

Low mislabeling rates indicate marked improvements in European seafood market operations

Stefano Mariani^{1*}, Andrew M Griffiths¹, Amaya Velasco², Kristina Kappel³, Marc Jérôme⁴, Ricardo I Perez-Martin², Ute Schröder³, Veronique Verrez-Bagnis⁴, Helena Silva⁵, Sara G Vandamme¹, Belgees Boufana¹, Rogerio Mendes⁵, Marc Shorten⁶, Cat Smith⁶, Elizabeth Hankard¹, Samantha A Hook¹, Alice S Weymer¹, Daryl Gunning⁶, and Carmen G Sotelo²

Over the span of a decade, genetic identification methods have progressively exposed the inadequacies of the seafood supply chain, revealing previously unrecognized levels of seafood fraud, raising awareness among the public, and serving as a warning to industry that malpractice will be detected. Here we present the outcome of the latest and largest multi-species, transnational survey of fish labeling accuracy to date, which demonstrates an apparent sudden reduction of seafood mislabeling in Europe. We argue that recent efforts in legislation, governance, and outreach have had a positive impact on industry regulation. Coordinated, technology-based, policy-oriented actions can play a pivotal role in shaping a transparent, sustainable global seafood market and in bolstering healthier oceans.

Front Ecol Environ 2015; 13(10): 536–540, doi:10.1890/150119

In little more than a decade, the rapid and widespread use of genetic identification protocols has transformed food authenticity testing from a niche area into a highly influential biotechnological application worldwide (Ogden 2008; Yancy *et al.* 2008; Lou 2015). Although livestock and agricultural products remain the main focus of certification schemes and trading standards controls (European Commission's Database of Origin & Registration; <http://ec.europa.eu/agriculture/quality/door/list.html>), the most notable changes in perception and attitude have been observed with seafood. Over half the seafood intended for direct human consumption is still “hunted and gathered” from wild communities and populations (FAO 2014), over which humans cannot exert the control afforded in the case of farmed organisms. Seafood identification investigations across the world unveiled a presumably long-standing lack of transparency in trade operations (Stanziani 2007), prompting extensive media coverage (Mariani *et al.* 2014), swaying public opinion, alerting conservation groups (Warner *et al.* 2013), and urging policy makers and governments to find rapid and effective solutions (FSAI 2012; FDA 2014).

Despite these developments, most seafood identification studies conducted so far tended to have a relatively narrow focus, either adopting a regional slant (eg Miller

and Mariani 2010) or targeting specific products and/or conservation concerns (eg Logan *et al.* 2008). Sampling effort and design of these studies also lacked the scope and rigor required to realistically represent the status of seafood authenticity in an entire sector of a major economy. Here, we present results of the largest seafood authenticity investigation conducted to date, spanning six European countries and nine different seafood products/species (Table 1). The analysis was designed to determine the current level of labeling accuracy in wild fisheries products in the European Union (EU) mainstream seafood retail sector, and to examine labeling accuracy in the context of EU regulations, the public perception of seafood authenticity, and similar recent multi-state, multi-species surveys conducted in North America (Warner *et al.* 2013; FDA 2014; Khaksar *et al.* 2015).

Methods

We obtained fresh, frozen, and tinned products labeled as “cod” (*Gadus* spp), “tuna” (*Thunnus* spp), “haddock” (*Melanogrammus aeglefinus*), “anchovy” (*Engraulis* spp), “hake” (*Merluccius* spp), “monkfish” (*Lophius* spp), “plaice” (*Pleuronectes platessa*), “swordfish” (*Xiphias gladius*), and “sole” (*Solea solea* in Germany; *S. solea* for “Dover sole”, *Microstomus kitt* for “lemon sole”, and *Limanda aspera* for “yellowfin sole” in the UK) – and/or using the corresponding, accepted market names in each respective country – from retailers in 19 cities in France, Germany, Ireland, Portugal, Spain, and the UK (Table 1) between 2013 and 2014 (WebTable 1). Samples of cod and tuna, the most popular finfish products consumed in Europe, were collected in all countries, while other species were

