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Chinese eel products in EU markets imply the effectiveness of trade regulations but expose fraudulent labelling

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ABSTRACT

The stock of the European eel (*Anguilla anguilla*) is in a multi-decadal decline. Therefore, trade in European eel is now restricted by EU law and the listing in CITES Appendix II. EU law prohibits the trade of European eel across the EU's outer border and CITES regulates the global trade elsewhere. In November and December 2019, we purchased 108 eel products in 21 cities in five major eel importing countries in Europe (Germany, Belgium, Netherlands, Great Britain, France) and three online shops. All were imported from China and 73 samples were genetically identified as American eel (*A. rostrata*), 33 as Japanese eel (*A. japonica*), and a single sample each as European eel and Indian shortfin eel (*A. bicolor pacifica*). The one European eel sample violated the EU trade ban and CITES trade regulations. However, 28.7 % of the product labels violated EU Regulation (EU) No 1169/2011 on the provision of food information to consumers (FIC). Our results imply that Chinese exporters sell their European eel products outside the EU market and therefore avoid violating EU law. However, fraudulent labelling point at inadequate existing EU labelling requirements for prepared and preserved products and ongoing molecular genetic control of eel commodities entering the EU from China.

Data availability statement: The data that support the findings of this study are openly available in Genbank at www.ncbi.nlm.nih.gov/genbank/ under the consecutive accession numbers MN973673-MN973780. Basic data on unagi kabayaki products are listed in Table 1, details can be obtained from the corresponding author on request.

1. INTRODUCTION

The European eel (*Anguilla anguilla* L.) stock has declined by about 90 % since the 1950s, and the recruitment of juveniles (glass eel) declined sharply after 1980 [20]. Since 2011, however, recruitment has levelled off [37]. The complex life cycle of European eel includes different life stages, often related to the long migrations between the Atlantic spawning area in the Sargasso Sea and the coastal and freshwater habitats ranging from North Africa to the Barents Sea. The juveniles are called glass eels or elvers, immigrating from the ocean into continental waters [57]. Due to the complex life cycle, European eel are particularly susceptible to disturbances [45]. In addition, artificial reproduction of European eel is challenging, and artificially bred eel larvae survive for not more than a month [51]. Therefore, global aquaculture of eel is based on raising wild-caught glass eels.

Trafficking of juvenile European eels from Europe to Asia is considered as one of the most devastating wildlife crimes [31] in terms of numbers of fish traded alive and market value [50]. This trade is driven by Asian demand for aquaculture, reinforced by high profit margins along the illegal supply chain [61]. Previous law enforcement operations [38] and a study in Hong Kong determined that high proportions of eel products imported from China comprised European eel [53].

Eel species belonging to the family *Anguillidae* (anguillids) are

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consumed globally, with dominant markets now in Asia [39]. With the global spread of Asian food culture and restaurants, however, consumer behaviour is shifting. In North America, Russia and Europe, so-called unagi kabayaki is increasingly consumed [39]. Unagi is the Japanese word for freshwater eels and kabayaki describes the preparation where the butterfly fillets are dipped in a soy sauce before cooking on a grill.

According to the Food and Agriculture Organisation of the United Nations (FAO) the vast majority of the global eel aquaculture commodities (87 % in 2018) are produced in China [32], mainly in the Guangdong and Fujian provinces [6–12]. Until 2010, Asian traders purchased large quantities of glass eel in Europe to meet the demand for aquaculture [4,61].

Trade in European eels is restricted by international and national regulations. International trade is regulated by the species' listing in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) [13]. In 2010, the EU banned trade in European eels across its external border in response to the decline in stocks and the listing in Appendix II of CITES. National legislations of countries within the species distribution area but outside the EU, restrict the exploitation and export of European eel [59].

Within the EU borders, protection and sustainable management of the depleted European eel stock is subject to the Eel Regulation [19,24], obliging EU Member States to implement national Eel Management Plans, achieving a common protection level. Though the implementation of the Eel Regulation has led to substantial reductions in human impacts - especially concerning the fisheries [23] - the achieved protection levels in many areas have not reached the minimal level for recovery in many Member States yet [19,36]. Dekker [19] identified the absence of international feedback on the achievements of national Eel Management Plans (i.e., scientific advice narrowly focused on the stock status only) as the main cause for this.

Since the trade of European eel across the EU's external border has been banned, other anguillids (e.g., American eel, *A. rostrata;* Indian shortfin eel, *A. bicolor pacifica*; Giant mottled eel, *A. marmorata;* African longfin eel. *A. mossambica*) are increasingly targeted to supply Asian aquaculture [47]. The availability of these alternative eel species, however, is also strongly regulated by national catch quotas and trade restrictions [16,39,48] and the reported glass eel input into Chinese farms is not sufficient to produce the reported Chinese eel aquaculture production [14,39]. Because of this, it is unlikely that the demand for *Anguilla* seed-material can be met from legal markets; illegal supplies will comprise European eel as well as other *Anguilla* species [39].

Since 2011, targeted police operations throughout Europe and elsewhere have repeatedly demonstrated that the European eel trade ban is being circumvented: live glass eels are illegally exported from Europe and North Africa to Asia [5,30,39,49,55,61]. These are on-grown in Chinese aquaculture, processed, and sold on the domestic Chinese market as well as globally [39]. Whether these products of European eel are also re-exported to Europe, is currently unclear.

The labelling requirements for food products sold in the EU, including prepared, processed or preserved fish are defined in EU Regulation (EU) No 1169/2011 also known as the Food Information to Consumers (FIC) Regulation which applies since 13 December 2016 [27]. In Article 7(1) the regulation requires that food information shall not be misleading, particularly in regard to (a) its nature, identity, properties, composition, quantity, durability, country of origin or place of provenance and method of manufacture or production. Article 8(2). refers to the business operator's responsibility for the food information that shall ensure presence and accuracy. In Article 9(1), the regulation sets the following information to be displayed on the packages: (a) name of the food; (b) the list of ingredients; (c) any ingredient (…) causing allergies or intolerances (…); (d) the quantity of certain ingredients or categories of ingredients; (e) the net quantity of food; (f) the date of minimum durability or the 'use by' date; (g) any special storage conditions and/or conditions of use; (h) the name or business name and address of the food business operator referred to in Article 8(1); (i) the country of origin or place of provenance where provided for in Article 26; (j) instructions for use where it would be difficult to make appropriate use of the food in the absence of such instructions; (k) with respect to beverages containing more than 1.2 % by volume of alcohol, the actual alcoholic strength by volume; (l) a nutrition declaration.

Additional labelling requirements apply to fishery and aquaculture products marketed in the EU, having to comply with the following, mandatory labelling requirements: (a) the commercial designation of the species and its scientific name; (b) the production method; (c) the area where the product was caught or farmed; (d) whether the product has been defrosted; and (e) the date of minimum durability. This has been laid down in Article 35 in Regulation (EU) No 1379/2013 on the Common Organisation of the Markets of Fishery and Aquaculture Products (CMO) [28]. However, prepared or processed seafood products are excluded from this regulation, making it difficult to trace the species and origin of unagi kabayaki products.

