Food Control 155 (2024) 110043

Contents lists available at ScienceDirect

Food Control

journal homepage: www.elsevier.com/locate/foodcont

Labelling compliance assessment and molecular authentication of Grilled Fish Products Sold on Chinese e-commerce: Traceability issues related to the use of umbrella trade names

Xia Zhang[a,b,1], Tinacci Lara[c,1], Zhenzhu Sun[d], Yuan Li[d], Jing Guo[d], Weide Deng[d], Yanfei Chen[d], Ailan He[d], Hongyuan Peng[d], Andrea Armani[c,*], Wen Jing[d,**]

[a] Guangdong Provincial Key Laboratory of Utilization and Conservation of Food and Medicinal Resources in Northern Region, Shaoguan University, Shaoguan, 512005, China
[b] Henry Fok School of Food Science, Shaoguan University, Shaoguan, 512005, China
[c] FishLab, Department of Veterinary Sciences, University of Pisa, 56124, Pisa, Italy
[d] Henry Fok School of Biology and Agriculture, Shaoguan University, Shaoguan, 512005, China

ARTICLE INFO

Keywords:
DNA barcoding
Molecular identification
Labelling compliance
Seafood frauds

ABSTRACT

The present study aimed to verify the labelling compliance, the accuracy of the trade names, and to molecularly identify 74 pre-packaged grilled fish products purchased online on Taobao, the largest e-commerce platform in China. The labelling compliance was assessed in the light of the Chinese standard GB7718-2011 for pre-packaged foods. Products identification was performed by DNA barcoding targeting two mitochondrial genes (*COI* and *cytb*) while, the accuracy of the trade name, was assessed by analysing the results obtained using the 'common name search tool' available on the FAO FishBase portal. The trade name reported on the label was considered: 1) species-specific when only a species resulted from the search; 2) genus specific when more than one species belonging to the same genus resulted from the search; 3) umbrella term when more than one species belonging to different genera and/or families and orders resulted from the search. These results were compared to the molecular results, and the products were declared not-matching if the molecular results did not match the scientific names obtained by querying the trade name to FishBase portal. All products were fully compliant to the national labelling standard. Species identification was achieved for 97.3% of the tissue samples tested belonging to 72 products by using the two targets (*COI* and *cytb*). All products were sold using 12 different trade names consisting of two generic not informative terms (marine fish, fish), seven umbrella terms (eel, anglerfish, sardine, Navodon, snapper, leatherjacket, lionfish) which framed the products in a taxonomic family/order or several taxonomic orders, two genus specific terms (Bombay duck, Yellow croaker) and one species specific term (Tanaka's snailfish). A final mismatching rate of 48.6% was highlighted. The lack of accuracy in the trade names utilization highlighted in this study may favor substitution phenomena with economic and potential environmental impact.

1. Introduction

The increasing interest in seafood traceability in response to the global expansion of the sector has highlighted the seafood supply chain as one of the main targets of fraud for economic gain (Fox et al., 2018).

The species substitution, which is the most frequently reported type of seafood fraud (Silva et al., 2021), has a direct impact on consumers' trust on the entire sector, and potentially exposes consumers to health risk associated with toxic or allergenic species. In addition, it represents a major threat for the sustainable management of aquatic resources as it is often associated with Illegal, Unreported and Unregulated (IUU) fishing activities (Fox et al., 2018; Loeffler et al., 2022; Luque & Donlan, 2019; Tamm et al., 2016).

To promote a coordinated control of the seafood supply chain, numerous activities have been proposed by international organizations, also by the redaction of codes of practice for the traceability and the

* Corresponding author.
** Corresponding author.
E-mail addresses: andrea.armani@unipi.it (A. Armani), jw82123@126.com (W. Jing).
[1] The authors equally contributed to the manuscript.

https://doi.org/10.1016/j.foodcont.2023.110043
Received 15 March 2023; Received in revised form 24 July 2023; Accepted 12 August 2023
Available online 12 August 2023

labelling of globally marketed seafood (FAO & WHO, 2020). In addition, official databases (FishBase.org, Sealifebase.org) have been implemented as supportive tool for seafood identification. Consequently, specific legislative initiatives have been promoted nationally. The European Union (EU) implemented a regulatory system for the common organization of the markets in fishery and aquaculture products. Requirements for seafood labelling have been especially imposed (Regulation (EU) No. 1379/2013). Specifically, the EU Member States have been delegated to the drafting and updating of official lists reporting the trade names accepted for seafood products throughout the country, in association with valid scientific names retrievable from FAO (FishBase, SeaLifeBase, ASFIS), and World Register of Marine Species (WorMS) databases (Tinacci et al., 2019). The trade names accepted within the Member States are accessible for consultation through a dedicated site available on the European Commission's portal (EU Commission, Commercial designations). In the US, a similar approach for seafood labelling was adopted by Food and Drug administration (FDA) from 1994 (FDA-1994-D-0221) aimed to provide consistent advice on trade names and promote their utilization by the fish industry (FDA Seafood List, 2023). The list has been subsequently adopted for the control of seafood authenticity in Canada (Canadian Food Inspection Agency, CFIA), (CFIA Fish List, 2022). Also in Australia, a standard for the seafood labelling has been produced by the Fisheries Research and Development Corporation (FRDC), and it is currently available in association with a fish trade names database for the labelling of fish products in the country (Australian Fish Names Standard AS 5300-2019; Australian Fish Name Standard database, 2019).

The aforesaid legislative framework has internationally contributed to the implementation of analytical methods for seafood authentication, mostly based on DNA analysis (Clark, 2015; Silva et al., 2021). The DNA-barcoding has especially been validated as official tool for species identification in the US (Handy et al., 2011) and subsequently the use of DNA based methods has also been encouraged by the EU legislation (Regulation (EU) No. 1379/2013). These methods have been extensively used to investigate the species substitution rate on the markets (Fernandes et al., 2021; Giusti et al., 2023; Luque & Donlan, 2019; Pardo et al., 2016).

