Sushi-bar-coding in the UK: another kettle of fish

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SUSHI-BAR-CODING IN THE UK: ANOTHER KETTLE OF FISH

Sara G. Vandamme 1,4, Andrew M. Griffiths 2,3,4, Sasha-Ann Taylor 1 Cristina Di Muri 1,
Elizabeth A. Hankard 1, Jessica Towne 2, Mhairi Watson 2, & Stefano Mariani 1

Affiliations:
1: Ecosystems & Environment Research Centre, School of Environment & Life Sciences,
University of Salford, Greater Manchester, M5 4WT, UK.
2: School of Biological Sciences, University of Bristol, Bristol Life Sciences Building, 24 Tyndall
Avenue, Bristol BS8 1TQ, UK.
3: Biosciences, College of Environment and Life Sciences, University of Exeter, United Kingdom,
EX4 4QD.
4: These authors contributed equally to the work.

ABSTRACT

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Corresponding authors: Vandamme Sara: vandammesara@hotmail.com; Stefano Mariani: s.mariani@salford.ac.uk, Tel: +44 (0) 161-295-6913.
INTRODUCTION

Seafood is a popular and healthy food choice and, therefore, one of the most commonly traded food commodities in the world (FAO 2014). Regardless of the growing demand, studies on seafood mislabelling have identified that consumers are still too often given insufficient, confusing or misleading information about the seafood they purchase (Warner et al. 2013, Pramod et al. 2014, Cawthorn et al. 2015, Di Pinto et al. 2015). Due to increasingly complex supply chains, it is often unclear where and when seafood fraud is actually taking place, but restaurants and take-aways have been identified as the worst point of consumption for species substitution (Jacquet & Pauly 2008, Warner et al. 2013, Bernard-Capelle et al. 2015). For example, large studies across North America illustrate that sushi venues have the highest level of mislabelling (74% - 16%), followed by restaurants (38%) and grocery stores (18%) (Warner et al. 2013, Pramod et al. 2014, Khaksar et al. 2015). Such findings suggest that, as restaurants often represent the end-point of these long and intricate supply chains, without needing to comply with the standardised labelling practices of the retail sector, they could be consistently associated with the highest levels of substitution.

Seafood fraud encompasses any illegal activity that misrepresents the fish being purchased. Although some mislabelling may result from unintended human errors in identifying fish or their origin, often it is driven by economic gain, where cheaper or more readily available species are sold instead of expensive, desirable or supply-limited species e.g. farmed tilapia, Oreochromis sp., sold as snapper, Lutjanus sp. (Jacquet & Pauly 2008, Warner et al. 2013). Mislabelling can also provide cover and profit for illegal and unregulated fishing and seafood (Watson et al. 2015), which could have damaging implications for fisheries management and conservation, e.g.
Atlantic halibut *Hippoglossus hippoglossus* sold as Pacific halibut *Hippoglossus stenolepis*, (Warner *et al.* 2013). Seafood fraud can also have serious health consequences when mislabelled seafood masks undeclared allergens, contaminants or toxins. This is exemplified by escolar, *Lepidocybium flavobrunneum*, sold as “white tuna” (Lowenstein *et al.* 2010, Warner *et al.* 2013); escolar can naturally contain a toxin, gempylotoxin, which can cause mild to severe gastrointestinal problems, meaning this species is banned from the market in Italy and Japan.

The European Union (EU) is the largest single market for imported fish and fishery products, representing about 23% of world imports, and continuing to grow (FAO 2014). As such, the EU has a great responsibility to demonstrate legal and sustainable seafood supply chains to consumers. Its illegal fishing regulation (EC No 1005/2008) is an innovative and pioneering legal tool that has placed the EU at the forefront of global efforts to address illegal, unreported and unregulated (IUU) fishing. Part of the ongoing legal framework is the new European regulation (EC No 1379/2013), enacted in December 2014, which places an onus on anybody selling seafood to label it clearly and accurately, providing consumers with highly transparent information. This new EU labelling legislation applies to all pre-packed and non-packed fishery and aquaculture products (excluding preserved and prepared meals) at all stages in the retail supply chain, but excludes restaurants, which only have to provide mandatory information on allergens. In other words, restaurants are not obliged to mention on their menu what species is being sold but they are obliged to keep and give this information to the consumer if asked for. Additionally, EU Member States have to draw up a list of the commercial designations accepted in their territory, together with their scientific names. However, for some groups, like eels or tunas, the authorized commercial names cover a large number of species, including those with
serious conservation concern. In such cases, there is no way for knowledgeable consumers to choose according to sustainability criteria.

Given recent indication that the European seafood retail sector may have significantly lower levels of fraudulent substitutions than its North American counterpart (Bernard-Capelle et al. 2015, Heylar et al. 2014, Mariani et al. 2015), we set out to investigate the levels of seafood mislabelling in Britain’s raw seafood restaurants. Since sushi venues were so susceptible to fraud in the American seafood trade (Lowenstein et al. 2009, Warner et al. 2013), we focussed on this specific part of the supply chain. Sampling was spread across six different cities, focussing on tuna, eel and opportunistic samples of less distinguishable white-fleshed fish.

