, Bruce and Professor Alfried Vogler (Imperial College) winning a NERC Follow-on-Fund grant in 2015 [Grant B] to co-found NatureMetrics Ltd. Bruce was the CEO for the first four years, and **Yu** and Vogler are members of the scientific advisory board.

In a parallel development, in 2008 molecular ecologists started reporting that trace amounts of DNA in the environment can be detected via quantitative PCR and metabarcoding. Such "environmental DNA" (eDNA) comes, for example, from organismal secretions dissolved into water (e.g. mucus shed by fish or amphibians) or from organismal tissue released externally by other means (e.g. residual vertebrate bloodmeals in leeches). In particular, it was found that eDNA sampled from water bodies can be used to detect, identify and partially quantify the abundance of aquatic vertebrates, especially fish species. **Yu** co-authored a highly-cited review that showcased potential uses of eDNA [R5] and lead-authored a research study showing that accurate estimates of fish abundances are achievable using quantitative PCR of eDNA present in streamwater samples [R6]. The combination of metabarcoding and eDNA is revolutionising biomonitoring, especially in aquatic habitats, which were previously some of the most difficult habitats to survey and are now among the most straightforward.

Image: Great Crested Newts. *Credit:* Bouke ten Cate - Own work, CC BY-SA 4.0, <https://commons.wikimedia.org/w/index.php?curid=75475057>.

3. References to the research

Underpinning research: The six outputs underpinning the research have all been published in competitive, international peer-reviewed journals, with three of them having been cited more than 400 times each (citation numbers are from Google Scholar; UEA author names are in bold):

- R1 **Yu DW**, Ji YQ., **Emerson BC**, Wang XY, Ye CX, Yang CY, Ding ZL (2012) Biodiversity soup: metabarcoding of arthropods for rapid biodiversity assessment and biomonitoring. *Methods in Ecology & Evolution*, 3: 613-623. DOI:10.1111/j.2041-210X.2012.00198.x [453 citations]
- R2 Ji YQ, Ashton L, **Pedley SM**, Edwards DP, Tang Y, Nakamura A, Kitching RL, **Dolman, P**, Woodcock P, Edwards FA, Larsen TH, Hsu WW, Benedick S, Hamer KC, Wilcove DS, **Bruce C**, Wang XY, Levi T, **Lott M**, Emerson BC, **Yu DW** (2013) Reliable, verifiable and efficient monitoring of biodiversity via metabarcoding, *Ecology Letters*, 16: 1245-1257. DOI:10.1111/ele.12162 [428 citations]
- R3 Edwards, DP, Magrach A, Woodcock P, Ji, YQ, Lim NTL, Edwards FA, Larsen TH, Hsu W, Benedick S, Khen CV, Chung AYC, Reynolds G, Fisher G, Laurance W, Wilcove DS, **Yu DW** (2014) Selective-logging and oil palm: multitaxon impacts, biodiversity indicators, and trade-offs for conservation planning. *Ecological Applications*, 24: 2029-2049. DOI:10.1890/14-0010.1 [76 citations]
- R4 Barsoum N, Bruce C, Forster J, Ji YQ, **Yu DW** (2019) The devil is in the detail: Metabarcoding of arthropods provides a sensitive measure of biodiversity response to forest stand composition compared with surrogate measures of biodiversity. *Ecological Indicators*, 101: 313-323. DOI:10.1016/j.ecolind.2019.01.023 [13 citations]

- R5 Bohmann K, Evans A, Gilbert MTP, Carvalho GR, Creer S, Knapp M, **Yu DW**, de Bruyn, M (2014) Environmental DNA for wildlife biology and biodiversity monitoring. *Trends in Ecology & Evolution*, 29: 358-367. DOI:10.1016/j.tree.2014.04.003 [614 citations]
- R6 Levi T, Allen JM, Bell D, Joyce J, Russell JR, Tallmon DA, Vulstek SC, Yang CY, **Yu DW** (2019) Environmental DNA for the enumeration and management of Pacific salmon. *Molecular Ecology Resources* 19: 597-608. DOI:10.1111/1755-0998.12987 [24 citations]

Funding: Funding for the research came from a UKRI Research Council PhD studentship [Grant A] and from UKRI Research Council Follow-on Funding [Grant B]: Grant A: Primary supervisor: **DW Yu**. Title: *From metacommunity dynamics to rapid biodiversity assessment: DNA-based approaches expand horizons in both fundamental and applied ecology*. Funder: NERC PhD Studentship to Catharine Bruce. Project dates: 2010-2014. Value GBP59,951; Grant B: PI: **DW Yu**. Title: *High-throughput, DNA-based biodiversity assessment and detection for the environmental consultancy market*. Funder: NERC Follow-on-Fund. Project dates: 30 June 2015 – 29 June 2016. Total value: GBP197,612 between UEA and Imperial College (GBP81,085 to UEA).