¹Ecosystems & Environment Research Centre, School of Environment & Life Sciences, University of Salford, Greater Manchester, UK (*s.mariani@salford.ac.uk); ²Instituto de Investigaciones Marinas (CSIC), Vigo, Spain; ³Max Rubner-Institute, Department of Safety and Quality of Milk and Fish Products, Kiel, Germany; ⁴Ifremer, rue de l'Île d'Yeu, Nantes, France; ⁵Portuguese Institute for the Sea and Atmosphere, Lisbon, Portugal; ⁶Indigo Rock Marine Research Station, Cork, Ireland

also selected to cover a broad spectrum of popular finfish on offer in Western Europe. To ensure proper replication and extensive spatial coverage, we surveyed between two and four cities within each country (Table 1). In each of the cities, sampling was conducted over a wide metropolitan area and included collection of products from supermarkets, traditional markets, and specialized fishmongers. Collected tissue samples were stored in molecular-grade ethanol, and were subsequently transferred to the laboratory and genetically identified using a suite of established molecular and bioinformatics procedures (details in WebPanel 1).

Results and discussion

High-quality DNA sequence data were obtained for 1563 samples, of which only 77 (4.93%) proved to be mislabeled under European law (see WebTable 1). For each country, overall mislabeling rates were 2.7% (France), 3.25% (UK), 3.9% (Ireland), 6.21% (Germany), 6.7% (Portugal), and 8.9% (Spain) (Figure 1). Out of 15 possi-

ble inter-country pairwise comparisons, percentages were significantly different only between Spain and France ($\chi^2 = 10.9$; degrees of freedom [df] = 1; $P = 0.02$) and Spain versus the UK ($\chi^2 = 5.18$; df = 1; $P = 0.001$). However, this difference was caused by the high mislabeling incidence in Spanish tinned anchovy products, six of which had to be deemed mislabeled purely because the word “anchoa”, rather than “anchoas”, was used on labels containing non-European *Engraulis* species. If these six samples are not taken into account, the Spanish mislabeling rate drops to 6.74% and becomes statistically indistinguishable from all others. Sampling effort did not explain variance in mislabeling rates among either countries (Spearman's $r = 0.08$, $P = 0.84$) or seafood products ($r = 0.10$, $P = 0.77$), and no effect of retail product type was detected, including in the largest and most diverse category of mislabeled samples: tinned versus fresh/frozen tuna products ($\chi^2 = 0.36$, $P = 0.54$). The city of Vigo was the only place where yellowfin tuna (*Thunnus albacares*) was on occasion found to be replaced by albacore (*Thunnus alalunga*) and where other *Thunnus* species

Table 1. Summary of seafood product genetic identification across retailers from 19 European cities between 2013 and 2014

	Cod	“Tuna”	Haddock	Anchovy	Hake	Monkfish	“Sole”	Plaice	Swordfish	TOTAL	(mislab)
UK (647/21)											
Cardiff	35	42	33			12			5	127	(6)
Glasgow	30	38	33			12			7	120	(2)
Manchester	40	40	41			20	53	60	8	262	(10)
Plymouth	41	36	40			21				138	(3)
Spain (267/24)											
Bilbao	11	10		12						33	(5)
Madrid	13	20		11						44	(2)
Santiago de Compostela	50	27		15						92	(3)
Vigo	48	30		20						98	(14)
Ireland (180/7)											
Cork	21	27	20			16				84	(6)
Dublin	35	26	28			7				96	(1)
Portugal (178/12)											
Faro	14	11			5					30	(3)
Lisbon	33	46			18					97	(6)
Porto	24	14			13					51	(3)
France (146/4)											
Boulogne sur Mer	22									22	(0)
Marseille	4	59								63	(4)
Nantes	22	39								61	(0)
Germany (145/9)											
Berlin	8	20					3			31	(1)
Frankfurt	6	12					5			23	(2)
Hamburg	28	55					8			91	(6)
Total	485	552	195	58	36	88	69	60	20	1563	(77)
Mislabeled rate	3.50%	6.88%	3.07%	15.5%	11.1%	0%	2.89%	0%	0%		

Notes: Partial country-specific sampled/mislabeled ratios are reported in parentheses adjacent to country names. Numbers in parentheses appearing in the “(mislab)” column refer to city-specific mislabeling levels. Product-specific mislabeling levels are summarized along the table's bottom row.