On the contrary, other countries have not yet provided for mandatory regulations in terms of seafood labelling. In China the only available reference is the GB7718-2011 standard (for pre-packaged foods), but neither specific labelling provisions nor standardized trade names for seafood are provided. Numerous studies based on DNA analysis have been conducted on the main Chinese distribution channels, namely at retails (Sun et al., 2021; Tang et al., 2022; Wen et al., 2017; Xiong et al., 2016a, 2018, 2019), on the e-commerce (Xiong et al., 2016b, 2020; Zhang et al., 2022), or both (Chen et al., 2021; Wang et al., 2021; Xing et al., 2021). Regardless the distribution channel, dried or grilled products, widely appreciated on the Chinese market, have been observed to be particularly exposed to species substitution (Wen et al., 2017; Xiong et al., 2016b, 2019, 2020). The occurrence of species substitutions has been highlighted in processed seafood sold on the e-commerce with substitution rates ranging from 37 to 87.5% (Chen et al., 2021; Reilly, 2018; Xiong, Guardone, Cornax, et al., 2016).

The consumer's risk to be exposed to fraudulent activities during online purchasing has indeed been studied especially in large metropolitan districts (Wang & Somogyi 2018; Lu, 2020a). Chinese e-commerce was described as plagued with a plethora of counterfeit goods and fraudulent activities and the use of generic trade names (umbrella terms) was identified as a relevant factor contributing and potentially enhancing consumers' misleading (Wen et al., 2017; Xiong et al., 2016b, 2020).

In this study, pre-packaged grilled seafood products purchased on the Chinese e-commerce were analyzed. The labels' compliance to the Chinese standard GB7718-2011 was assessed and the accuracy of the trade names was evaluated. Then, after products authentication by DNA barcoding, the molecular results were compared to the trade names to calculate the mismatching rate.

2. Materials and methods

2.1. Products collection and assessment of labels compliance to Chinese standard GB7718-2011

Seventy-four grilled fish products were purchased from Taobao (www.taobao.com), one of the largest e-commerce third-party platforms in China (Lu, 2020; Shi et al., 2020). The platform was selected by virtue of the extensive branching and type of manufacturers present which include a network of local producers (a.k.a. Taobao villages) mostly distributed in rural areas (Wei, Lin, & Zhang, 2020).

A convenience, non-probabilistic sampling was conducted from October to December 2021. It was structured to include a proportional number of products according to trade names, origin, and monthly transaction volume retrievable by the use of a specific search function provided within the platform in analogy with Xiong et al. (2020) and Shi et al. (2020).

The labelling information was translated into English by a native Chinese speaker, also with the use of multimedia translation tools (Google Translator; Word of Reference). Based on the Article 4 of the Chinese standard GB7718-2011, the following mandatory information was collected both on the product's web page and on the physical label accompanying the received sample and analyzed: 1) trade name, 2) list of ingredients, 3) net weight, 4) manufacturer and/or distributor's name, 5) date of production and expiration, 6) storage conditions, 7) food production license number, 8) code of the product standard. Additionally, the presence of the following recommended information was verified: a) batch identification, b) instruction of use, c) declaration of food or ingredients causing allergies. The products were kept in their original packaging and stored at room temperature in accordance with the storage conditions requested by the producer until further analysis. All the analysis were performed before the end of the minimum durability indicated on the product.

2.2. Molecular identification

2.2.1 Sampling, DNA extraction, amplification, and sequencing. All the seventy-four collected products consisted of pre-packed fish slices or fillets composed of a variable number of pieces ranging from 5 to 8. Three slices/fillets were randomly sampled from each product corresponding to a tissue sampling percentage per product ranging from 37.5 to 60%. A total of 222 tissue samples (TS) were subjected to subsequent total DNA extraction, which was performed, starting from 30 mg of tissue, using the TIANamp Marine Animals DNA Kit (TIANGEN, China) according to the manufacturer's instructions. Concentration and purity of the TS DNA samples were determined with a U-1800 spectrophotometer (Hitachi, Japan). A ~655 bp *COI* region (without primers) was amplified using the primer pair FishF1 (5′ -TCAACCAACCACAAAGACATTGGCAC-3′) and FishR1 (5′ -TAGACTTCTGGGTGGCCAAAGAATCA-3′) (Ward et al., 2009). In case of 1) the failure of the *COI* 655bp region amplification, or 2) the impossibility to identify the TS at species level after *COI* sequence analysis (conducted as reported in section 2.2.2), an alternative gene (*cytb*) was analyzed. Specifically, the amplification of a ~413 *cytb* bp region (without primers) was performed using the primers pair L14735 (5′ -AAAAACCACCGTTGTT ATTCAACTA-3′) and H15149 (5′ -GCCCCTCAGAATGATATTTGTCCTC A-3′) (Burgener & Hübner, 1998; Kocher et al., 1989). Both *COI* and *cytb* region amplifications were performed according to the protocol described in Zhang et al. (2022). The PCR products were analyzed by 1.2% agarose gel electrophoresis at 160 V for 30 min, and their length and concentration were determined by comparison with the DL2000 DNA ladder (TaKaRa, Japan). PCR products were purified with the AxyPrep™ DNA Gel Extraction Kit (Axygen, USA) and sequenced with the Applied Biosystems 3730 Automatic Sequencer.

2.2.2. Sequence editing and comparison with databases. The sequences were analyzed with Chromas lite v2.23 software and subsequently aligned with Editseq (DNASTAR Lasergene Version 7.1.0) and Jellyfish v1.4 software programs. The final sequences were queried for species identification against the reference sequences available in GenBank (http://www.ncbi.nlm.nih.gov) using Megablast program within Basic Local Analysis Search Tool (BLAST) interface. Final *COI* sequences were also queried against the reference sequences available in the Barcode of Life Data system (BOLD) (http://www.boldsystems.org/) using the Species Level Barcode Records Identification System (IDs) (Ratnasingham & Hebert, 2007). Specific identity score cut-offs were set for the final species identification, as described in Zhang et al. (2022).