We sampled Chinese eel products in EU markets and used mitochondrial DNA barcoding to identify the true species and assess the effectivity of trade regulations. Based on this, we discuss the importance of trafficking of young, and re-imports of grown European eel. Further, we analysed the product information displayed on the product packages in order to assess compliance with EU labelling requirements for seafood products.

2. Material and methods

2.1. Sample collection

We examined EUROSTAT data for Harmonized System Code 160417 (Prepared and preserved eels whole or in pieces; which identifies the targeted unagi kabayaki) for the period 2012–2018 and identified the main importing countries: Germany (DE), Belgium (BE), Netherlands (NL), Great Britain (GB) and France (FR). Shops in targeted locations, potentially selling eel, were selected searching google maps on keywords like "Asia market" and "Asian food" (also in local language). Posted images were checked to determine whether they might sell unagi kabayaki products. Aiming at 20 samples per country (100 samples in total), limited availability of products in some selected markets modified the actual number to 108, varying from 13 in Great Britain to 41 in Germany. Subsequently, purchased samples were individually tagged and frozen. Frozen samples were wrapped in insulating foil and sent to the laboratory by normal mail. At the laboratory, samples were kept frozen at − 20 °C until DNA sample extraction.

Following information displayed on the product packages were recorded in order to verify compliance with the labelling requirements of EU Regulation (EU) No 1169/2011: (1) product name/description; (2) legal name (scientific name or otherwise); (3) production and/or best before date; (4) weight in gram; (5) proportion of meat and sauce in percentage; (6) place of origin; (7) EU approval number of the exporter. The EU approval number of exporters enables identification of the exporters' names and locations via the publicly accessible list of Chinese companies that are approved for the trade with the EU [58]. The mandatory consumer information laid down in points (b), (g), (j), (k) and (l) of Article 9(1) of Regulation (EU) no 1169/2011 were not recorded in this study. Additionally, we recorded: (8) Price in Euro (€) or British Pound (£) (converted into €), and (9) importer name.

Considering that EU Regulation (EU) No 1379/2013 does not cover prepared, preserved and processed fish products like unagi kabayaki, compliance to this regulation was not included in this study.

2.2. Genetic analysis

Muscle tissue was sampled from frozen kabayaki fillets and subsequently placed in 70 % ethanol. To extract DNA, preserved, defrosted tissue was rinsed in sterile water, placed in 500 ml of 5 % Chelex 100 (Bio-Rad Laboratories; [62]) made up in sterile water, and incubated for

1 h at 95 °C. After brief vortexing the extracts were centrifuged and stored at − 20 °C. Aliquots (2 µl) of the supernatants were directly used in the polymerase chain reaction (PCR). Reactions were performed using the following amplification profile: an initial denaturation for 60 s at 94 °C, followed by 35 cycles of 30 s at 94 °C, 30 s at 50 °C and 40 s at 72 °C and 5 min at 72 °C for the final extension step. Amplification was carried out using 0.25 U of HotStar Taq Polymerase (Quiagen) in 20 µl reactions containing 2 µl Chelex 100 extracted DNA, 2 µl of 10x PCR buffer, 3 mM $MgCl_2$, 250 µM of each deoxyribonucleoside triphosphate and 10 pmol of each primer. A fragment of the cytochrome b gene (Cytb, 362 bp) was amplified using the universal primers CytbF 5'-TTCCATCCAACATCTCCGCATGATGAAA-30 and CytbR 50-AGCCCCTCAGAATGATATTTGTCCTCAC-3' [41]. PCR products were purified using High Pure PCR Product Purification Kit (Roche Molecular Systems, Inc.) according to the manufacturer's instructions, and sequenced on an ABI 3500 Genetic Analyzer (Life Technologies Corporation). Sequences were analysed using the software CEQ2000XL (Beckman Coulter), visually edited and aligned using the ClustalW algorithm implemented in BioEdit Sequence Alignment Editor [35].

For species identification, the published sequences of the mitochondrial genomes of all recent *Anguilla* species were used as references [46]. The evolutionary relationships were inferred using the UPGMA method [54]. The bootstrap consensus tree (Fig. 1) was computed from 1000 replicates [33] and rooted with the most likely ancestral species *A. mossambica* [46]. Branches corresponding to partitions reproduced in less than 50 % bootstrap replicates were collapsed. The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test (1000 replicates) are shown next to the branches [33]. The evolutionary distances were computed using the Kimura 2-parameter method [40] and are in the units of the number of base substitutions per site. The rate variation among sites was modelled with a gamma distribution (shape parameter = 0.15). The analysis involved 37 nucleotide sequences with all codon positions included. There was a total of 305 positions in the final dataset. Evolutionary analyses were conducted in MEGA6 [56]. Supplementary a comparison of nucleotide sequences with previously published data was performed by a BLAST search using blastn algorithm ([1]; accessed 09 November 2020). Haplotype diversity (Hd) and nucleotide diversity (pi) were calculated with DNASPv5 [44].

3. Results

3.1. Species determination and spatial distribution in destination countries

The molecular analysis determined four different anguillids, accounting for 73 American eels, 33 Japanese eels, one European eel and one Indian shortfin eel (Fig. 1).

For 86 samples (79.6 %), the species name, specified on the product label matched the true species identity - these appeared in all target countries. An additional six samples (5.6 %) indicated the correct species in one or many languages but gave no scientific name - these were imported by German or Dutch companies and sold in Germany or Great Britain. Product labels of five samples (4.6 %) did not indicate the species but were labelled as "Anguilla" (one sample) or "Eel (Fish)" (four samples) - those were imported into and sold in Germany or the Netherlands. We found that 12 samples (11.1 %) labelled with a species name (scientific, English or local language) differed from the true species. These samples were imported into all target countries except Belgium and sold in all target countries.

One true European eel (*A. anguilla*) sample was imported by a Dutch company and sold in Brussels, Belgium. One Indian shortfin eel (*A. bicolor pacifica*) sample was imported by a German company and sold in London, Great Britain.