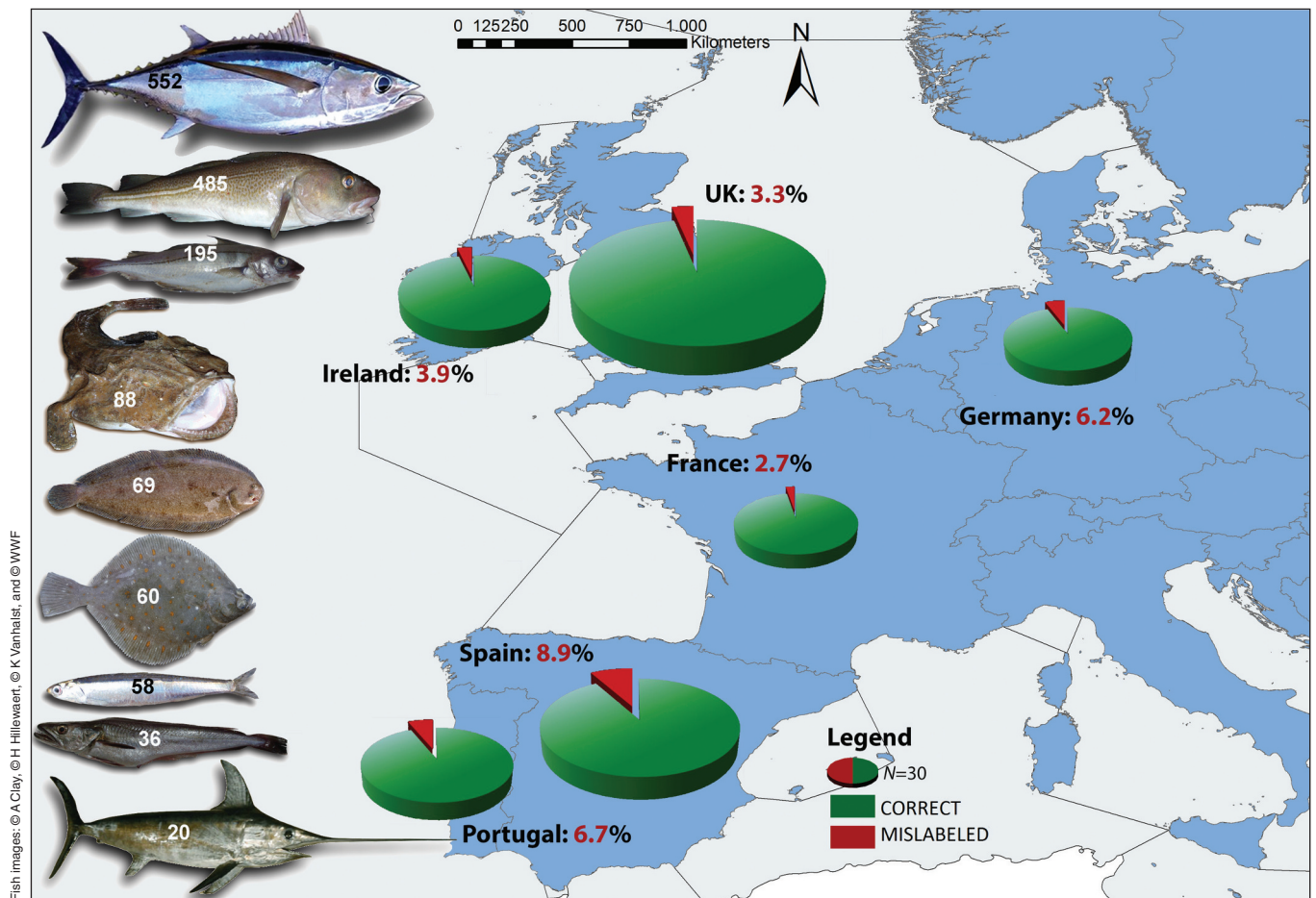


Figure 1. Map summarizing the levels of fish product mislabeling recorded in six European countries. The nine species tested are stacked to the left, with overall sample numbers imprinted on the images. Pie chart size is proportional to the number of samples screened (see chart size corresponding to a sample size of $N = 30$ in the legend). Red segments and percentages indicate mislabeled products.