2.3. Assessment of the trade names accuracy

When possible, the English translation of the Chinese trade names reported on the label were queried against the "common name search tool" available on the official FAO database FishBase (https://www.fishbase.se/search.php). This database is in fact recommended at EU and international level as reference database for fish names. Based on the search output, the trade name reported on the label was considered: 1) species-specific when only one species was retrieved; 2) genus specific when more than one species belonging to the same genus was retrieved; 3) umbrella term when more than one species belonging to different genera and/or families/orders was retrieved. The search was not conducted when umbrella terms namely "fish or marine fish" were reported, and these terms were considered "generic not informative". The results from this section were compared to the TS molecular results (section 2.2), and the products were declared "mismatching" if the species (or higher taxonomic level) identified molecularly did not match the species (or higher taxonomic level) assessed throughout the trade names analysis performed in this section. The mismatching rate was then calculated.

3. Results and discussion

3.1. Product collection and assessment of labels compliance to Chinese standard GB7718-2011

No differences were observed between the information collected on the e-commerce platform and the information verified on the physical label of the collected products. In agreement with Xiong et al. (2020), this might be recollected to the corporate policy for vendor selection of Taobao platform which provides specific rules for online product presentation (Xiong et al., 2020). The labels of all the seventy-four products were found as fully compliant to the Article 4 of the national standard GB7718-2011, namely that accurate mandatory information was available to the consumer. With respect to the recommended information, the batch number and the instruction of use were voluntary declared in 100% and 89.2% of the products, respectively. Comparable results were highlighted in a survey investigating caviar products sold on a Chinese e-commerce platform (Zhang et al., 2022). On the contrary the declaration of food or ingredients causing allergies was only reported in 18.9% (N = 14) of the products (Table 1). Therefore, the attention on the allergenic risk disclaimer seems to be slightly increased respect to the survey by Zhang et al. (2022), in which this information was not reported in any of the products under study. Nevertheless, this aspect should be further stressed in virtue of its health implications. Indeed, this information will be included among the mandatory labelling requirements with the enactment of the updated version of GB7718 standard (GAIN, 2020). Overall, the presence of non-mandatory information in a high percentage of the products, denotes a willingness on the part of food business operators to provide transparent information to the consumer.

3.2. Molecular identification

3.2.1. Sampling, DNA extraction, amplification, and sequencing

Given the small number of pieces per product package, no computational algorithms were applied, and standard numerical sampling was performed, which the authors deemed representative for the analysis of the products. The total DNA was extracted from all the 222 TS sampled from the 74 products, was successfully amplified, and sequenced with one of the two molecular targets selected for the study. Specifically, the *COI* gene was amplified from 165 DNA samples while the *cytb* was amplified from the remaining 57 DNA samples, for which the first *COI* amplification failed. To note that 54 out of the 57 total DNA samples (94.7%) failing the first COI amplification belonged to 17 products labelled as Anglerfish and 1 product labelled as 'Marine fish', all subsequently identified as *Lophius litulon* (Table 1SM, Table 2SM). In that case, a suboptimal *COI* primer pair binding efficiency was hypothesized. Indeed, a dedicated in silico analysis of the primers on *L. litulon* mitochondrion complete genomes (Accession number: NC_023828, OL627348) highlighted mismatches in both forward (5 mismatches) and reverse (3 mismatches) annealing sites, potentially affecting amplification performance. As regards the 3 remaining DNA samples in which the *COI* amplification failed (TS9, TS21, TS33), the presence of fragmentation of the extracted DNA was assumed. Indeed, several authors agree in emphasizing the effect of different processing treatments such as exposure to elevated temperatures and pressures, drying or salting as contributing factors in inducing DNA fragmentation at the expense of amplification efficiency (Armani, Tinacci, et al., 2015). This was also pointed out in similar barcoding studies for the molecular identification of roasted fish snacks (Xiong et al., 2016a, 2018). In such cases, reducing the length of the molecular target under study may favor successful amplification (Armani et al., 2015a, 2015b; Shokralla et al., 2015; Xiong et al., 2018). In this respect, the use of the *cytb* primers pair targeting a shorter gene fragment allowed the amplification of all the three TS (TS9, TS21, TS33) for which total DNA degradation had been hypothesized.

Additionally, the *cytb* was applied as alternative target for the amplification of 64 DNA samples belonging to 22 products, for which the *COI* target had not allowed the identification at species level (see section 3.2.2). Fifty-eight out of the 64 DNA samples were successfully amplified and returned readable *cytb* target sequences for subsequent molecular identification. For six unamplified TS belonging to P4 (TS10,11,12) and P42 (TS124.125.126), which had been respectively identified at genus level by the previous analysis on *COI* target as belonging to *Uroconger* sp/*Bathycongrus wallacei* and *Gnathopis* sp (Table 1SM, 2SM), a primer matching failure was hypothesized during annealing. However, this hypothesis could not be verified in silico since no *cytb* reference sequences are available for any species belonging to either of the above-mentioned genera.

3.2.2. Sequence editing and comparison with databases

All sequences produced in this study are reported in Table 1SM. The sequences obtained from the DNA samples extracted from the three randomly selected TS returned overlapping results.

Overall, the species identification was achieved in 216 out of 222 sequences produced (97,3%) belonging to 72 products (Table 1SM, Table 2SM). Specifically, for the *COI*, unambiguous species identification was achieved in 101 out of 165 TS sequences (62.8%) which were identified as *Rhynchoconger ectenurus* (N = 42 belonging to 14 products), *Larimichthys polyactis* (N = 36 belonging to 12 products), *Ariosoma meeki* (N = 12 belonging to 4 products), *Harpadon nehereus* (N = 5 belonging to 2 products), *Pennahia argentata* (N = 6 belonging to 2 products).