MATERIALS AND METHODS

Sampling

A total of 115 fish samples were collected in 31 sushi restaurants in Manchester, London, Bristol, Liverpool, Exeter and Newcastle, between September 2014 and 2015. Two independent sets of samples were collected in restaurants in Manchester, Liverpool, and Newcastle, with a minimum of two weeks between sampling. In all cases the individuals involved in the collection of tissue posed as normal customers and sampled in an as unobtrusive way as possible.

Samples were placed in pre-numbered tubes and stored in 95% ethanol at -20°C until extraction.

Data were recorded, including commercial name, date, price, location, restaurant name, as well as photographs of samples when possible. Sampling focused on tuna (Thunnus sp.) and eel
samples; these two product types are highly sought-after and include critically endangered species. A selection of less distinguishable white-fleshed fish available in each restaurant was also collected (Table 1) as these can comprise hundreds of fish species whose flesh is virtually unrecognisable by consumers and hence easily susceptible to substitution.

DNA extraction and sequencing

Genomic DNA was extracted from muscle tissue according to a Chelex resin protocol (Estoup et al. 1996). The partial cytochromoxidase 1 (COI) was amplified using the FishF2 and FishR2 from Ward et al. (2005), following the PCR amplifications by Serra-Pereira et al. (2010). If samples could not be successfully amplified, the COI mini-barcode primers (mICOIintF and jgHCO2198) following Leray et al. (2013) or the L14735 and H15149 cytochrome b (cytb) primers as described by Burgener (1997) were used. In the case of cytb amplification, 2 µl 10x reaction buffer, 1.6 µl MgCl2 (50mM), 1 µl of each primer (0.01 mM), 0.5 Units of DNA Taq Polymerase (PROMEGA, Madison, WI, USA) and 0.2 µl of each dNTP (10 µM) were used in a total volume of 20 µL. PCR conditions entailed 5 min at 94°C, following a cycle of 40 sec at 94°C, 80 sec at 55°C, 80 sec at 72°C, which is repeated 35 times, finalized by 7 min at 72°C, until the PCR was held at 10°C.

DNA sequencing was carried out by Source Bioscience (Cambridge, UK) and all sequences were obtained with the forward primer. Sequences were checked manually against their chromatogram and edited in BioEdit (Hall, 1999). Each sequence was then used to BLAST-search both the GenBank reference database (www.ncbi.nlm.nih.gov/) and the Barcode of Life Data system (BOLD, http://www.boldsystems.org/, see Ratnasingham & Hebert 2007), using the “Public...
Record Barcode Database”, which restricts the search to sequences that have been published. In the supplementary material, results are presented for the alternative BOLD reference databases: the default “Species Level Barcode Records” database and the “Full Length Record Barcode Database”, which is recommended to use with short sequences as it provides a maximum overlap. Identification was determined by sequence similarity to the reference dataset (Wong & Hanner 2008), and checked by “Tree based identification” (i.e. distance trees in BOLD; Costa et al. 2012). With the NCBI database a minimum similarity of 90% was required. The match with the highest expectation value (E-value) of the BLAST program was retained as potential species identification. The E-value is a parameter that describes the number of hits one can expect to see just by chance when searching a database of a particular size.

For each sample, the list of admissible species that can be sold under the commercial name indicated on the menu was determined by consulting the UK governmental list with commercial designations of fish (DEFRA 2013). The sample was declared mislabelled if the species name determined through molecular identification did not match the commercially accepted names in this list. Species or commercial names obtained orally from waiting staff in restaurants were not utilised in calculations of substitution rates, but this information is available in the supplementary material (Table S1).

RESULTS and DISCUSSION

This study represents the largest sampling of UK sushi venues to date. A relatively intensive effort was made to collect samples across multiple time-points and regions, going beyond the sampling of only the most commonly consumed species like tuna, eel and salmon. The inherently high cost of sampling raw fish restaurants as consumers represents a limitation to the collection
of huge sample sizes. However, the final sample size (N = 115) is of the same order of magnitude as recent comparable investigations and the sample design that was spread over 31 restaurants and a 12-month span, strove to avoid high levels of repeated sampling from any one location or restaurant, giving a degree of independence to the data.

Interpretable sequences were obtained for a total of 115 samples, ranging between 166 and 674 base pairs (bp) (average length 531 bp). These include 48 ‘tuna’, 20 ‘eel’, 16 ‘seabass’, 12 ‘yellowtail’, 8 ‘mackerel’, 3 ‘seabream’, 2 ‘swordfish’, 2 ‘kingfish’, and single samples of ‘black cod’, ‘barramundi’, ‘snapper’ and ‘flying fish’ (Table 1). Searches on BOLD and GenBank generally produced clear matches allowing for confident assignment of species and there was good agreement between databases (supplementary materials Table S1). In fact, all searches yielded matches that were within the 98% similarity to database records. For all seabass samples and one eel sample, no successful COI amplifications could be produced, and the cytb primers were utilised instead. A BOLD search could not be made in these instances, as this database only contains COI sequences, so the GenBank identification was used.