were used as substitutes for Atlantic bluefin tuna (*Thunnus thynnus*); Manchester and Hamburg had a higher incidence of yellowfin–bigeye tuna (*T. albacares*–*Thunnus obesus*) substitution (WebPanel 1). However, despite our use of a stringent 100% sequence match criterion to define species identity, currently available diagnostic methods – when applied to distinguishing between these closely related species – yield ambiguous results (Viñas and Tudela 2009); thus, caution is warranted in such instances. Overall, no country-associated trends were identified.

A few notable outcomes arise from this study. First, the rate of mislabeling across a considerable portion of the European seafood market is rather low, and decisively lower than that originally documented by the initial wave of seafood identification studies conducted only a few years ago (Logan *et al.* 2008; Wong and Hanner 2008; Miller and Mariani 2010). Interestingly, these current mislabeling rates are consistent with those found in two independent analyses of fish market samples from France (371 samples; Bernard-Capelle *et al.* 2014) and the UK (386 samples; Helyar *et al.* 2014). Together, these results appear to lend support to the suggestion that rapid changes in seafood trade operations may be

influenced in part by mass media coverage (Mariani *et al.* 2014). Although Di Pinto *et al.* (2015) reported high rates of mislabeling in a southeastern portion of Italy, the narrow regional context, the niche market investigated (“perch”, “grouper”, and “swordfish”), and the lack of information on sampling dates make those findings difficult to compare with our broad, standardized, Western European analysis.

A second line of evidence emerging from our Europe-wide dataset contrasts sharply with even the most recent investigations in the US retail sector (Warner *et al.* 2013; Khaksar *et al.* 2015), which document mislabeling rates between 12% and 41%. Even when the US Food and Drug Administration recently applied genetic testing to wholesale seafood products prior to the point of retail (FDA 2014), mislabeling was still around 15%, a rate that is likely to be higher in the retail sector, as the products move farther along the supply chain (Miller *et al.* 2012).

The fact that such low levels of mislabeling, and the underlying mechanisms, appear essentially consistent across several European countries with profound historical and cultural differences in seafood provision and consumption indicates that a common, transnational set of

factors is currently at play in regulating the European market. Media coverage may have had a measurable short-term impact (Mariani *et al.* 2014) in raising consumer awareness and holding industry operators accountable for unacceptable trading standards, but less encouraging results from North America show that mass media and civil society action alone cannot serve as industry regulators (Warner *et al.* 2013). On the other hand, the factor that appears to be driving the difference between Europe and the US is the EU policy-making process, which continues to introduce updated food-labeling regulations to be implemented by member states, with emphasis on standardization and traceability (EC 2013). US federal regulations on food labeling, by contrast, are less detailed, often non-binding (FDA 2014), and inconsistent, with notable

differences in accepted market names of fish observed among US states (Logan *et al.* 2008). Considering that North America mostly lacks the historical, political, and language barriers present in Europe, it is reasonable to expect relatively greater efficiency in the processes of standardization, legislation, implementation, and enforcement in North America than in the EU. Recent efforts advocating for an alignment of US labeling standards with European regulations (Lowell *et al.* 2015) may help promote the necessary steps for a more transparent and accountable retail sector.

Europe and North America play similarly influential roles in the world's seafood trade (FAO 2014), with substantial impacts on natural resources and the global economy. Both regions also act as pivotal research hubs for scientific advancement in this field; thus, positive breakthroughs achieved in Europe and the US are likely to result in positive change at the global level. Undoubtedly, even a small percentage of mislabeled seafood products available in the market have undesirable consequences for human health, the economy, and the environment. Furthermore, greater challenges lie outside the bounds of the mainstream retail sector (Figure 2); restaurants (including “carry-out” or “take-away” options) and other food services are subject to relatively fewer labeling regulations and to reduced enforcement (Mariani *et al.* 2014), and arguably represent the next target for a standardized assessment of seafood substitution (Kappel and Schröder 2015). Yet the scenario emerging from this Europe-wide assess-