Fifty-two of the remaining 64 TS sequences for which the *COI* target did not allow species-specific allocation, were finally ascribed to the genus *Liparis* sp. In particular, overlapping identities values (98–100%) were found for three distinct species (*L. agassizi*; *L. tanakae*; *L. chefuensis*). This evidence apparently stands in disagreement with previous studies in which *COI* had been applied as marker gene for the

Table 1
Results of the analysis of labels content in the light of the GB 7718-2011 standard requirements. GB 7718-2011 mandatory information: 1) name of the food, 2) list of ingredients, 3) net weight, 4) manufacturer and/or distributor's name, 5) date of production and expiration, 6) storage conditions, 7) food production license number, 8) code of the product standard. Recommended information: a) batch identification, b) instruction of use, c) declaration of food or ingredients causing allergies.

Code	Label information on product name and production site		Analysis of label information vs GB7718-2011 requirements										
	Trade name	Processing plant location Province/city	Mandatory information (Yes = Y, No=N)								Recommended information (Yes = Y, No=N)		
			1	2	3	4	5	6	7	8	a	b	c
P1	Anglerfish	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N
P2	Anglerfish	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N
P3	Bombay-duck	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P4	Eel	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P5	Leather jacket	Shandong/Qingdao	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P6	Anglerfish	Shandong/Qingdao	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P7	Lionfish	Shandong/Weihai	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P8	Anglerfish	Shandong/Weihai	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P9	Anglerfish	Liaoning/Dalian	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
P10	Anglerfish	Liaoning/Dalian	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P11	Tanaka's snailfish	Liaoning/Dalian	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
P12	Tanaka's snailfish	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N
P13	Lionfish	Shandong/Qingdao	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P14	Lionfish	Shandong/Qingdao	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P15	Yellow croaker	Zhejiang/Wenzhou	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
P16	Anglerfish	Liaoning/Dalian	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P17	Marine fish	Zhejiang/Ningbo	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P18	Tanaka's snailfish	Liaoning/Dalian	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
P19	Anglerfish	Liaoning/Dalian	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
P20	Yellow croaker	Fujian/Shishi	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P21	Bombay-duck	Shandong/Qingdao	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P22	Sardine	Shandong/Binzhou	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P23	Navodon	Shandong/Qingdao	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P24	Eel	Shandong/Qingdao	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P25	Anglerfish	Shandong/Qingdao	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P26	Anglerfish	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P27	Lionfish	Shandong/Qingdao	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P28	Anglerfish	Liaoning/Donggang	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P29	Eel	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P30	Eel	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P31	Snapper	Fujian/Zhangzhou	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
P32	Anglerfish	Anhui/Xuancheng	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N
P33	Anglerfish	Anhui/Xuancheng	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N
P34	Lionfish	Anhui/Xuancheng	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N
P35	Eel	Anhui/Xuancheng	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N
P36	Marine fish	Anhui/Xuancheng	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P37	Yellow croaker	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P38	Eel	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P39	Anglerfish	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P40	Eel	Zhejiang/Wenzhou	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
P41	Lionfish	Shandong/Qingdao	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P42	Eel	Zhejiang/Taizhou	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P43	Anglerfish	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P44	Yellow croaker	Zhejiang/Wenzhou	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
P45	Yellow croaker	Zhejiang/Wenzhou	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
P46	Anglerfish	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P47	Yellow croaker	Guangxi/Beihai	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P48	Yellow croaker	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P49	Yellow croaker	Shandong/Weihai	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
P50	Yellow croaker	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P51	Yellow croaker	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P52	Yellow croaker	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P53	Yellow croaker	Shandong/Binzhou	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
P54	Eel	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P55	Eel	Zhejiang/Wenzhou	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
P56	Yellow croaker	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
P57	Eel	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P58	Lionfish	Shandong/Qingdao	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P59	Eel	Shandong/Yantai	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P60	Eel	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P61	Eel	Guangxi/Beihai	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P62	Lionfish	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P63	Yellow croaker	Zhejiang/Ningbo	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P64	Eel	Guangxi/Beihai	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
P65	Lionfish	Shandong/Weihai	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P66	Eel	Anhui/Xuancheng	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P67	Eel	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P68	Lionfish	Liaoning/Donggang	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P69	Eel	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N

(*continued on next page*)

Table 1 (*continued*)

Code	Label information on product name and production site		Analysis of label information vs GB7718-2011 requirements										
	Trade name	Processing plant location Province/city	Mandatory information (Yes = Y, No = N)								Recommended information (Yes = Y, No = N)		
			1	2	3	4	5	6	7	8	a	b	c
P70	Lionfish	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P71	Eel	Zhejiang/Zhoushan	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P72	Anglerfish	Liaoning/Donggang	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P73	Eel	Shandong/Yantai	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
P74	Fish	Shandong/Weihai	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N

study of phylogenetic relationships of snailfishes of the family Liparidae (Orr et al., 2019). Genus-level allocation was also obtained for 3 TS sequences belonging to an eel product (P42), assigned to *Gnathopis* sp. Finally, for 9 TS belonging to 3 products (P4, P22, P31), even identification at genus level was not achieved due to overlapping identities values for species belonging to different genera (Table 1SM, Table 2SM).

For the *cytb*, unambiguous species identification was achieved in 100% of the sequences produced (N = 115) which were finally ascribed to *L. litulon* (N = 54 belonging to 18 products); *Liparis tanakae* (N = 54 belonging to 18 distinct products); *Escualosa thoracata* (N = 3 belonging to 1 product); *Parargyrops edita* (N = 3 belonging to 1 product); and *Harpadon nehereus* (N = 1). For six TS sequences, originating from 2 products (P4 and P42), the amplification of the alternative *cytb* failed and the two products were ascribed to *Uroconger* sp. or the species *Bathycongrus wallacei* (P4) and to *Gnathopis* sp. (P42) according to the results obtained by the analysis on the *COI* target. Incidentally, as abovementioned, the analysis on the *cytb* target would have been nonetheless inconclusive given the absence of *cytb* reference sequences for *Bathycongrus wallacei* and any species belonging to the two genera of interest.