In the case of certain *Thunnus* species, little interspecific divergence can limit the power of COI to discriminate among species pair, owing to the short evolutionary history and/or introgression among them (Tseng *et al.* 2012, Vinas & Tudela 2009). However, in the current study this would not generally cause issues in assessing the levels of substitution as the commercial designation by DEFRA allows restaurants to sell all *Thunnus* species under the umbrella term “tuna” (DEFRA 2013). Despite the limitation in *Thunnus* identification, in some instances there is the potential to go down to species level identification. We can distinguish *T. thynnus* from the other
Thunnus species by following a set of criteria. First, when there is 100% sequence match
criterion alongside the reduced similarity between the unknown sequences and any other
matching species record. Second, the phylogenetic tree option in the BOLD reference database
provides further evidence of the origin of the species. Finally, comparison of results of
different/more stringent sets of reference data in BOLD further provides an unambiguous
identification. Therefore, it was possible with some samples to assign the sequence obtained to
either the yellowfin or bluefin tuna group, providing evidence of mislabelling.

The overall level of mislabelling and substitution was moderate (10.4%, Table 2). In the case of
tuna, three samples were sold as tuna, but identified as Yellowtail and Japanese Amberjack
(Seriola lalandi and Seriola quinqueradiata, respectively). In two other cases, the restaurant
deliberately advertised a specific Thunnus species: one restaurant claimed to sell Yellowfin tuna
(Thunnus albacares) while highest similarity scores by COI barcoding suggested potential
substitution with Big-eye tuna (Thunnus obesus). Another restaurant claimed to serve Bluefin
tuna, but COI barcoding revealed matches with Big-eye and Yellowfin tuna. Although the
common name Bluefin tuna encompasses Atlantic Bluefin (Thunnus thynnus), Pacific Bluefin
(Thunnus orientalis) and Southern Bluefin (Thunnus maccoyii), none of them matched the COI
barcoding results. Kingfish was sampled in London and Manchester. According to the official
list on commercial designation of fish in the United Kingdom (DEFRA 2013) this common name
represents all species of Scomberomorus. However, both samples were identified as Seriola
lalandi and hence regarded as mislabelled. Among the 16 samples of seabass, two samples were
identified as Lateolabrax maculaus also known as the Japanese seabass. In the case of one
“swordfish” sample, the reference database inquiry identified the species *Makaira nigricans* (Atlantic blue marlin), with additional matches from closely related sister taxa belonging to other marlin species (Family: Istiophoridae). Although it is difficult to pinpoint the exact species ID, it is evident that the sample did not match with swordfish (*Xiphias gladius*). Further mislabelling was found for a sample of snapper (Family: Lutjanidae) which was identified as *Sparus aurata* (gilt-head sea bream) and the sample of the flying fish eggs (representing all species of the family *Exocoetidae*) were identified as herring (*Clupea harengus*) eggs. The sample of Black cod was identified as *Anoplopoma fimbria*. According to Fishbase, both Black cod and Sablefish are accepted common names for *Anoplopoma fimbria*; however, the official list on commercial designation of fish in the United Kingdom (DEFRA 2013) only accepts ‘sablefish’. As both common names are accepted by the scientific community, this particular example was not deemed to be mislabelled, as the restaurant business aimed to serve a rather unfamiliar species to the UK public and used a scientifically correct name. Rather than mislabelling, this example can be seen as a misapplied market nomenclature, which shows how, in a context of increasingly global and diverse seafood market, regular communication between governments, fisheries managers and scientific advisors should be improved in order to guarantee an updated and accurate list of valid names. Yet, the new labelling regulations (EC 1379/2013, article 37) requiring the use of scientific names, may offer the necessary level of universality to commercial designations.

When compared to recent studies on sushi labelling in North America, which returned 74% (Warner *et al.* 2013) and 16.3% (Khaksar *et al.* 2015) in the level of substitution, the UK food service sector comes under a more positive light (Table 1, Figure 1). Similarly, Bernard-Capelle
et al. (2015) found only 3% substitution in French restaurants, which suggests lower levels of mislabelling in restaurants across Europe. In contrast to North America, mislabelling of tuna is less pronounced (10.2%). Generally in Europe substitution occurred between tuna species (Bernard-Capelle et al. 2015), or with amberjack, unlike in the US where a large portion of the tuna is substituted with escolar (Lepidocybium flavobrunneum, Warner et al. 2013). Comparisons between mislabelling in North America and the EU are valid as labelling regulation for the FDA (2016) and the EU are similar as to allowing umbrella term to be used for the sale of product in restaurants. Interestingly, in one case where oral enquiry about which tuna species was being sold was made to the waiting staff, the response was Bluefin tuna, which was not supported by the results of DNA barcoding. In this study, it was not included as a case of mislabelling, as the menu did not explicitly mention “Bluefin tuna”, but it does illustrate an absence of care or knowledge in the usage of this commercial name. Given that consumers are not expected to know every possible regional name, and the need to standardise labels across a large region with many different languages, the EU’s policy to require scientific names on display appears inevitable. The lowest level of mislabelling among the most studies detected only 16.3% of mislabelling in North America (Khaksar et al. 2015). In spite of the short sampling time and moderate samples size, their result is in sharp contrast to the study by Warner et al. (2013) who detected 74% mislabelling, suggesting a decreasing trends in mislabelling and illustrating that the role of media, environmental Non-governmental Organisations and scientific outputs in increasing public awareness is undeniable, which in turn raises the demand for enforcement of more rigorous inspection and audit processes in the food supply chain. Surveillance studies like this can help further refine the scope of such efforts and identify existing knowledge gaps.
Conservation issues