Figure 2. A typical European fishmonger's display (Barcelona, Spain). Popular aquaculture finfish products (salmon, gilthead sea bream, sea bass) are on sale alongside produce from wild catches, such as tuna loins (in the background), hake, Atlantic bonito, and monkfish (in the foreground).

ment shows that rapid, positive changes in the seafood supply chain are possible. Perhaps for the first time since the repercussions of seafood mislabeling studies started to influence the fields of fisheries, environmental conservation, and food science, we document a clear and substantial improvement in EU seafood retail sector operations, an improvement that stands as an exceptional opportunity to realize a sustainable global seafood market. Improved legislation, continued surveillance entrenched within governance, and the adoption of forensic genetics tools represent the foundation upon which a safe and transparent food supply chain can be built.

■ Acknowledgements

This study is part of the LABELFISH project (www.labelfish.eu), supported by the EU Atlantic Area Programme (project number 2011-1/163) and the UK Department for Environment, Food & Rural Affairs (grant FA0116). All sequence data used are available on the Barcode of Life Data Systems (BOLD) and National Center for Biotechnology Information (NCBI) databases (see Web-only materials), and have been uploaded to www.labelfish.eu. We are grateful to D Miller for comments on earlier versions of the manuscript, and to the many stakeholders willing to discuss their experiences with the seafood supply chain. We also thank A Clay, H Hillewaert, K Vanhalst, and the World Wildlife Fund for the fish images in Figure 1.

References

- Bérnard-Capelle J, Guillonnet V, Nouvian C, *et al.* 2014. Fish mislabelling in France: substitution rates and retail types. *PeerJ* 2: e714.
- Di Pinto A, Marchetti P, Mottola A, *et al.* 2015. Species identification in fish fillet products using DNA barcoding. *Fish Res* 170: 9–13.
- EC (European Commission). 2013. EU Regulation No 1379/2013 on the common organisation of the markets in fishery and aquaculture products. *Official Journal of the European Union* L354: 1–21.
- FAO (Food and Agriculture Organization of the United Nations). 2014. State of World Fisheries & Aquaculture. Rome, Italy: FAO.
- FDA (US Food and Drug Administration). 2014. DNA testing at wholesale level to evaluate proper labeling of seafood species. www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/Seafood/ucm419982.htm. Viewed 2 Sep 2015.
- FSAI (Food Safety Authority of Ireland). 2012. FSAI establishes a food fraud task force. FSAI News Jul/Aug 2012, Volume 14, Issue 4. Dublin, Ireland: FSAI.
- Helyar S, Lloyd HaD, de Bruyn M, *et al.* 2014. Fish product mislabelling: failings of traceability in the production chain and implications for illegal, unreported and unregulated (IUU) fishing. *PLoS ONE* 9: e98691.
- Kappel K and Schröder U. 2015. Substitution of high-priced fish with low-priced species: adulteration of common sole in German restaurants. *Food Control* 59: 478–86.
- Khaksar R, Carlson T, Schaffner DW, *et al.* 2015. Unmasking seafood mislabeling in US markets: DNA barcoding as a unique technology for food authentication and quality control. *Food Control* 56: 71–76.
- Logan CA, Alter SE, Haupt AJ, *et al.* 2008. An impediment to consumer choice: overfished species are sold as Pacific red snapper. *Biol Conserv* 141: 1591–99.
- Lou N. 2015. Bait & switch: the fraud crisis in the seafood industry. *The Atlantic*. Mar 19. www.theatlantic.com/business/archive/2015/03/bait-and-switch/388126. Viewed 2 Sep 2015.
- Lowell B, Mustain P, Ortenzi K, and Warner K. 2015. One name, one fish: why seafood names matter. <http://usa.oceana.org/sites/default/files/onenameonefishreport.pdf>. Viewed 16 Oct 2015.
- Mariani S, Ellis J, O'Reilly A, *et al.* 2014. Mass media influence and the regulation of illegal practices in the seafood market. *Conserv Lett* 7: 478–83.
- Miller D, Jessel A, and Mariani S. 2012. Seafood mislabelling: comparisons of two Western European case studies assist in defining influencing factors, mechanisms and motives. *Fish Fish* 13: 345–58.
- Miller DD and Mariani S. 2010. Smoke, mirrors, and mislabeled cod: poor transparency in the European seafood industry. *Front Ecol Environ* 8: 517–21.
- Ogden R. 2008. Fisheries forensics: the use of DNA tools for improving compliance, traceability and enforcement in the fishing industry. *Fish Fish* 9: 462–72.
- Stanziani A. 2007. Negotiating innovation in a market economy: foodstuffs and beverages adulteration in nineteenth-century France. *Enterp Soc* 8: 375–412.
- Viñas J and Tudela S. 2009. A validated methodology for genetic identification of tuna species (genus *Thunnus*). *PLoS ONE* 4: e7606.
- Warner K, Timme W, Lowell B, and Hirschfield M. 2013. Oceana study reveals seafood fraud nationwide. <http://oceana.org/reports/oceana-study-reveals-seafood-fraud-nationwide>. Viewed 2 Sep 2015.
- Wong EH-K and Hanner RH. 2008. DNA barcoding detects market substitution in North American seafood. *Food Res Int* 41: 828–37.
- Yancy HF, Zemlak TS, Mason JA, *et al.* 2008. Potential use of DNA barcodes in regulatory science: applications of the Regulatory Fish Encyclopedia. *J Food Protect* 71: 210–17.