Although *COI* is still often selected as elective target in DNA barcoding analysis for seafood products identification a slow gene's evolution and a low nucleotide sequence divergence in certain taxonomic groups has been demonstrated (Bénard-Capelle et al., 2015; Cawthorn et al., 2011; Tinacci et al., 2018; Zhang et al., 2022). Data from the present study confirms the possibility of flanking the gene with other target to increase the resolution of the analytical technique (Fernandes et al., 2021).

3.3. Evaluation of trade name accuracy

Totally, 10 trade names and 2 generic not informative terms (Marine fish, Fish) were associated to the collected products (Table 2). Specifically, the predominant presence of four trade names consisting of eel (20/74; 27%), anglerfish (17/74; 22.9%), yellow croaker (14/74; 18.9%), and lionfish (11/74; 14.9%) was observed. The 6 remaining trade names highlighted were only marginally represented, each of them labelled in 1–3 products collected in the study (Table 2, Table 3). The results of the evaluation of the trade names accuracy (section 2.2) are summarized in Table 2. The analysis performed on FishBase on the 10 trade names highlighted the presence of 7 umbrella terms (eel, anglerfish, sardine, Navodon, snapper, leatherjacket, lionfish), 2 genus specific terms (Bombay duck, yellow croaker) and only 1 species specific term (Tanaka's snailfish). FishBase search showed for each umbrella term the association with a variable number of species (4–76) belonging to one or more families within one or more taxonomical orders. The highest number of species was highlighted for the trade name "snapper", which was associated with a total of 76 different species belonging to 12 genera of the family Lutjanidae (N = 73 species), of which *Lutjanus* sp. appears as the most represented (N = 48 species), 2 species of two distinct genera within the family Sparidae (*Pagrus auratus, Sparus aurata*), and 1 species of the family Sebastidae (*Sebastes alutus*). Specifically, in the case of Navodon a change in the search mode for scientific names to be associated to the term was necessary after the observation that the use of the 'common name search tool' did not returned any result. The alternative quest on FishBase portal applied by the use of 'genus name search tool' showed the term as corresponding to an obsolete genus, *Navodon* sp., including 4 fish species which were relocated within two distinct genera of the family Monacanthidae.

It is therefore evident that umbrella terms do not offer a precise characterization of the product. Indeed, as highlighted by several authors, umbrella terms have a relevant negative impact on the clarity of information provided potentially representing an obstructive element to a fully informed consumer's purchase (Cawthorn et al., 2018, 2021; Lowell et al., 2015; Tinacci et al., 2019, 2022; Vandamme et al., 2016; Zeng et al., 2019). Furthermore, the lack of taxonomic resolution of the trade names constitutes a potential major impediment to the protection of seafood chain traceability and sustainability as it creates opportunities for substitution and promotes the inadvertent introduction into legitimate marketplaces and the consumption of threatened or illegally harvested species (Cawthorn et al., 2018, 2021). Specifically, 2 of the 7 umbrella terms (snapper, eel) can refer to species often involved in traceability, economic, and sustainability issues (Cawthorn et al., 2018; Nijman & Stein, 2022).

A total mismatching rate of 48.6% (36/74) was highlighted (Table 3). In particular, two types of mismatches were found: 1) the species or genus identified by DNA barcoding was different from the expected scientific names in accordance with FishBase data and belonging to a different taxonomic family or order (N = 13 products 17.6%); 2) the species or genus identified by molecular analysis was different from the expected scientific names but belonging to the same family (N = 23 products 31.0%).

The 13 products pertaining to the first mismatching type included 11 products labelled as lionfish, one product labelled as Navodon, and one product labelled as leatherjacket, all molecularly identified as *L. tanakae* (Tanaka's snailfish in FishBase). An evident morphological difference between the molecularly identified species and each of the expected taxonomical names associated with the labelled trade names was highlighted. Therefore, for all these products the hypothesis of an involuntary misidentification was ruled out in favor of the hypothesis of a deliberate substitution. In fact, given the lower commercial value of *L. tanakae* (Chen et al., 2022) compared to the majority of the expected species replaced (Table 3), a noticeable economic gain for the producer can be assumed. This substitution could conceivably be favored by the high availability of *L. tanakae* whose population is subjected to an intensive fishing regime mainly intended for the fish processing industry (Chen et al., 2018, 2022). *L. tanakae*, indeed, together with *Gadus chalcogrammus*, *Gadus morhua*, *Lophius litulon*, *Pangasius bocourti* and *Thamnaconus septentrionalis* is one of the most frequently species processed for the preparation of grilled fish fillets (Li et al., 2021; Xiong et al., 2018). Thus, the systematic untraced and undeclared use of *L. tanakae*, for the preparation of these types of products could further contribute to affecting the species' stocks preservation already reported as gradually decreasing due to overfishing phenomena along the Yellow Sea coastline (Chen et al., 2022).

The 23 not-matching products (31.0%) pertaining to the second mismatch type consist of products labelled as eel (N = 20), Yellow croaker (N = 2) and snapper (N = 1) for each of which a brief discussion is provided.

Eel: The use of this umbrella term potentially entails relevant

Table 2
Results of the analysis conducted using the 'common name search tool' on the FishBase portal (https://www.fishbase.se/search.php last access on 07.07.2023) to associate the trade name to species and assess the accuracy of the labelled trade names of the products under study. *Scientific names associated to the labelled trade name through the use of the "common name search tool" available on the official FAO database FishBase. ** Scientific names associated to the labelled trade name through the use of the "genus name search tool" available on FishBase. NI not informative term.