Concerns over the conservation and sustainable management of large oceanic fish are well established and the Big-eye and Yellowfin tunas identified in this study are listed as vulnerable and near-threatened by the International Union for Conservation of Nature and Natural Resources (IUCN) Red List (IUCN 2015). Somewhat surprisingly, given the high conservation concern of Bluefin tuna species with the red listing of many species as endangered or critically endangered (IUCN 2015) and its inclusion as a product to avoid due to sustainability issues in the Good Fish Guide (MSC 2013), this product was listed on the menus of two restaurants. Bluefin tuna is particularly highly valued for its quality and taste. This would also make it an obvious target for economic fraud, with substitution for a lower value tuna species, as was identified in one case. In another instance, a product labelled with the umbrella term of “tuna” was also identified as Bluefin, which given its premium would appear as a missed promotion opportunity. Perhaps, due to the conservation issues around Bluefin tuna selling this meat under higher anonymity may help conceal that the species or individual was caught illegally (Jacquet & Pauly 2008).

Mercury levels have been highlighted as a concern in some species. Some species like Skipjack (Katsuwonus pelamis) and Yellowfin, often have lower mercury levels than other tuna species, such as Big-eye and Bluefin, and capture location in certain ocean basins can also be related to differing mercury levels (Lowenstein et al. 2010, Burger et al. 2014). Therefore, knowing what tuna species are being served and where they are caught is not only critical to making conservation informed consumer choices, but is also helpful in minimizing the health concerns of mercury exposure (Khaksar et al. 2015). This sort of crucial information is not easily accessible
for consumers in restaurants, including sushi bars, and oral enquiries for this type of information appear to be unreliable.

Perhaps less well-known to the general public than conservation issues surrounding tuna, is the fact that most eel species are also of very poor conservation status. The European eel (*Anguilla anguilla*) is regarded as critically endangered (ICUN 2015), and made up 62% of the eel products analysed. American (*Anguilla rostrata*) and Japanese (*Anguilla japonica*) eels, also found among the samples, and these are classified as endangered (ICUN 2015). Although 90% of the freshwater eel consumed are farm-raised, they are not bred in captivity in economically relevant numbers (Mordenti *et al.* 2014, Okamura *et al.* 2014), young eels are still collected in the wild, further threatening wild populations (Okamura *et al.* 2014). The critical status of eel, might explain why such a high diversity of species (4) is being found among the total of 21 samples analysed in this study. A worrying pattern of exploitation has already been noticed with eels; when one Anguilla species or population becomes over-exploited or fisheries restrictions are imposed, the industry moves to the next in order to fulfil demand (Crook and Nakamura 2013). This may explain the occurrence of ‘new’ species, such as the Giant mottled eel (*Anguilla marmorata*), identified in the UK market for the first time.

CONCLUSION

This study detected a low percentage of substitution, which could be an indicator that many restaurants have a positive attitude towards labeling accuracy due to heightened consumer awareness (Miller *et al.* 2012, Mariani *et al.* 2014). Even products, such as tuna, that are
typically known to exhibit high levels of mislabeling, showed a remarkable level of compliance, corroborating the idea that seafood trade in the EU is addressing issues concerning mislabeling and food authenticity (Mariani et al. 2015). Although the substitutions appear infrequent compared to studies in other territories, or those conducted some years ago, improvements can be made to increase the reliability of the market. The legislation on labelling differs between restaurants, fresh sales and deep-frozen fish. For some groups, such as tuna, snapper or eel, the authorized commercial names cover a large number of species, including species with serious conservation and management issues. In such cases, consumers are unable to choose according to sustainability criteria. Additionally, because our study was restricted to seafood sold in a specific type of food service, at the end of a complex supply chain, it is difficult to determine if fraud is occurring at the landing site, during processing, at the wholesale level, at the retail counter or somewhere else along the way (Cawthorn et al. 2012). Therefore, in such a complex landscape, where restaurants may be just as much victims of mislabelling practices as consumers, more interdisciplinary research will be necessary to identify the mechanisms that still pose a threat to a transparent seafood supply chain.
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Table 1 (on next page)

Summary of the samples collected in sushi venues across the UK.