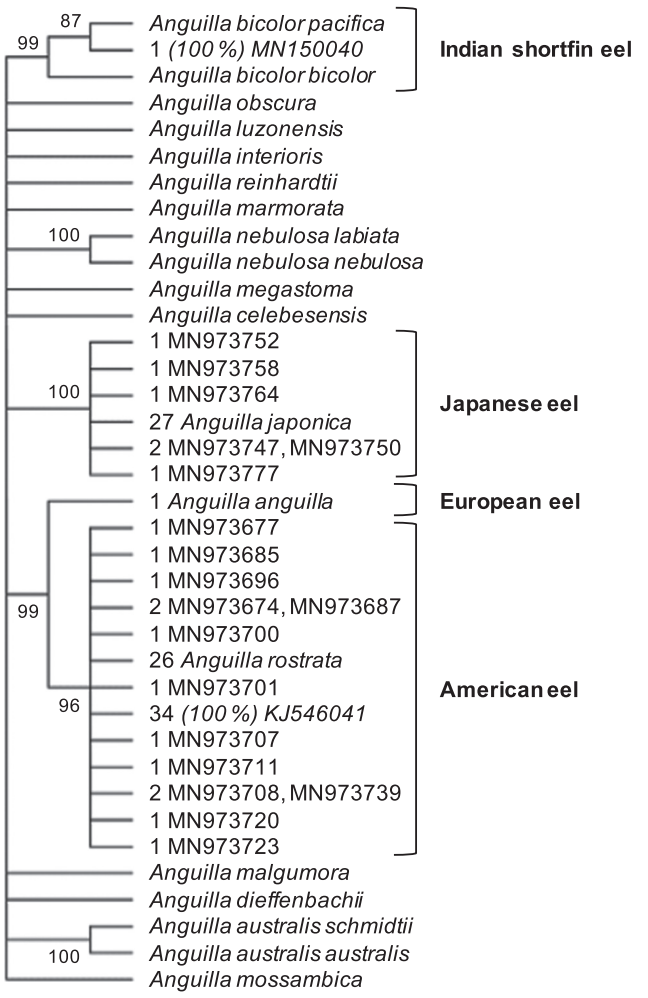

Fig. 1. Identification tree of unagi kabayaki samples (n = 108). Scientific species names refer to reference sequence haplotypes [46] and the number of samples identified for each haplotype is given at branch ends. The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test (1000 replicates) are shown next to the branches [33]. Please refer to Material and Methods for analysis details. The sequence analysis revealed 21 different haplotypes that could be assigned to four anguillids (bold). Taking the haplotype diversity (Hd) and nucleotide diversity (pi) as measures, most genetic diversity was present and thus trafficked within the American eel (73 sequences,13 haplotypes, Hd = 0.662, pi = 0.003) followed by the Japanese eel (33 sequences, 6 haplotypes, Hd = 0.333, pi = 0.001). BLAST search resulted in 5 haplotypes with 100 % match to one or more existing Genbank entries, the accession number of one best matching entry is given in italics despite for reference haplotypes. The assignment of one variant to Indian shortfin eel with 87 % bootstrap support was evidenced with an identical haplotype from Genbank. 16 haplotypes were not present in Genbank, indicated by only 99.67 % best match each. These variants are denoted in the tree with new accession number.

3.2. Compliance with EU Regulation (EU) No 1169/ 2011, FIC Regulation

Compliance with mandatory consumer information according to EU Regulation (EU) No 1169/2011 has been matched by 71.3 % of the sampled products. Samples that were labelled with a species name that was different from the true species (11.1 %) were considered not to comply with point (a) of Article 7(1) which requires that food information shall not be misleading. Samples labelled with insufficient information about the quantity of certain categories of ingredients (21.3 %) were considered not to comply with point (d) of Article 9(1). In both cases, samples were furthermore considered not to comply with Article 8

(2) on the business operator's responsibility in regard of the presence and accuracy of the food information, accounting for 28.7 % in total (Table 1).

3.3. Product composition and price analysis

On the unagi kabayaki packages, the product composition was summarised in percentage for eel meat and sauce. The percentage of eel meat ranged between 70 % and 95 % (average: 81 %) but did not differ between the two predominant species American eel and Japanese eel ($t = 1.377$, $P = 0.1880$).

The price of eel meat per kilogram differed between the four species we identified. The lowest mean price was paid for American eel, €66,60 ± 18.28 (n = 73). The highest mean price was paid for Japanese eel, €84.76 ± 19.91 (n = 33). The difference in price between those two predominant species was significant (*t*-test, $t = 3.682$, $P = 0.000408$). The single European and Indian shortfin eel samples were sold for €71.08 and €83.27, respectively.

The price of eel meat differed between importing countries (Anova, $F_{4,83} = 10.383$, $P < 0.00001$). The price in Great Britain (€94.17 ± 21.43) was higher than the price in the other four target countries combined ($t = 4.4255$, $P = 0.00014$) and the price in France (€88.24 ± 18.15) was higher than that in the other three continental European countries ($t = 4.487$, $P = 0.00025$). The lowest mean price per kilogram eel meat was charged in Belgium (€62.37 ± 16.37), the Netherlands (€64.70 ± 15.13) and Germany (€65.38 ± 14.96).

The price of eel meat differed between the three exporting Chinese provinces ($F_{2,84} = 7.0028$, $P = 0.00154$). Products being imported from the southern Guangdong province (n = 35, Japanese eel = €93.58 ± 20.60, American eel = €71.42 ± 11.83) were higher than products imported from Fujian (n = 52, Japanese eel = €62.19 ± 18.29, American eel = €66.94 ± 17.25) and Jiangxi (n = 19, Japanese eel = €85.86, American eel = €63.22 ± 17.16). The price for the one product from Taiwan, Province of China (PoC) accounted for €99.44 per kilogram eel meat.

Of the products that were labelled with the wrong species (n = 12), only one product was labelled as the higher priced species Japanese eel but identified as the lower priced species American eel. In contrast, seven products were labelled as the lower priced species American eel but contained the higher priced species Japanese eel.

Of all samples, 41 % were imported into an EU member state by one of the 19 importing companies which was located in an EU member state different from the eventual country where the sample was sold. More than half of the samples (n = 55) was imported into the Netherlands (51 %) followed by Germany (27 %).

3.4. Species-composition and geographic origin

Of the 35 samples exported from the southern coastal Guangdong province, the majority was Japanese eel. Of the 52 products exported from northern coastal Fujian province, the majority was American eel (Fig. 2). All 19 samples exported from the interior Jiangxi province were American eel, except for one being Japanese eel. (Fig. 2). One Japanese eel sample was exported from Taiwan, PoC. The European eel and Indian shortfin eel samples were both exported from Fujian province.

4. Discussion

During the early 2000s eel aquaculture companies moved and expanded their businesses from Taiwan, PoC to southern China, predominantly Guangdong province. The most likely driver behind this was the rapid economic development in Taiwan, PoC in combination with opening of China to the global market and the availability of Japanese glass eels from the nearby Pearl River Delta [60]. During the second half of the 2000s eel production spread further north into Fujian and Jiangxi provinces. Forced by economic pressures as well as adaption to the cooler climate, indoor aquaculture was established for the cultivation of European eels and, more recently, complemented by American eels [60, 61]. Our finding on the origins of imported products (Fig. 2) matches this distribution of the expected major species-specific exporting points. Based on the Chinese eel aquaculture business structure described in UNIDO [60], we conclude that eel aquaculture production facilities are usually located in the same province as the exporting company. Between 2011 and 2017, 87 % of the annual Chinese eel aquaculture output was produced in the two Chinese provinces Guangdong and Fujian [6–12].

Molecular species identification of unagi kabayaki fillets imported from China into the United States, Canada, Australia and the European Union during Interpol operation "Eel-Icit trade II" in 2018 and 2019, indicated that fillets of European eels were imported from China. During the course of operation, approximately half a million European eel fillets were seized and identified [38].