4. Details of the impact

Yu's research has had a large number of impacts on a global scale, including the direct impacts of NatureMetrics Ltd on commerce and the economy, which have been followed by downstream impacts via the effects of NatureMetrics on clients, practitioners, production, public policy and the environment.



Direct impact on commerce and the economy: NatureMetrics began trading in 2016, starting with the use of aquatic eDNA to detect Great Crested Newts at building sites. Related to this, NatureMetrics developed a filter kit for aquatic eDNA and filed a patent, now at international application Patent Cooperation Treaty (PCT) stage (WO2020128503A1). The company has grown very rapidly. By 2019, its third full year of operation, it was processing 4,750 samples from 92 clients and over 15 countries, with approximately 60% of revenue coming from commercial organisations, 20% from government, 10% from NGOs and 10% from grant-funded projects [S1a]. In 2020, despite the COVID-19 pandemic, it processed 3,285 samples from 90 clients [S1b], with approximately 68% of revenue coming from commercial organisations, 6% from government, 8% from NGOs, 10% from grant-funded projects and 8% from universities and research institutes [S1a]. By the end of 2019, it had doubled gross profit [S1b]. In June 2019, NatureMetrics raised GBP2,500,000 [S1c] in a Series A investment round that was oversubscribed by 2.5 times, valuing the company at GBP7,500,000 [S1d]. NatureMetrics then implemented a growth plan, which has been slowed but not interrupted by the COVID-19 pandemic. Revenue in 2019 was GBP713,796, and revenue in 2020 was GBP1,000,976 [S1b]. The company's size in terms of numbers of people employed has also increased rapidly. As at December 2020, NatureMetrics had 33 employees (headcount 33, FTE 31.4), including 15 with PhDs (headcount 15, FTE 14.8) [S1e].

Impacts on clients, practitioners, production, public policy and the environment: NatureMetrics helps clients undertake work that would be far more costly, or outright impossible, without the company's services. The eDNA sampling kits and analysis services offered by NatureMetrics make biomonitoring safer for clients and their employees to conduct in challenging natural environments. The following is a selection of leading examples of clients and spheres of activity that have benefited from NatureMetrics:

NatureSpace Partnership: NatureMetrics is a key service provider to and investor in the NatureSpace Partnership, a private company operating the UK's largest biodiversity offset market. NatureMetrics's eDNA service makes it possible for NatureSpace to rapidly survey hundreds of ponds to model the distribution of the Great Crested Newt, a species protected in the UK under the Wildlife and Countryside Act, 1981. Builders in surveyed areas can buy a licence to offset the effects of developments on Great Crested Newt populations, the fee rising with their modelled

impact on the newt. This arrangement reduces costs and risk compared to newt relocation, while also funding the creation of four new ponds per affected pond. As of 2020, NatureSpace have raised GBP1,000,000 and created 100 new ponds, operating across 40 Local Planning Authorities in the UK. As NatureSpace Partnership's Chief Executive has stated, "*Without NatureMetrics' technical expertise and early investment, we would not have succeeded*" [S2].

Environmental Resources Management: NatureMetrics gives the multinational environmental consultancy ERM "*a competitive edge over consultants using conventional survey techniques alone,*" as stated by ERM's Chief Ecologist [S3]. A large part of ERM's work consists of surveys of aquatic habitats to establish baselines for future monitoring (e.g. to detect pollutant spills), to identify offset sites and to select amongst alternative project sites. In 2016-17, ERM piloted NatureMetrics's kits in Sierra Leone. Relative to their standard methods, ERM sampled more safely, covered a larger area, detected four times as many fish species and halved survey costs [S3]. In 2020, ERM used NatureMetrics for surveys in Russia and Serbia and is now considering eDNA for further projects around the world. As ERM's Technical Director stated, "*ERM believes that eDNA provides both business and conservation benefits, and NatureMetrics role in developing the new technology has included assisting ERM to become a more informed consumer and user of eDNA*" [S3].

Environmental charities: In 2019, the Freshwater Habitats Trust (FHT) used NatureMetrics's kits to survey 21 New Forest sites where they had data from conventional surveys. Using eDNA, volunteers were able to detect more species and "*[a]t low cost, collected data in a couple of days from a network of stream sites that would otherwise have taken a conventional 2-3 person survey team most of the summer to visit,*" as stated by FHT's Director [S4].