Identification represented in this table is obtained by using the BOLD ‘Public Record Barcode’ database. Samples marked by (*) represent samples which were identified using cyt b sequencing and the Genbank public database, the (²) characterises samples identified by the COI mini-barcodes. Results by using other database can be found in the supplementary material (Table S1). The conservation status of the species can by assessed by their IUCN Red List of Threatened Species status.
| City       | Sold as  | BOLD Public Record Barcode Database (% match)                                      | Actual scientific name | Mislabelled | IUCN status      | Accession number |
|------------|----------|-----------------------------------------------------------------------------------|------------------------|-------------|------------------|-----------------|
| Bristol    | Tuna     | Thunnus albagula 100%, Thunnus obesus 100%, Thunnus orientalis 99.81%, Thunnus thynnus 99.61%, Thunnus atlanticus 99.03% | Albacore              | NO          | Near threatened  | KU168615        |
| Exeter     | Tuna     | Thunnus albagula 100%, Thunnus obesus 100%, Thunnus orientalis 99.81%, Thunnus maccocyii 99.81%, Thunnus atlanticus 99.04% | Albacore              | NO          | Near threatened  | KU168616        |
| London     | Tuna     | Thunnus albagula 99.79%, Thunnus obesus 99.38%, Thunnus orientalis 99.17%, Thunnus maccocyii 99.17%, Thunnus thynnus 98.96%, Thunnus albaca 98.33% | Albacore              | NO          | Near threatened  | KU168617        |
| Bristol    | Tuna     | Thunnus thynnus 100%                                                             | Atlantic Bluefin tuna  | NO          | Endangered       | KU168618        |
| Liverpool  | Tuna     | Thunnus albaca 100%, Thunnus atlanticus 100%, Thunnus obesus 100%, Thunnus maccocyii 99.85% | Yellowfin tuna         | YES         | Near threatened  | KU168619        |
| Bristol    | Tuna     | Thunnus albaca 100%, Thunnus obesus 100%, Thunnus maccocyii 99.83%, Thunnus tonggol 99.83% | Yellowfin tuna         | NO          | Near threatened  | KU168620        |
| Bristol    | Tuna     | Thunnus albaca 100%, Thunnus atlanticus 100%, Thunnus maccocyii 99.83%, Thunnus tonggol 99.83% | Yellowfin tuna         | NO          | Near threatened  | KU168621        |
| Exeter     | Tuna     | Thunnus albaca 100%                                                             | Yellowfin tuna         | NO          | Near threatened  | KU168622        |
| London     | Tuna     | Thunnus albaca 100%, Thunnus atlanticus 99.79%, Thunnus obesus 99.79%, Thunnus maccocyii 99.79% | Yellowfin tuna         | NO          | Near threatened  | KU168623        |
| Manchester | Tuna     | Thunnus obesus 100%, Thunnus albaca 99.69%, Thunnus atlanticus 99.62%, Thunnus tonggol 99.52%, Thunnus maccocyii 99.4% | Bigeye tuna            | YES         | Vulnerable       | KU168624        |
| Manchester | Tuna     | Thunnus albaca 100%, Thunnus atlanticus 100%, Thunnus maccocyii 100%, Thunnus obesus 100% | Yellowfin tuna         | NO          | Near threatened  | KU168625        |
| Bristol    | Tuna     | Thunnus albaca 100%, Thunnus obesus 99.82%, Thunnus maccocyii 99.67%, Thunnus tonggol 99.67% | Yellowfin tuna         | NO          | Near threatened  | KU168627        |
| Bristol    | Tuna     | Thunnus albaca 100%, Thunnus obesus 99.82%, Thunnus maccocyii 99.67%, Thunnus tonggol 99.67% | Yellowfin tuna         | NO          | Near threatened  | KU168628        |
| Bristol    | Tuna     | Thunnus albaca 100%, Thunnus obesus 100%, Thunnus maccocyii 99.83%, Thunnus tonggol 99.83% | Yellowfin tuna         | NO          | Near threatened  | KU168629        |
| Bristol    | Tuna     | Thunnus albaca 100%, Thunnus atlanticus 100%, Thunnus maccocyii 99.83%, Thunnus tonggol 99.83% | Yellowfin tuna         | NO          | Near threatened  | KU168630        |
| Bristol    | Tuna     | Thunnus obesus 100%, Thunnus albaca 99.34%                                        | Bigeye tuna            | NO          | Vulnerable       | KU168631        |
| Bristol    | Tuna     | Thunnus albaca 100%, Thunnus obesus 99.83%                                        | Yellowfin tuna         | NO          | Near threatened  | KU168632        |
| Bristol    | Tuna     | Thunnus albaca 100%, Thunnus atlanticus 100%, Thunnus maccocyii 100%, Thunnus obesus 100%, Thunnus tonggol 99.84% | Yellowfin tuna         | NO          | Near threatened  | KU168633        |
| Bristol    | Tuna     | Thunnus albaca 100%, Thunnus atlanticus 100%, Thunnus maccocyii 99.84%, Thunnus tonggol 99.83% | Yellowfin tuna         | NO          | Near threatened  | KU168634        |
| Exeter     | Tuna     | Thunnus albaca 100%, Thunnus atlanticus 99.49%, Thunnus obesus 99.49%, Thunnus maccocyii 99.48 | Yellowfin tuna         | NO          | Near threatened  | KU168635        |
| Location     | Type     | Species                                                                 | Status          | Code     |
|--------------|----------|--------------------------------------------------------------------------|-----------------|----------|
| Liverpool    | Tuna*    | Thunnus albacares 100%, Thunnus obesus 100%, Thunnus atlanticus 99.81%, Thunnus maccocyii 99.68% | Yellowfin tuna  | NO       |
| Liverpool    | Tuna     | Thunnus albacares 100%                                                   | Yellowfin tuna  | NO       |
| London       | Tuna     | Thunnus albacares 100%, Thunnus maccocyii 100%, Thunnus obesus 100%       | Yellowfin tuna  | NO       |
| London       | Tuna     | Thunnus albacares 100%, Thunnus atlanticus 100%, Thunnus maccocyii 100%, Thunnus obesus 100% | Yellowfin tuna  | NO       |
| London       | Tuna     | Thunnus albacares 99.82%, Thunnus atlanticus 99.82%, Thunnus obesus 99.81% | Yellowfin tuna  | NO       |
| London       | Tuna     | Thunnus albacares 100%, Thunnus atlanticus 99.79%, Thunnus obesus 99.79%, Thunnus maccocyii 99.79% | Yellowfin tuna  | NO       |
| London       | Tuna     | Thunnus albacares 99.79%, Thunnus atlanticus 99.79%, Thunnus obesus 99.79%, Thunnus maccocyii 99.79% | Yellowfin tuna  | NO       |
| London       | Tuna     | Thunnus albacares 100%, Thunnus atlanticus 100%, Thunnus maccocyii 100%, Thunnus obesus 100% | Yellowfin tuna  | NO       |