In March 2021, a Canada-based trade company was ordered to pay a fine of CA$163,776 after entering a guilty plea to two charges related to the illegal importation of significant quantities of European eel meat in contravention of subsection 6(2) of the Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act (WAPPRIITRA). During the course of the ongoing, multi-year Operation Vitrum, enforcement officers inspected and sampled 147 metric tonnes of eel meat between October 2017 and May 2018, imported from Xiamen, China. Five of the seven 40-foot sea containers inspected were found to contain CITES Appendix II listed European eel meat mixed with legally imported American eel meat. The amount of European eel meat versus American eel meat ranged from a low of 6.5 % per container to a high of 47.8 % [22].

Richards et al. [53] sampled raw, frozen, previously cooked and ready-to-eat eel meat from Hong Kong retail outlets and identified 45 % as being European eel. Most of their tested products were labelled as "*eel*" without indicating the species, which is not in conflict with Hong Kong legislation. In our study, only one out of 108 eel meat samples (0.93 %) was identified as European eel, violating the EU trade ban and CITES trade regulations, since over the last five years no import of European eel from China into Europe was reported by any European country [17].

This suggests that Chinese exporters are hesitant to ship European eel products directly into the EU, since it would violate CITES restrictions [13] and the EU trade ban [26]. Nevertheless, several cases of illegal imports of eel meat from China into Cyprus, Germany, Poland and Spain were reported by CITES [15] and according to Lithuanian e-court documents, eel meat from China was illegally imported into Lithuania by lorry via Belarus ([2,3]). These cases imply that an enhanced molecular genetic control programme for eel commodities entering the EU from China is urgently needed.

We examined a single eel commodity type (unagi kabayaki, available as butterfly fillets and sushi slices) from Asian shops located in the five major European importing countries. Likely, regions at the eastern edge of Europe and other eel commodities might be used for illegal imports from China. In this regard, there is an additional risk that unprocessed eel commodities (whole fish or fresh/frozen fillets) are imported from China into the EU and mixed with Europe-sourced eels before processing (e.g., smoking), losing product traceability. Hence, there is no basis for general conclusions on the constitution of all eel imports from China to Europe.

Following a transition period from 2010 until the beginning of 2013, all trade in European eel products from and into Europe is now banned [47]. The non-European countries at the southern and eastern edges of the species distribution area (e.g., Morocco, Tunisia, Turkey) have strictly regulated their eel trade and none of the mentioned countries permits the export of live European glass eels [59]. Therefore, the inevitable conclusion is that the vast majority of European eels in Asian eel farms (including our single sample of proven European eel) originate from illegal sources, violating (1) trade regulations set by CITES Appendix II [13], and, if glass eels originate from EU, (2) the EU trade ban

Table 1
Unagi kabayaki sample information and compliance with EU labelling requirement. Table summarises the basic sample information (unique identifier, date, location, importer/exporter, product parameters, molecular species identification) and results of our analysis in regard of compliance with EU labelling requirements laid down in EU Regulation (EU) No 1169/2011. Company names in column „Importer / Export" were anonymized and replaced by individual codes. First two letter of the code indicate the country according to ISO 3166-2; - indicates that information was not displayed on the package; ? indicates that no conclusion about fraudulent labelling was made, due to inconclusive species information provided on the package; [#] sample was purchased from fish counter and therefore no package information was available; [‡] additional production date was available on the package, not displayed here; [†]additional production date was not available on the package; [¶] only production date was available, displayed here.

Genbank accession number	Date	City, country (online, Italics)	Importer / Exporter	Product category	Total mass / meat (g)	Price in €	Best Before	Species labelled	Molecular species identification	Point (a) of §7 (1), wrong species labelled	§ 8 (2), responsibilities	Point (d) of § 9 (1), ingredient proportion
MN973673	2019–11–07	Duesseldorf, DE	NL-3 / CN-C	slices	160 / 144	6.90	2021–03–14[‡]	American Eel	*A. rostrata*			
MN973674	2019–11–07	Duesseldorf, DE	NL-3 / CN-C	butterfly fillet	255 / 204	9.70	2021–06–07[‡]	*Anguilla rostrata*	*A. rostrata*			
MN973675	2019–11–07	Duesseldorf, DE	NL-3 / CN-C	butterfly fillet	255 / 204	12.89	2021–06–07[‡]	*Anguilla rostrata*	*A. rostrata*			
MN973676	2019–11–07	Duesseldorf, DE	DE-3 / CN-E	butterfly fillet	300 / 204	15.89	2021–03–17[†]	Eel (Fish)	*A. rostrata*	?		
MN973677	2019–11–07	Duesseldorf, DE	NL-3 / CN-C	slices	160 / 144	8.89	2020–10–17[‡]	American Eel	*A. rostrata*			
MN973678	2019–11–07	Duesseldorf, DE	DE-2 / CN-A	butterfly fillet	250 / 200	9.50	2021–03–23[‡]	*Anguilla rostrata*	*A. rostrata*			
MN973746	2019–11–07	Duesseldorf, DE	DE-2 / CN-F	slices	160 / 128	13.00	2020–05–08[†]	*Anguilla japonica*	*A, japonica*			
MN973679	2019–11–07	Duesseldorf, DE	NL-4 / CN-A	butterfly fillet	255 / 204	14.00	2021–02–01[†]	*Anguilla rostrata*	*A. rostrata*			
MN973680[#]	2019–11–07	Duesseldorf, DE	- / -	butterfly fillet	229 / -	16.03	–	Anguilla	*A. rostrata*	?	X	X
MN973681	2019–11–07	Duesseldorf, DE	DE-4 / CN-E	slices	160 / 112	8.95	2020–04–20[‡]	*Anguilla rostrata*	*A. rostrata*			
MN973747	2019–11–07	Duesseldorf, DE	DE-1 / CN-F	slices	160 / 136	11.95	2021–09–01[†]	Japanischer Aal	*A. japonica*			
MN973748	2019–11–07	Duesseldorf, DE	DE-3 / CN-E	butterfly fillet	250 / -	16.50	2021–04–27[†]	*Anguilla japonica*	*A. japonica*		X	X
MN973749	2019–11–07	Duesseldorf, DE	DE-3 / CN-E	butterfly fillet	208 / -	13.90	2020–12–09[†]	*Anguilla japonica*	*A. japonica*		X	X
MN973682	2019–11–07	Duesseldorf, DE	DE-1 / CN-F	butterfly fillet	256 / 218	11.98	2021–09–01[†]	Anguilla americana	*A. rostrata*	?		
MN973683	2019–11–08	Frankfurt, DE	DE-4 / CN-E	slices	160 / 112	7.95	2020–04–20[‡]	*Anguilla rostrata*	*A. rostrata*			
MN973684	2019–11–08	Frankfurt, DE	NL-5 / CN-D	butterfly fillet	255 / -	10.59	2021–01–20[‡]	*Anguilla rostrata*	*A. rostrata*		X	X
MN973750	2019–11–08	Frankfurt, DE	DE-3 / CN-E	butterfly fillet	250 / -	14.95	2020–10–26[†]	*Anguilla japonica*	*A. japonica*		X	X
MN973685	2019–11–08	Frankfurt, DE	DE-2 / CN-A	slices	160 / 128	8.50	2018–10–17[¶]	Unagi, Aal	*A. rostrata*	?		
MN973686	2019–11–08	Frankfurt, DE	NL-3 / CN-C	slices	160 / 144	8.50	2020–10–17[‡]	*Anguilla rostrata*	*A. rostrata*			
MN973687	2019–11–08	Frankfurt, DE	NL-3 / CN-C	slices	160 / 144	10.50	2021–03–14[‡]	*Anguilla rostrata*	*A. rostrata*			
MN973688	2019–11–08	Frankfurt, DE	NL-5 / CN-D	butterfly fillet	255 / 204	13.00	2021–04–15[‡]	*Anguilla rostrata*	*A. rostrata*			
MN973751	2019–11–08	Frankfurt, DE	DE-3 / CN-E	butterfly fillet	208 / -	14.95	2021–04–27[†]	*Anguilla japonica*	*A. japonica*		X	X
MN973752	2019–11–08	Frankfurt, DE	DE-3 / CN-E	butterfly fillet	208 / -	14.50	2021–04–27[†]	*Anguilla japonica*	*A. japonica*		X	X
MN973689	2019–11–08	Frankfurt, DE	NL-5 / CN-D			15.99	2021–03–09[‡]		*A. rostrata*			