Internationally, in 2018, Worldwide Fund for Nature (WWF) Peru surveyed a 390 km stretch of the Marañón River in Amazonian Peru and "*fully achieve[d] their survey goal of detecting the spatial distributions of six culturally and commercially important aquatic species..., and we exceeded our goal by also detecting hundreds of additional vertebrate species, which we can now start to take into account in designing a sensitive index of basin-ecosystem health....NatureMetrics has made it possible for WWF Peru to generate baseline biodiversity data much more efficiently and comprehensively,*" as stated by WWF Peru's Associate Ecosystem Services Research Officer [S5].

In 2020, Fauna and Flora International (FFI) collected aquatic eDNA in the transboundary Wonegizi-Ziama Massif Protected Areas between Guinea and Liberia. A total of 112 vertebrate species were detected, including the endangered White-bellied Pangolin. As FFI's Senior Programme Manager for West and Central Africa stated, "*The key benefits to FFI are increased biodiversity data...reduced survey costs...and ease of sampling...[W]e can increase the...coverage of our sampling at a reduced cost, and we can more fully involve local people in conservation monitoring*" [S6].

The British Trust for Ornithology (BTO) is using NatureMetrics's metabarcoding service for arthropods to measure the efficacy of restoration projects in Polesia (a wetland running from Poland to Russia). Reduced costs allowed doubling of sample size from 120 to 240 sites. As BTO's Senior Research Ecologist stated, "*Without NatureMetrics, we at BTO would not have had the capacity to carry out this part of the project, whereas with NatureMetrics, we anticipate an increased probability of success in achieving the aims of the Polesia project*" [S7].

Regulatory standards-setting and end-user education: In her role as NatureMetrics's first CEO, from 2017-2020, Bruce co-led a working group of a European Union Cooperation in Science and Technology (EU COST) action, DNAqua.Net, that submitted to the European Committee for Standardization the first European Standard related to eDNA [S8]. Bruce will also be on the steering committee of the soon-to-be-launched UK Business and Biodiversity Forum, a government-supported initiative exploring ways businesses can act to reverse biodiversity declines. In 2019, Yu wrote a contracted "Think Piece" for the UK Government's Environment Agency for England to design an R&D strategy for incorporating DNA-based methods in the

agency's reporting [S9]. Lastly, in 2020, NatureMetrics was competitively selected as one of five small companies to join the UK's High Speed 2 rail (HS2) Innovation Accelerator programme, the purpose of which is to accelerate the uptake of new technologies in building the HS2 railway. NatureMetrics was chosen to ensure the quality of HS2's green corridor, including newly-created woodland [S10].

5. Sources to corroborate the impact

S1 NatureMetrics financial and size data:

- a. E-mail from Business Development Director, NatureMetrics (6.11.20).
- b. NatureMetrics Shareholders' Report, Q4, 2020.
- c. Article from UK Business Angels Association (UKBAA) on NatureMetrics (8.7.19).
- d. Investors' document (2019) with calculation of company valuation.
- e. Letter from the Operations Director of NatureMetrics with December 2020 data on employee number (25.1.21).

S2 Letter from the Chief Executive of NatureSpace Partnership, Stamford (20.10.20).

S3 Letters from the Chief Ecologist (17.4.19), and the Technical Director (22.10.20), of Environmental Resources Management, Edinburgh.

S4 Letter from the Director of Freshwater Habitats Trust (15.4.19).

S5 Letter from the Associate Ecosystem Services Research Officer, WWF Peru (17.4.19).

S6 Letter from the Senior Programme Manager for West and Central Africa, Fauna and Flora International (2.11.20).

S7 Letter from the Senior Research Ecologist, British Trust for Ornithology (28.10.20).

S8 Working draft of European Committee for Standardization (CEN) Standard: *Water sampling for capture of microbial environmental DNA in aquatic environments*. New Work Item Proposal N 1229 in Technical Committee (TC) 230 (working group 28), pp. 3-10; and the UK Government announcement of the proposed standard from standardsdevelopment.bsigroup.com (accessed 14.1.21), p. 11; and the DNAqua.Net list of working group leaders, including Kat Bruce as co-leader of Working Group 3, Field & Lab Protocols from dnaqua.net (accessed 14.1.21), p. 13.

S9 Yu's consultancy contract for the "Think Piece" (pp. 1-2), and Yu DW, Matechou E (2020) *The contribution of DNA-based methods to achieving socio-ecological resilience: "Think Piece"* commissioned by the UK Environment Agency (pp. 3-45).

S10 Webpage announcing selection of NatureMetrics for HS2 Innovation Accelerator programme, mediacentre.hs2.org.uk (accessed 4.11.20). [NatureMetrics is listed fourth in the alphabetical list.]