| London       | Tuna²    | Thunnus thynnus 100%                                                    | Atlantic Bluefin tuna | NO       |
| London       | Tuna     | Thunnus albacares 100%, Thunnus atlanticus 100%, Thunnus maccocyii 100%, Thunnus obesus 100% | Yellowfin tuna  | NO       |
| London       | Tuna     | Thunnus albacares 100%                                                   | Yellowfin tuna  | NO       |
| London       | Tuna     | Thunnus albacares 100%, Thunnus obesus 100%, Thunnus atlanticus 100%, Thunnus maccocyii 99.85% | Yellowfin tuna  | NO       |
| Manchester   | Tuna*    | Seriola quinqueradiata 99.85%, Seriola lalandi 94.97%                     | Japanese amberjack | YES       |
| Manchester   | Tuna     | Thunnus obesus 100%, Thunnus albacares 99.69%                            | Bigeye tuna     | NO       |
| Manchester   | Tuna*    | Thunnus albacares 100%, Thunnus atlanticus 100%, Thunnus obesus 100%, Thunnus maccocyii 99.85% | Yellowfin tuna  | NO       |
| Manchester   | Tuna (Spicy) | Thunnus albacares 100%, Thunnus atlanticus 100%, Thunnus obesus 100%, Thunnus maccocyii 99.85% | Yellowfin tuna  | NO       |
| Manchester   | Tuna     | Thunnus albacares 100%, Thunnus atlanticus 100%, Thunnus obesus 100%, Thunnus maccocyii 99.85% | Yellowfin tuna  | NO       |
| Manchester   | Tuna     | Thunnus thynnus 100%, Thunnus orientalis 99.69%, Thunnus atlanticus 99.69%, Thunnus maccocyii 99.54%, Thunnus albacares 99.53% | Atlantic Bluefin tuna | NO       |
| Manchester   | Tuna     | Thunnus albacares 100%                                                   | Bigeye tuna     | NO       |
| Location  | Species          | occuring species                                 | Threat Status         | KU Number |
|-----------|------------------|--------------------------------------------------|-----------------------|-----------|
| Manchester Tuna | *Thunnus albacares* 100% | Yellowfin tuna                                      | NO Near threatened    | KU168657  |
| Manchester Tuna | Thunnus thynnus 100%, Thunnus orientalis 99.84%, Thunnus maccoyii 99.84%, Thunnus alalunga 99.69%, Thunnus obesus 99.68%, Thunnus atlanticus 99.19%, Thunnus albacares 99% | Atlantic Bluefin tuna | NO Endangered | KU168658  |
| Manchester Tuna | Thunnus albacares 100%, Thunnus maccoyii 99.84%, Thunnus obesus 99.82%, Thunnus atlanticus 99.8% | Yellowfin tuna                                      | NO Near threatened    | KU168659  |
| Manchester Tuna* | Thunnus albacares 100%, Thunnus atlanticus 100%, Thunnus maccoyii 100%, Thunnus obesus 100%, Thunnus tonggol 99.84% | Yellowfin tuna                                      | NO Near threatened    | KU168660  |
| Newcastle Tuna | Thunnus albacares 100%, Thunnus atlanticus 100%, Thunnus maccoyii 100%, Thunnus obesus 100% | Yellowfin tuna                                      | NO Near threatened    | KU168661  |
| Newcastle Tuna | Thunnus albacares 100%, Thunnus atlanticus 99.84%, Thunnus maccoyii 99.84%, Thunnus obesus 99.82% | Yellowfin tuna                                      | NO Near threatened    | KU168662  |
| Bristol Eel | Anguilla anguilla 100% | European eel                                      | NO Critically endangered | KU168664  |
| Bristol Eel | Anguilla anguilla 100% | European eel                                      | NO Critically endangered | KU168665  |
| Bristol Eel | Anguilla marmorata 99.84% | Giant mottled eel                                  | NO Least concern      | KU168666  |
| Exeter Eel | Anguilla japonica 99.36% | Japanese eel                                      | NO Endangered         | KU168667  |
| Liverpool Eel | Anguilla anguilla 99.84% | European eel                                      | NO Critically endangered | KU168668  |
| Liverpool Eel | Anguilla rostrata 99.84% | American eel                                      | NO Endangered         | KU168669  |
| Liverpool Eel | Anguilla japonica 100% | Japanese eel                                      | NO Endangered         | KU168670  |
| London Eel (Freshwater)² | Anguilla japonica 100% | Japanese eel                                      | NO Endangered         | KU168671  |
| London Eel (grilled) | Anguilla anguilla 100% | European eel                                      | NO Critically endangered | KU168672  |
| London Eel² | Anguilla japonica 99.49% | Japanese eel                                      | NO Endangered         | KU168673  |
| Manchester Eel | Anguilla anguilla 99.84% | European eel                                      | NO Critically endangered | KU168674  |
| Manchester Eel (Freshwater) | Anguilla anguilla 100% | European eel                                      | NO Critically endangered | KU168675  |
| Manchester Eel | Anguilla anguilla 99.84% | European eel                                      | NO Critically endangered | KU168676  |
| Manchester Eel | Anguilla japonica 99.54%, Anguilla marmorata 94.74% | Japanese eel                                      | NO Endangered         | KU168677  |
| Manchester Eel | Anguilla rostrata 99.84% | American eel                                      | NO Endangered         | KU168678  |
| Location | Type | Common Name | Scientific Name | Percentage | Category | Status | Accession Number |
|----------|------|-------------|-----------------|------------|----------|--------|-----------------|
| Manchester | Eel | Anguilla anguilla | Anguilla anguilla | 100% | European eel | NO | Critically endangered | KU168679 |
| Manchester | Eel | Anguilla anguilla | Anguilla anguilla | 100% | European eel | NO | Critically endangered | KU168680 |
| Manchester | Eel* | Anguilla anguilla | Anguilla anguilla | 90% | European eel | NO | Critically endangered | KU168681 |
| Newcastle | Eel | Anguilla anguilla | Anguilla anguilla | 100% | European eel | NO | Critically endangered | KU168683 |
| Newcastle | Eel | Anguilla anguilla | Anguilla anguilla | 99.37% | European eel | NO | Critically endangered | KU168684 |
| Liverpool | Seabass* | Dicentrarchus labrax | Dicentrarchus labrax | 99% | European seabass | NO | Least concern | KU168685 |
| Liverpool | Seabass* | Dicentrarchus labrax | Dicentrarchus labrax | 100% | European seabass | NO | Least concern | KU168686 |
| Liverpool | Seabass² | Dicentrarchus labrax | Dicentrarchus labrax | 100% | European seabass | NO | Least concern | KU168687 |