Assistant or Associate Professor in Limnology Rubenstein School of Environment and Natural Resources, University of Vermont

The Rubenstein School of Environment and Natural Resources (RSEN) invites applications for a 9-month, tenure-track Assistant or Associate Professor of Limnology.

We seek an outstanding scholar and educator to join the growing center of excellence in freshwater ecology and lake management at the University of Vermont (UVM). An ideal candidate will work within the broader field of aquatic ecology, combining theory, observations, and/or experiments to address contemporary research questions and management challenges in lake ecosystems from local to international scales, including linkages to water-land interactions. The incumbent is expected to develop and maintain a vibrant, collaborative research program, based out of the Rubenstein Ecosystem Science Laboratory; participate actively in preparing students to become environmental leaders and globally-informed citizens through undergraduate and graduate instruction in both the RSEN core curriculum and the candidate's field of expertise; and provide leadership to the university, state, region, and professional communities through outreach, engagement, and other service activities.

Required qualifications

- Earned doctorate in limnology, aquatic ecology, or other appropriate environmental or natural sciences
- Outstanding record of collaborative research and publication in freshwater systems, commensurate with time since degree
- Strong background and interest in undergraduate and graduate education, with a demonstrated record of instructional excellence at the university level, commensurate with time since degree
- Demonstrated competency and capacity to collaboratively work with diverse groups of people both on and off campus
- Demonstrated record of securing extramural funding from a diversity of sources, commensurate with time since degree

Preferred qualifications

- Demonstrated leadership in globally significant, and complex water-related issues
- Demonstrated capacity for engaged research and outreach on contemporary lake management issues
- Demonstrated expertise in student-centered learning pedagogy
- Research background and interests that complement the current expertise of faculty within RSEN and across campus

To apply

Review of applications will begin January 15, 2016. Incomplete applications will not be considered. We anticipate the appointment will begin fall 2016. Applicants must submit a letter of interest that includes qualifications for the position, a curriculum vitae, a statement of research accomplishments and future directions, a statement of teaching experiences and interests, and contact information of three references to <http://www.uvmjobs.com>



**The
UNIVERSITY
of VERMONT**

Inquiries can be made to Dr. Jason Stockwell, Chair, Limnology Search Committee, at jstockw@uvm.edu.

UVM is located in Burlington, Vermont, an increasingly ethnically and culturally diverse city.

UVM is an Equal Opportunity/Affirmative Action Employer and actively encourages applications from women, veterans and people with diverse racial, ethnic, and cultural backgrounds who can contribute to the diversity and excellence of the academic community. Applicants are requested to include in their cover letter information about how they will further this goal.