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Table 1 (*continued*)

Genbank accession number	Date	City, country (online, Italics)	Importer / Exporter	Product category	Total mass / meat (g)	Price in €	Best Before	Species labelled	Molecular species identification	Point (a) of §7 (1), wrong species labelled	§ 8 (2), responsibilities	Point (d) of § 9 (1), ingredient proportion
				butterfly fillet	255 / 204			*Anguilla rostrata*				
MN973753	2019–11–12	*Gelsenkirchen, DE*	DE-3 / CN-E	butterfly fillet	208 / -	16.80	2021–04–27†	*Anguilla japonica*	*A. japonica*		**X**	**X**
MN973690	2019–11–12	*Gelsenkirchen, DE*	NL-3 / CN-C	slices	160 / 144	9.99	2020–03–21‡	*Anguilla rostrata*	*A. rostrata*			
MN973691	2019–11–12	*Koeln, DE*	DE-1 / CN-B	butterfly fillet	256 / 218	12.73	2021–05–01†	Aal (anguilla americana)	*A. rostrata*	**?**		
MN973754	2019–11–12	*Koeln, DE*	DE-1 / CN-F	slices	160 / 136	12.73	2021–11–01†	Japanischer Aal	*A. rostrata*	**X**	**X**	
MN973755	2019–11–12	*Duesseldorf, DE*	DE-3 / CN-E	butterfly fillet	250 / -	34.53	2021–05–05†	*Anguilla japonica*	*A. japonica*		**X**	**X**
MN973692	2019–11–18	Berlin, DE	NL-3 / CN-C	slices	160 / 144	8.00	2021–03–14‡	*Anguilla rostrata*	*A. japonica*	**X**	**X**	
MN973693	2019–11–18	Berlin, DE	NL-5 / CN-D	butterfly fillet	283 / 226	12.00	2021–01–20‡	*Anguilla rostrata*	*A. rostrata*			
MN973694	2019–11–18	Berlin, DE	NL-5 / CN-D	butterfly fillet	283 / 226	8.00	2021–01–20‡	*Anguilla rostrata*	*A. rostrata*			
MN973695	2019–11–18	Berlin, DE	NL-1 / CN-A	butterfly fillet	100 / 92	3.25	2019–12–21‡	*Anguilla rostrata*	*A. rostrata*			
MN973696	2019–11–18	Berlin, DE	NL-3 / CN-C	slices	160 / 144	8.50	2021–03–14‡	*Anguilla rostrata*	*A. rostrata*			
MN973697	2019–11–18	Berlin, DE	DE-4 / CN-E	slices	160 / 112	8.50	2020–04–20‡	*Anguilla rostrata*	*A. rostrata*			
MN973698	2019–11–18	Berlin, DE	DE-4 / CN-E	slices	160 / 112	8.50	2020–04–20‡	*Anguilla rostrata*	*A. rostrata*			
MN973756	2019–11–19	Hamburg, DE	NL-3 / CN-C	slices	160 / 144	7.90	2021–06–08‡	*Anguilla rostrata*	*A. japonica*	**X**	**X**	
MN973699	2019–11–19	Hamburg, DE	NL-5 / CN-D	butterfly fillet	283 / 226	12.69	2021–01–20‡	*Anguilla rostrata*	*A. rostrata*			
MN973757	2019–11–19	Hamburg, DE	DE-3 / CN-E	butterfly fillet	208 / -	15.90	2021–04–27†	*Anguilla japonica*	*A. japonica*		**X**	**X**
MN973700	2019–11–19	Hamburg, DE	NL-3 / CN-C	slices	160 / 144	9.99	2021–03–14‡	*Anguilla rostrata*	*A. rostrata*			
MN973701	2019–11–19	Hamburg, DE	DE-2 / CN-A	butterfly fillet	250 / 200	13.95	2020–05–09‡	*Anguilla japonica*	*A. rostrata*	**X**	**X**	
MN973758	2019–11–01	Amsterdam, NL	NL-2 / CN-A	butterfly fillet	250 / 200	10.99	2020–12–02‡	*Anguilla rostrata*	*A. japonica*	**X**	**X**	
MN973702	2019–11–01	Amsterdam, NL	NL-5 / CN-D	butterfly fillet	255 / 204	11.99	2021–04–15‡	*Anguilla rostrata*	*A. rostrata*	**X**	**X**	
MN973703	2019–11–01	Amsterdam, NL	NL-5 / CN-D	butterfly fillet	255 / 204	10.60	2021–05–15‡	*Anguilla rostrata*	*A. rostrata*			
MN973704	2019–11–07	Amsterdam, NL	NL-2 / CN-A	butterfly fillet	230 / 184	17.00	2021–02–14‡	*Anguilla rostrata*	*A. rostrata*			
MN973705	2019–11–07	Amsterdam, NL	NL-7 / CN-E	butterfly fillet	255 / 204	13.95	2021–06–01†	Eel (Fish)	*A. rostrata*	**?**		
MN973706	2019–11–10	Amsterdam, NL	NL-4 / CN-A	butterfly fillet	255 / 204	10.75	2021–02–21†	*Anguilla rostrata*	*A. rostrata*			
MN973707	2019–11–10	Amsterdam, NL	NL-7 / CN-E	butterfly fillet	255 / 204	11.60	2021–06–21†	Eel (Fish)	*A. rostrata*	**?**		
MN973708	2019–10–25	Amsterdam, NL	NL-4 / CN-A	butterfly fillet	255 / 204	9.99	2021–02–01†	*Anguilla rostrata*	*A. rostrata*			

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Table 1 (*continued*)