| London | Seabass* | Dicentrarchus labrax | Dicentrarchus labrax | 100% | European seabass | NO | Least concern | KU168688 |
| London | Seabass | Lateolabrax japonicus, Lateolabrax maculatus | Lateolabrax japonicus, Lateolabrax maculatus | 99.63% | Japanese seabass | YES | Not assessed | KU168689 |
| London | Seabass | Lateolabrax japonicus, Lateolabrax maculatus | Lateolabrax japonicus, Lateolabrax maculatus | 99.49% | Japanese seabass | YES | Not assessed | KU168690 |
| London | Seabass* | Dicentrarchus labrax | Dicentrarchus labrax | 100% | European seabass | NO | Least concern | KU168691 |
| London | Seabass* | Dicentrarchus labrax | Dicentrarchus labrax | 100% | European seabass | NO | Least concern | KU168692 |
| London | Seabass* | Dicentrarchus labrax | Dicentrarchus labrax | 100% | European seabass | NO | Least concern | KU168693 |
| Manchester | Seabass* | Dicentrarchus labrax | Dicentrarchus labrax | 99% | European seabass | NO | Least concern | KU168694 |
| Manchester | Seabass* | Dicentrarchus labrax | Dicentrarchus labrax | 99% | European seabass | NO | Least concern | KU168695 |
| Manchester | Seabass* | Dicentrarchus labrax | Dicentrarchus labrax | 99% | European seabass | NO | Least concern | KU168696 |
| Manchester | Seabass* | Dicentrarchus labrax | Dicentrarchus labrax | 100% | European seabass | NO | Least concern | KU168697 |
| Manchester | Seabass* | Dicentrarchus labrax | Dicentrarchus labrax | 100% | European seabass | NO | Least concern | KU168698 |
| Manchester | Seabass* | Dicentrarchus labrax | Dicentrarchus labrax | 100% | European seabass | NO | Least concern | KU168699 |
| Manchester | Seabass* | Dicentrarchus labrax | Dicentrarchus labrax | 100% | European seabass | NO | Least | KU168700 |
| Location     | Species         | Caspian Sea Presence | Japanese amberjack | Assessment Status          | Reference ID |
|--------------|-----------------|----------------------|--------------------|---------------------------|--------------|
| Bristol      | Yellowtail      | Seriola quinqueradiata 99.34%, Seriola lalandi 94.53% | Japanese amberjack | NO                        | KU168701     |
| Bristol      | Yellowtail      | Seriola quinqueradiata 99.51%, Seriola lalandi 94.75% | Japanese amberjack | NO                        | KU168702     |
| Bristol      | Yellowtail      | Seriola quinqueradiata 99.84%, Seriola lalandi 94.9%  | Japanese amberjack | NO                        | KU168703     |
| Liverpool    | Yellowtail      | Seriola quinqueradiata 99.63%, Seriola lalandi 93.85% | Japanese amberjack | NO                        | KU168704     |
| London       | Yellowtail      | Seriola lalandi 100%, Seriola zonata 99.34%         | Yellowtail amberjack | NO                        | KU168705     |
| London       | Yellowtail      | Seriola quinqueradiata 99.80%                          | Japanese amberjack | NO                        | KU168707     |
| London       | Yellowtail      | Seriola quinqueradiata 99.79%                          | Japanese amberjack | NO                        | KU168708     |
| London       | Yellowtail      | Seriola quinqueradiata 99.79%                          | Japanese amberjack | NO                        | KU168709     |
| London       | Yellowtail      | Seriola quinqueradiata 99.77%                          | Japanese amberjack | NO                        | KU168710     |
| Manchester   | Yellowtail      | Seriola quinqueradiata 99.55%, Seriola lalandi 94.97% | Japanese amberjack | NO                        | KU168711     |
| Manchester   | Yellowtail      | Seriola quinqueradiata 99.7%, Seriola lalandi 94.9%   | Japanese amberjack | NO                        | KU168712     |
| London       | Mackerel        | Scomber scombrus 100%                                   | Mackerel           | NO                        | KU168713     |
| London       | Mackerel        | Scomber scombrus 99.80%                                 | Mackerel           | NO                        | KU168714     |
| London       | Mackerel        | Scomber scombrus 100%                                   | Mackerel           | NO                        | KU168715     |
| London       | Mackerel        | Scomber scombrus 100%                                   | Mackerel           | NO                        | KU168716     |
| London       | Mackerel        | Scomber scombrus 100%                                   | Mackerel           | NO                        | KU168717     |
| London       | Mackerel        | Scomber scombrus 100%                                   | Mackerel           | NO                        | KU168718     |
| London       | Mackerel        | Scomber scombrus 100%                                   | Mackerel           | NO                        | KU168719     |
| London       | Mackerel        | Scomber scombrus 100%                                   | Mackerel           | NO                        | KU168720     |
| Location   | Species          | Scientific Name | Threat Level | Status   | Reference Code |
|------------|------------------|-----------------|--------------|----------|----------------|
| Manchester | Seabream         | *Sparus aurata* 100% | Gilthead bream | NO       | KU168721       |
| Manchester | Seabream         | *Sparus aurata* 100% | Gilthead bream | NO       | KU168722       |
| Manchester | Seabream         | *Sparus aurata* 100% | Gilthead bream | NO       | KU168723       |
| Liverpool  | Swordfish        | *Makaira nigricans* 99.52% | Blue marlin | YES      | Data deficient |
| Newcastle  | Swordfish        | *Xiphias gladius* 100% | Swordfish    | NO       | Least concern  |
| London     | King Fish        | *Seriola lalandi* 100%, *Seriola zonata* 99.38% | Yellowtail amberjack | YES      | Not assessed   |
| Manchester | King Fish        | *Seriola lalandi* 100%, *Seriola zonata* 99.43% | Yellowtail amberjack | YES      | Not assessed   |
| Manchester | Barramundi²      | *Lates calcarifer* 100% | Barramundi   | NO       | Not assessed   |
| Manchester | Black Cod        | *Anoplopoma fimbria* 100% | Sablefish    | NO       | Not assessed   |
| Liverpool  | Flying Fish eggs | *Clupea harengus* 100% | Herring      | YES      | Least concern  |
| London     | Snapper          | *Sparus aurata* 100% | Gilthead bream | YES      | Least concern  |
Figure 1 (on next page)