Trade name and number of sampled products	Tot. no. of species retrieved (Fishbase.org)	Expected Scientific name (FishBase.org)*	Taxonomical ranking of the species retrieved			Accuracy of the trade name
			Genus	Family	Order	
Eel (N = 20)	11	*Anguilla japonica*	*Anguilla* sp.	Anguillidae	Anguilliformes	Umbrella term leading back to a taxonomic order
		Anguilla anguilla				
		Anguilla marmorata				
		Anguilla rostrata				
		Anguilla australis				
		Bassanago albescens	*Bassanago* sp.	Congridae		
		Bathyuroconger vicinus	*Bathyuroconger* sp.			
		Conger conger	*Conger* sp.			
		Gymnothorax moringa	*Gymnothorax* sp.	Murenidae		
		Mystriophis rostellatus	*Mystriophis* sp.	Ophichthidae		
		Ophisurus serpens	*Ophisurus* sp.			
Anglerfish (N = 17)	9	*Abantennarius coccineus*	*Abantennarius* sp.	Antennariidae	Lophiiformes	Umbrella term leading back to a taxonomic order
		Antennarius hispidus	*Antennarius* sp.			
		Chaunax abei	*Chaunax* sp.	Chaunacidae		
		Chaunax fimbriatus				
		Lophius piscatorius	*Lophius* sp.	Lophiidae		
		Lophius gastrophysus				
		Lophius litulon				
		Halieutaea indica	*Halieutaea* sp.	Ogcocephalidae		
		Halieutaea stellata				
Yellow croaker (N = 14)	2	*Larimichthys crocea*	*Larimichthys* sp.	Sciaenidae	Eupercaria *incertae sedis*	Genus specific term
		Larimichthys polyactis				
Lionfish (N = 11)	4	*Pterois mombasae*	*Pterois* sp.	Scorpaenidae	Perciformes, Scorpaenoidei	Umbrella term leading back to a taxonomic family
		Pterois russelii				
		Pterois volitans				
		Dendrochirus barberi	*Dendrochirus* sp.			
Tanaka's snailfish (N = 3)	1	*Liparis tanakae*	*Liparis* sp.	Liparidae	Perciformes, Cottoidei	Species-specific term
Bombay duck (N = 2)	2	*Harpadon nehereus*	*Harpadon* sp.	Synodontidae	Aulopiformes	Genus specific term
		Harpadon translucens				
Sardine (N = 1)	38	*Hemibrycon taeniurus*	*Hemibrycon* sp.	Characidae	Characiformes	Umbrella term leading back to more than one taxonomic order
		Piabucus dentatus	*Piabucus* sp.	Iguanodectidae		
		Sardina pilchardus	*Sardina* sp.	Alosidae	Clupeiformes	
		Sardinops sagax	*Sardinops* sp.			
		Clupea harengus	*Clupea* sp.	Clupeidae		
		Sprattus sprattus	*Sprattus* sp.			
		Amblygaster leiogaster	*Amblygaster* sp.	Dorosomatidae		
		Amblygaster sirm				
		Escualosa thoracata	*Escualosa* sp.			
		Ethmalosa fimbriata	*Ethmalosa* sp.			
		Harengula clupeola	*Harengula* sp.			
		Harengula humeralis				
		Harengula jaguana				
		Herklotsichthys dispilonotus	*Herklotsichthys* sp.			
		Lile stolifera	*Lile* sp.			
		Nematalosa japonica	*Nematalosa* sp.			
		Odaxothrissa mento	*Odaxothrissa* sp.			
		Pellonula leonensis	*Pellonula* sp.			
		Pellonula vorax				
		Sardinella albella	*Sardinella* sp.			
		Sardinella aurita				
		Sardinella brachysoma				
		Sardinella brasiliensis				
		Sardinella fimbriata				
		Sardinella gibbosa				
		Sardinella jussieu				
		Sardinella longiceps				
		Sardinella maderensis				
		Sardinella melanura				
		Sardinella sindensis				
		Etrumeus micropus	*Etrumeus* sp.	Dussumieriidae		
		Etrumeus sadina				
		Anchoviella guianensis	*Anchoviella* sp.	Engraulidae		
		Cetengraulis edentulus	*Cetengraulis* sp.			
		Ilisha elongata	*Ilisha* sp.	Pristigasteridae		
		Pellona ditchela	*Pellona* sp.			
		Alburnus alburnus	*Alburnus* sp	Leuciscidae	Cypriniformes	
		Rastrineobola argentea	*Rastrineobola* sp.	Danionidae		

(*continued on next page*)

Table 2 (*continued*)