Genbank accession number	Date	City, country (online, Italics)	Importer / Exporter	Product category	Total mass / meat (g)	Price in €	Best Before	Species labelled	Molecular species identification	Point (a) of §7 (1), wrong species labelled	§ 8 (2), responsibilities	Point (d) of § 9 (1), ingredient proportion
MN973709	2019–10–31	The Hague, NL	NL-4 / CN-A	butterfly fillet	255 / 204	10.95	2021–02–01†	*Anguilla rostrata*	*A. rostrata*			
MN973710	2019–10–31	The Hague, NL	NL-2 / CN-A	butterfly fillet	255 / 204	14.45	2021–12–07‡	*Anguilla rostrata*	*A. rostrata*			
MN973711	2019–11–08	Utrecht, NL	NL-2 / CN-A	butterfly fillet	255 / 204	11.95	2021–02–14‡	*Anguilla rostrata*	*A. rostrata*			
MN973712	2019–11–09	Utrecht, NL	NL-3 / CN-C	slices	160 / 144	7.95	2020–03–21‡	*Anguilla rostrata*	*A. rostrata*			
MN973713	2019–10–26	Rotterdam, NL	NL-2 / CN-A	butterfly fillet	212 / 170	16.95	2021–02–14‡	*Anguilla rostrata*	*A. rostrata*			
MN973714	2019–10–26	Rotterdam, NL	NL-2 / CN-A	butterfly fillet	212 / 170	14.45	2021–02–14‡	*Anguilla rostrata*	*A. rostrata*			
MN973715	2019–07–02	Rotterdam, NL	NL-2 / CN-A	butterfly fillet	212 / 170	14.45	2020–06–23‡	*Anguilla rostrata*	*A. rostrata*			
MN973716	2019–07–02	Rotterdam, NL	NL-2 / CN-A	butterfly fillet	242 / 194	10. v+95	2020–12–02‡	*Anguilla rostrata*	*A. rostrata*			
MN973717	2019–11–02	Nijmegen, NL	NL-2 / CN-A	butterfly fillet	242 / 194	12.95	2020–02–12‡	*Anguilla rostrata*	*A. rostrata*			
MN973718	2019–11–02	Nijmegen, NL	NL-5 / CN-D	butterfly fillet	255 / 204	11.95	2020–07–28‡	*Anguilla rostrata*	*A. rostrata*			
MN973719	2019–11–10	Arnhem, NL	NL-4 / CN-A	butterfly fillet	255 / 204	10.95	2020–02–01†	*Anguilla rostrata*	*A. rostrata*			
MN973720	2019–11–19	Brussels, BE	NL-4 / CN-A	butterfly fillet	255 / 204	14.50	2021–02–01†	*Anguilla rostrata*	*A. rostrata*			
MN973721	2019–11–19	Brussels, BE	NL-4 / CN-A	butterfly fillet	255 / 204	15.90	2021–04–06†	*Anguilla rostrata*	*A. rostrata*			
MN973722	2019–11–19	Brussels, BE	NL-4 / CN-A	butterfly fillet	255 / 204	14.50	2021–02–01†	*Anguilla rostrata*	*A. rostrata*			
MN973779	2019–11–19	Brussels, BE	NL-4 / CN-A	butterfly fillet	255 / 204	14.50	2021–02–01†	*Anguilla rostrata*	*A. anguilla*	**X**	**X**	
MN973723	2019–11–19	Brussels, BE	NL-2 / CN-A	slices	160 / 152	8.50	2020–04–15†	*Anguilla rostrata*	*A. rostrata*			
MN973724	2019–11–19	Brussels, BE	NL-4 / CN-A	butterfly fillet	255 / 204	9.35	2021–02–14‡	*Anguilla rostrata*	*A. rostrata*			
MN973759	2019–11–19	Brussels, BE	FR-3 / CN-E	butterfly fillet	208 / -	23.50	2020–04–13†	*Anguilla japonica*	*A. japonica*		**X**	**X**
MN973725	2019–11–19	Antwerp, BE	NL-5 / CN-D	slices	160 / 128	6.99	2010–10–16‡	*Anguilla rostrata*	*A. rostrata*			
MN973726	2019–11–19	Antwerp, BE	NL-5 / CN-D	butterfly fillet	255 / 204	9.50	2021–04–15‡	*Anguilla rostrata*	*A. rostrata*			
MN973727	2019–11–19	Antwerp, BE	NL-5 / CN-D	butterfly fillet	283 / 226	10.50	2020–10–15‡	*Anguilla rostrata*	*A. rostrata*			
MN973728	2019–11–19	Antwerp, BE	DE-2 / CN-A	slices	160 / 128	6.95	2020–10–16‡	*Anguilla rostrata*	*A. rostrata*			
MN973760	2019–11–19	Antwerp, BE	DE-2 / CN-A	butterfly fillet	220 / 176	8.95	2020–03–25‡	*Anguilla japonica*	*A. japonica*			
MN973761	2019–11–19	Antwerp, BE	FR-3 / CN-E	butterfly fillet	208 / -	17.50	2020–10–26†	*Anguilla japonica*	*A. japonica*		**X**	**X**
MN973729	2019–11–19	Antwerp, BE	NL-6 / CN-D	butterfly fillet	225 / 180	8.65	2021–03–09‡	*Anguilla rostrata*	*A. rostrata*			
MN973730	2019–11–19	Antwerp, BE	NL-5 / CN-D	butterfly fillet	225 / 180	13.95	2020–07–28‡	*Anguilla rostrata*	*A. rostrata*			

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Table 1 (*continued*)