Level of mislabelling per species.

For the two ‘Swordfish’ samples, one sample was found correctly labelled, where the other was substituted with Marlin. Both the Marlin and Swordfish are depicted on either side of the diagram. Furthermore, substitution was recorded in tuna, seabass, kingfish, snapper and flying fish eggs samples.
Tuna
Eel
Seabass
Yellowtail
Seabream
Mackerel
Black cod
Barramundi
Kingfish
Snapper
Flying fish eggs
"Eel"
"Tuna"
Table 2 (on next page)

Samples collected across the UK per species and per city
| City      | "Tuna" | "Eel" | Seabass | Yellowtail | Seabream | Mackerel | Swordfish | Black cod | Barramundi | Kingfish | Snapper | Flying fish eggs | TOTAL |
|-----------|--------|-------|---------|------------|----------|----------|-----------|-----------|------------|----------|---------|-----------------|-------|
| Manchester| 14     | 8     | 7       | 2          | 3        | 1        | 1         | 1         | 1          | 1        | 1       |                 | 37    |
| London    | 14     | 3     | 6       | 6          | 8        | 1        | 1         | 1          | 1          | 1        | 1       |                 | 39    |
| Bristol   | 12     | 3     | 3       | 3          | 8        | 1        | 1         | 1          | 1          | 1        | 1       |                 | 18    |
| Liverpool | 3      | 3     | 3       | 1          | 1        | 1        | 1         | 1          | 1          | 1        | 1       |                 | 12    |
| Newcastle | 2      | 2     |         | 1          | 1        | 1        | 1         | 1          | 1          | 1        | 1       |                 | 5     |
| Exeter    | 3      | 1     |         |            |          |          |           |            |            |          |         |                 | 4     |
| TOTAL mislabelled | 5 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 1 | 12 |
| TOTAL      | 48     | 20    | 16      | 12         | 8        | 2        | 1         | 1          | 2          | 1        | 1       |                 | 115   |