Trade name and number of sampled products	Tot. no. of species retrieved (Fishbase.org)	Expected Scientific name (FishBase.org)*	Taxonomical ranking of the species retrieved			Accuracy of the trade name
			Genus	Family	Order	
Navodon** (N = 1)	4	*Meuschenia australis*	*Meuschenia* sp.	Monacanthidae	Tetraodontiformes	Umbrella term leading back to a taxonomic family
		Thamnaconus modestus	*Thamnaconus* sp.			
		Thamnaconus septentrionalis				
		Thamnaconus tessellatus				
Snapper (N = 1)	76	*Aphareus furca*	*Aphareus* sp.	Lutjanidae	Eupercaria *incertae sedis*	Umbrella term leading back to more than one taxonomic order
		Aphareus rutilans				
		Aprion virescens	*Aprion* sp.			
		Etelis carbunculus	*Etelis* sp.			
		Etelis coruscans				
		Etelis oculatus				
		Etelis radiosus				
		Lipocheilus carnolabrum	*Lipocheilus* sp.			
		Lutjanus analis	*Lutjanus* sp.			
		Lutjanus apodus				
		Lutjanus argentimaculatus				
		Lutjanus argentiventris				
		Lutjanus bengalensis				
		Lutjanus biguttatus				
		Lutjanus bitaeniatus				
		Lutjanus bohar				
		Lutjanus buccanella				
		Lutjanus campechanus				
		Lutjanus carponotatus				
		Lutjanus coeruleolineatus				
		Lutjanus colorado				
		Lutjanus cyanopterus				
		Lutjanus decussatus				
		Lutjanus dodecacanthoides				
		Lutjanus ehrenbergii				
		Lutjanus erythropterus				
		Lutjanus fulviflamma				
		Lutjanus fulvus				
		Lutjanus gibbus				
		Lutjanus goldiei				
		Lutjanus griseus				
		Lutjanus guilcheri				
		Lutjanus guttatus				
		Lutjanus jocu				
		Lutjanus johnii				
		Lutjanus jordani				
		Lutjanus kasmira				
		Lutjanus lemniscatus				
		Lutjanus lutjanus				
		Lutjanus madras				
		Lutjanus mahogoni				
		Lutjanus malabaricus				
		Lutjanus monostigma				
		Lutjanus notatus				
		Lutjanus novemfasciatus				
		Lutjanus purpureus				
		Lutjanus quinquelineatus				
		Lutjanus rivulatus				
		Lutjanus russellii				
		Lutjanus sanguineus				
		Lutjanus sebae				
		Lutjanus stellatus				
		Lutjanus synagris				
		Lutjanus vitta				
		Lutjanus vivanus				
		Lutjanus xanthopinnis				
		Macolor macularis	*Macolor* sp.			
		Macolor niger				
		Ocyurus chrysurus	*Ocyurus* sp.			
		Paracaesio caerulea	*Paracaesio* sp.			
		Paracaesio sordida				
		Paracaesio xanthura				
		Parapristipomoides squamimaxillaris	*Parapristipomoides* sp.			
		Pinjalo pinjalo	*Pinjalo* sp.			
		Pristipomoides argyrogrammicus	*Pristipomoides* sp.			
		Pristipomoides auricilla				
		Pristipomoides filamentosus				

(*continued on next page*)

Table 2 (*continued*)

Trade name and number of sampled products	Tot. no. of species retrieved (Fishbase.org)	Expected Scientific name (FishBase.org)*	Taxonomical ranking of the species retrieved			Accuracy of the trade name
			Genus	Family	Order	
		Pristipomoides flavipinnis				
		Pristipomoides multidens				
		Pristipomoides sieboldii				
		Pristipomoides zonatus				
		Symphorichthys spilurus	*Symphorichthys* sp.			
		Symphorus nematophorus	*Symphorus* sp.			
		Pagrus auratus	*Pagrus* sp.	Sparidae	Eupercaria *incertae sedis*	
		Sparus aurata	*Sparus* sp.			
		Sebastes alutus	*Sebastes* sp	Sebastidae	Perciformes	
Leatherjacket (N = 1)	17	*Oligoplites palometa*	*Oligoplites* sp.	Carangidae	Carangiformes	Umbrella term leading back to more than one taxonomic order
		Oligoplites saurus				
		Scomberoides tol	*Scomberoides* sp.			
		Abalistes stellatus	*Abalistes* sp.	Balistidae	Tetraodontiformes	
		Balistapus undulatus	*Balistapus* sp.			
		Balistes capriscus	*Balistes* sp.			
		Melichthys vidua	*Melichthys* sp.			
		Pseudobalistes flavimarginatus	*Pseudobalistes* sp.			
		Aluterus heudelotii	*Aluterus* sp.	Monacanthidae		
		Aluterus monoceros				
		Meuschenia scaber	*Meuschenia* sp.			
		Monacanthus chinensis	*Monacanthus* sp			
		Paramonacanthus sulcatus	*Paramonacanthus* sp.			
		Pseudalutarius nasicornis	*Pseudalutarius* sp.			
		Rudarius minutus	*Rudarius* sp.			
		Stephanolepis setifer	*Stephanolepis* sp.			
		Thamnaconus degeni	*Thamnaconus* sp.			
Marine fish (N = 1)	–	NI	NI	NI	NI	Generic not informative term
Fish (N = 1)	–	NI	NI	NI	NI	Generic not informative term

environmental sustainability issues since it is also associated with endangered species including *Anguilla rostrata* (American eel) and *A. japonica* (Japanese eel) which are traded internationally in substantial numbers (Nijman & Stein, 2022). In addition, the critically endangered species *A. anguilla* (European eel), for which trade outside the EU is generally banned or exceptionally permitted only with CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) trade certificates (Nijman & Stein, 2022), is comprised in this umbrella term. Studies have revealed glaring gaps in the traceability of eels and the presence of incorrectly identified endangered species on the Chinese market (Richards et al., 2020), or critically endangered species illegally exported processed and re-imported from China to the European market (Stein et al., 2021). It follows, therefore, that the use of this umbrella term not adequately accompanied by the species scientific name and can affect the conservation status of endangered species. Furthermore, the misuse of the term eel, and its association with species belonging to different families of the Order Anguilliformes, poses critical issues with respect to fair trade. In fact, species with vastly different commercial values are available at purchase especially in the Chinese market, which holds the production and distribution leadership of both caught and farmed Anguilliformes species (Yuan et al., 2022). In this respect, indeed a total of four (*A. japonica*; *A. marmorata*; *Muraenesox cinereus*, *Conger japonicus*) among the over 160 species of eel recorded in Chinese waters are reported as species of high commercial value (Dou, 2013). In this study, the 20 products labelled as eel were molecularly identified as Congridae species/genus (*Rhynchoconger ectenurus*, *Ariosoma meeki*, *Uroconger* sp.) not matching with any of the expected scientific names. However, common names are available on the portal for distinct species belonging to the genera *Ariosoma* sp., *Rhyncoconger* sp., and *Uroconger* sp., and the species *Bathycongrus wallacei* which appear all associated with the name conger or garden eel and adjectives referring to species-specific morphological features (e.g., Shorthead conger, Large eye conger, Barred sand conger). This aspect therefore confirms the misuse of the term eel to describe the products under study. In terms of environmental sustainability, issues related to the presence of endangered species were not observed. However, the use of the trade name eel for the detected conger species, of medium low commercial value (Dou, 2013), may constitute a misleading factor in the assessment of the real quality and commercial value of the product, potentially favoring opportunities to perpetrate species substitution with economic gain. An analogous misdescription incident is reported in a survey conducted by Armani et al. (2017), in which the presence of species belonging to the family Congridae in smoked products of Chinese origin labelled as eel was observed. Such occurrence was attributed by the authors to deficiencies in the identification and labeling system of fish products in the exporting country (Armani et al., 2017).