Genbank accession number	Date	City, country (online, Italics)	Importer / Exporter	Product category	Total mass / meat (g)	Price in €	Best Before	Species labelled	Molecular species identification	Point (a) of §7 (1), wrong species labelled	§ 8 (2), responsibilities	Point (d) of § 9 (1), ingredient proportion
MN973731	2019–11–19	Antwerp, BE	NL-5 / CN-D	butterfly fillet	225 / 180	18.50	2019–11–03‡	*Anguilla rostrata*	*A. rostrata*			
MN973732	2019–11–19	Leuven, BE	NL-4 / CN-A	butterfly fillet	225 / 204	9.75	2021–02–01†	*Anguilla rostrata*	*A. rostrata*			
MN973733	2019–11–19	Leuven, BE	NL-5 / CN-D	slices	160 / 128	9.75	2020–10–16‡	*Anguilla rostrata*	*A. rostrata*			
MN973734	2019–12–02	Paris, FR	NL-3 / CN-C	butterfly fillet	255 / 204	12.90	2021–03–14‡	*Anguilla rostrata*	*A. rostrata*			
MN973735	2019–12–02	Paris, FR	GB-2 / CN-C	butterfly fillet	178 / 142	16.99	2020–01–01†	*Anguilla rostrata*	*A. rostrata*			
MN973736	2019–12–02	Paris, FR	FR-3 / CN-E	butterfly fillet	250 / -	19.29	2021–03–17†	*Anguilla rostrata*	*A. rostrata*		**X**	**X**
MN973737	2019–12–02	Paris, FR	NL-2 / CN-A	butterfly fillet	212 / -	10.50	2021–02–14‡	*Anguilla rostrata*	*A. rostrata*		**X**	**X**
MN973738	2019–12–02	Paris, FR	BE-1 / CN-A	slices	160 / 128	9.80	2021–08–01‡	*Anguilla rostrata*	*A. rostrata*			
MN973762	2019–12–02	Paris, FR	FR-3 / CN-E	butterfly fillet	208 / -	13.20	2021–04–27†	*Anguilla rostrata*	*A. japonica*	**X**	**X**	**X**
MN973763	2019–12–02	Paris, FR	FR-3 / CN-E	butterfly fillet	208 / -	16.00	2020–12–09†	*Anguilla rostrata*	*A. japonica*	**X**	**X**	**X**
MN973764	2019–12–02	Paris, FR	FR-3 / CN-E	butterfly fillet	208 / -	18.90	2020–10–26†	*Anguilla rostrata*	*A. japonica*	**X**	**X**	**X**
MN973739	2019–12–02	Paris, FR	DE-2 / CN-A	butterfly fillet	250 / 200	18.90	2020–12–01‡	*Anguilla rostrata*	*A. rostrata*			
MN973740	2019–12–02	Paris, FR	FR-1 / CN-D	slices	160 / 144	8.50	2020–04–02‡	*Anguilla rostrata*	*A. rostrata*			
MN973765	2019–12–02	Paris, FR	FR-1 / CN-D	butterfly fillet	220 / 198	17.00	2021–03–02‡	*Anguilla japonica*	*A. japonica*			
MN973741	2019–12–03	Paris, FR	DE-2 / CN-A	butterfly fillet	280 / 224	18.90	2020–10–16‡	*Anguilla rostrata*	*A. rostrata*			
MN973742	2019–12–03	Paris, FR	NL-5 / CN-D	slices	160 / 128	13.80	2020–06–04‡	*Anguilla rostrata*	*A. rostrata*			
MN973766	2019–12–03	Paris, FR	FR-3 / CN-E	butterfly fillet	208 / -	19.20	2021–04–18†	*Anguilla japonica*	*A. japonica*		**X**	**X**
MN973767	2019–12–03	Paris, FR	FR-3 / CN-E	butterfly fillet	250 / -	16.30	2021–05–02†	*Anguilla japonica*	*A. japonica*		**X**	**X**
MN973768	2019–12–03	Paris, FR	FR-2 / TW-A	butterfly fillet	200 / -	17.90	2020–08–13†	*Anguilla japonica*	*A. japonica*		**X**	**X**
MN973769	2019–12–03	Paris, FR	DE-1 / CN-F	slices	160 / 136	12.55	2021–05–01†	*Anguilla japonica*	*A. japonica*			
MN973743	2019–11–06	Sheffield, GB	DE-1 / CN-B	butterfly fillet	256 / 218	£ 16.50	2021–5†	eel (+ other languages)	*A. rostrata*	**?**		
MN973770	2019–11–01	Oxford, GB	GB-2 / CN-C	butterfly fillet	200 / -	£ 10.59	2021–3†	*Anguilla rostrata*	*A. japonica*	**X**	**X**	**X**
MN973771	2019–11–06	Canterbury, GB	GB-4 / CN-F	butterfly fillet	220 / 154	£ 16.20	2020–08–01†	*Anguilla japonica*	*A. japonica*			
MN973744	2019–11–06	Canterbury, GB	NL-2 / CN-A	butterfly fillet	255 / -	£ 14.00	2021–02–14‡	*Anguilla rostrata*	*A. rostrata*		**X**	**X**
MN973772	2019–11–12	London, GB	GB-4 / CN-F	butterfly fillet	200 / 140	£ 14.95	2020–08–01†	*Anguilla japonica*	*A. japonica*			
MN973773	2019–11–12	London, GB	GB-1 / CN-E	butterfly fillet	198 / 158	£ 9.99	2021–05–03†	*Anguilla japonica*	*A. japonica*			

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Table 1 (*continued*)

Genbank accession number	Date	City, country (online, Italics)	Importer / Exporter	Product category	Total mass / meat (g)	Price in €	Best Before	Species labelled	Molecular species identification	Point (a) of §7 (1), wrong species labelled	§ 8 (2), responsibilities	Point (d) of § 9 (1), ingredient proportion
MN973774	2019–11–12	London, GB	GB-1 / CN-E	butterfly fillet	208 / -	£ 10.99	2021–04–18[†]	*Anguilla japonica*	*A. japonica*		**X**	**X**
MN973780	2019–11–12	London, GB	DE-2 / CN-A	butterfly fillet	195 / 156	£ 12.99	2020–05–09[‡]	*Anguilla japonica*	*A. bicolor*	**X**	**X**	
MN973775	2019–11–06	London, GB	DE-2 / CN-A	butterfly fillet	250 / 200	£ 18.95	2020–05–09[‡]	*Anguilla japonica*	*A. japonica*			
MN973776	2019–11–10	Birmingham, GB	GB-4 / CN-F	butterfly fillet	200 / 140	£ 12.25	2020–08–01[†]	*Anguilla japonica*	*A. japonica*			
MN973777	2019–11–10	Birmingham, GB	GB-4 / CN-F	butterfly fillet	200 / 140	£ 11.99	2020–08–01[†]	*Anguilla japonica*	*A. japonica*			
MN973745	2019–11–08	Chiddingford, GB	GB-5 / CN-B	butterfly fillet	255 / 204	£ 19.90	2020–11–07[‡]	*Anguilla rostrata*	*A. rostrata*			
MN973778	2019–11–06	Hatfield, GB	GB-4 / CN-F	butterfly fillet	200 / 140	£ 19.90	2020–08–01[†]	*Anguilla japonica*	*A. japonica*			
									Total	**11.1%**	**28.7%**	**21.3%**

EU Regulation (EU) No 1169/2011	
Point (a) of §7(1)	Food information shall not be misleading, particularly: (a) as to the characteristics of the food and, in particular, as to its nature, identity, properties, composition, quantity, durability, country of origin or place of provenance, method of manufacture or production
§8(2)	The food business operator responsible for the food information shall ensure the presence and accuracy of the food information in accordance with the applicable food information law and requirements of relevant national provisions
Point (d) of §9(1)	In accordance with Articles 10–35 and subject to the exceptions contained in this Chapter, indication of the following particulars shall be mandatory: (d) the quantity of certain ingredients or categories of ingredients

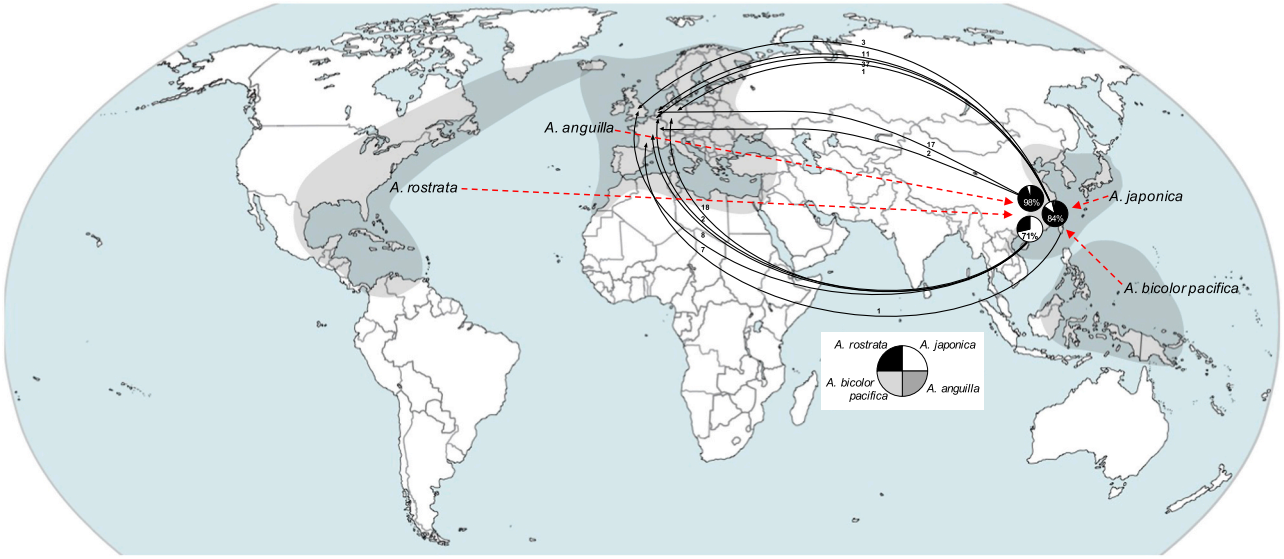

Fig. 2. Unagi kabayaki fillets sampled in Europe – origins and destinations. The pie diagrams show the species composition of the eel samples (predominant species expressed in percentage), grouped by exporting Chinese province from lower to upper pie diagram: Guangdong = 71 % Japanese eel; Fujian = 84 % American eel; Jiangxi = 98 % American eel. Shaded areas mark the natural species distribution areas (derived from [43]) of the identified species, containing the glass eel catch areas. Red dashed arrows indicate the direction of glass eel trade towards Chinese eel aquaculture. Black arrows (n = 107) indicate the export from Chinese provinces to destination countries in Europe (in-between import countries not displayed). Numbers labelling the black arrows indicate the number of samples. Map background downloaded from www.vecteezy.com.

[26], or (3) national trade regulations of countries within the species distribution area, outside the EU [59].

Seafood labelling fraud is increasingly recognised [42] but its causes are diverse and content dependent [21]. Our price analyses indicate that mislabelling generally did not result in higher prices. This implies that regulation avoidance and market access might be more important drivers than simply boosting prices [21]. Japanese eel, a species that can be sourced in southern China was not consistently cheaper than American eel, despite the latter having to have been imported from the other side of the globe.

Seafood products marketed in the EU have mandatory labelling requirements, including indication of the commercial designation of the species and its scientific name [28]. However, these requirements do not apply for prepared, processed or preserved fish, such as the unagi kabayaki fillets examined in our study. For those products only the Food Information to Consumers (FIC) Regulation applies since 13 December 2016 [27]. The CMO Regulation [28] does not apply for unagi kabayaki products – but in many cases the species and scientific name was displayed on the packages although it is not compulsatory, implying that the CMO Regulation is ambiguous. However, being non-applicable, it does allow species substitution, which is undesirable in the case of species with a protected status such as European eel.

According to the FIC Regulation which combines two previous food labelling Directives (200/13/EC, 90/496/ECC), unagi kabayaki fillet packages must include detailed consumer information regarding e.g., allergens, nutritions, food health and safety as well as the use of nanomaterials, but the mandatory information on fish products is limited to the product name and no scientific species name has to be provided [27]. This in combination with the exclusion of unagi kabayaki products from the CMO Regulation [28] prevents consumers from assessing the true species of their product, which in case of anguillids is particularly relevant. In total 28.7 % of our samples violated 2 or 3 Articles of the FIC Regulation requiring that food information shall not be misleading (point (a) of Article 7(1), that business operators are responsible to ensure the presence and accuracy of the food information (Article 8(2)) and that the quantity of certain categories of ingredients are provided (point (d) of Article 9(1)) [27].

Our study is based on a reasonable number of samples in total, but these are spread over five target countries, and unevenly distributed amongst them. Though this limits the statistical significance, it is important to highlight troubled compliance as well as shortcomings in relation with EU legislation (e.g., [18,34]), for those specific products.

4.1. Conclusions

Our molecular analysis identified only one European eel (0.93 %) among the 108 samples, implying that current trade regulations (CITES, EU trade ban) are effective in regard of the EU market. However, this does not correspond with previous findings in the EU (e.g., [15]) as well as other markets around the globe (e.g., [22,38,53]). Taking into account that law enforcement agencies put significant efforts into tackling illegal import of European eel meat into the EU, the current European legal framework regarding labelling requirements for eel products is insufficient. Since unagi kabayaki fillets are grilled and packages include sauce, they are considered as “prepared and preserved” and therefore do not require any indication of the scientific name. The exclusion of prepared and processed products from the CMO Regulation [28] in general has been identified as a major shortcoming that needs to be better addressed [18,34]. The EU is in the process of amending [29] the regulation that controls fisheries and imports [25], including the traceability of fisheries and aquaculture products (Article 56a-58). Many of the 16 anguillids are fished in outdoor waters or farmed in aquaculture, supplying global markets [39]. Comparing different data sources e.g., CITES trade data and Customs data, implies that much of the global eel trade does not conform with international and national law [47,52,61]. It is therefore of utmost importance that the EU achieves a straightforward labelling requirement, including the scientific name of the species concerned – also for prepared and preserved products.

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CRediT authorship contribution statement

Florian Stein: Conceptualization, Data Curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – Original Draft, Writing – Review & Editing; **Jens Frankowski**: Formal analysis, Methodology, Visualization, Writing – Original Draft, Writing – Review & Editing; **Vincent Nijman**: Formal analysis, Investigation, Validation, Writing – Review & Editing; **Christine Absil**: Conceptualisation, Writing – Review & Editing; **Irene Kraendonk**: Conceptualisation, Investigation; **Willem Dekker**: Supervision, Writing – Original Draft, Writing – Review & Editing.

Declaration of interest

None.

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GLOSSARY

Anguillids: species belonging to the family *Anguillidae* – *Anguilla anguilla* is the European eel
Glass eel: Juvenile, transparent eels, immigrating from the ocean into continental waters (also known as elvers in American English)
Recruitment: Number juvenile eels arriving in continental water, from the ocean
Unagi: Japanese word for anguillid
Kabayaki (Japanese): Japanese-style preparation of fish, where the butterfly fillets are repeatedly dipped in a soy sauce-based sauce and cooked on a grill