Yellow croaker: The 2 yellow croaker products found not matching the expected scientific name (*L. polyactis or L. crocea)* were finally identified as *P. argentata*, corresponding to the trade name white croaker (Sciaenidae family). *Sciaenidae* is a large family currently ascribed to Eupercaria *incertae sedis* (Betancur-R et al., 2017) including important economic fish species widely caught along the coasts of the Yellow Sea. Yellow and white croaker are not easily distinguishable macroscopically as they have similar morphological traits; yellow croaker, however, has superior organoleptic, sensory, and technological meat quality. This aspect results in a higher commercial value of yellow over silver croaker (Zhang et al., 2019). According to our results it is possible to hypothesize both the occurrence of unintentional substitution, linked to the morphological similarity between the specimens of the two species, but also the potential deceptive substitution. Similar cases of mislabelling with substitution of *L. polyactis* with *P. argentata* e *P. macrocephalus* were also described by Chen et al. (2021), in a DNA barcoding analysis conducted on processed *Larimichthys* sp. products purchased from local markets in Zhejiang Province and online. As in the present study, Chen et al. (2021) cited both unintentional and intentional substitution of products for financial gain as the cause of the detected mislabelling incidents.

Snapper: Numerous studies have reported high mislabelling rates involving products labelled as snapper (Cawthorn et al., 2012; Logan

Table 3
Comparison between the expected scientific name in accordance with the data collected from “common name search tool” available on the official FAO database FishBase (https://www.fishbase.se/search.php) and products’ molecular identities. Molecular identities not matching the expected scientific name associated with the trade name are highlighted in bold.

Trade name	No.	Expected species scientific name (FishBase.org)	Taxonomical ranking Family/Order	Molecular identification	No.	Products code
Eel	20	*Anguilla* sp. (5 species)	Anguillidae/ Anguilliformes	–	0	
		Bassanago albescens	Congridae/Anguilliformes	–	0	
		Bathyuroconger vicinus		–	0	
		Conger conger		–	0	
		-		***Uroconger* sp./ *Bathycongrus wallacei***	**1**	**P4**
		-		***Rhynchoconger ectenurus***	**14**	**P24,P35,P40, P55, P57, P59, P60, P61, P64, P66, P67, P69, P71, P73**
		-		***Ariosoma meeki***	**4**	**P29,P30,P38,P54**
		-		***Gnathophis* sp.**	**1**	**P42**
		Gymnothorax moringa	Muraenidae/ Anguilliformes	–	0	
		Mystriophis rostellatus	Ophichthidae/	–	0	
		Ophisusris serpens	Lophiiformes	–	0	
Anglerfish	17	*Abantennarius coccineus*	Antennariidae/	–	0	
		Antennarius hispidus	Lophiiformes	–	0	
		Chaunax sp. (2 species)	Chaunacidae/ Lophiiformes	–	0	
		Lophius sp. (3 species)	Lophiidae/Lophiiformes	*Lophius litulon*	17	P1, P2, P6, P8, P9, P10, P16, P19, P25, P26, P28, P32, P33, P39, P43, P46, P72
		Halieutea sp. (2 species)	Ogcocephalidae/ Lophiiformes	–	0	
Yellow croaker	14	*Larimichthys* sp. (2 species)	Sciaenidae/Eupercaria	*Larimichthys polyactis*	12	P37, P44, P45, P47, P48, P49, P50, P51, P52, P53, P56, P63
				Pennahia argentata	**2**	**P15, P20**
Lionfish	11	*Pterois* sp. (3 species)	Scorpaenidae/Perciformes	–	0	
		Dendrochirus barberi				
		-	**Liparidae/Perciformes**	***Liparis tanakae***	**11**	**P7, P13, P14, P27, P34, P41, P58, P62, P65, P68, P70**
Tanaka’s snailfish	3	*Liparis tanakae*	Liparidae/Perciformes	*Liparis tanakae*	3	P11, P12, P18
Marine fish or fish	3	NC	Liparidae/Perciformes	*Liparis tanakae*	2	P36, P74
			Lophiidae/Lophiiformes	*Lophius litulon*	1	P17
Bombay duck	2	*Harpadon* sp. (2 species)	Synodontidae/ Aulopiformes	*Harpadon nehereus*	2	P3, P21
Navodon	1	*Meuschenia australis*	Monacanthidae/	–	0	
		Thamnaconus sp (3 species)	Tetraodontiformes	-	0	
		-	**Liparidae/Perciformes**	***Liparis tanakae***	**1**	**P23**
Sardine	1	*Hemibrycon taeniurus*	Characidae/Characiformes		0	
		Piabucus dentatus	Iguanodectidae/ Characiformes		0	
		Sardina pilchardus	Alosidae/Clupeiformes		0	
		Sardinops sagax			0	
		Clupea harengus	Clupeidae/Clupeiformes		0	
		Sprattus sprattus			0	
		Amblygaster sp. (2 species)	Dorosomatidae/		0	
		Escualosa thoracata	Clupeiformes	*Escualosa thoracata*	1	P22
		Ethmalosa fimbriata			0	
		Harengula sp. (3 species)			0	
		Herklotsichthys dispilonotus			0	
		Lile stolifera			0	
		Nematalosa japonica			0	
		Odaxothrissa mento			0	
		Pellonula sp. (2 species)			0	
		Sardinella sp. (11 species)			0	
		Etrumeus sp. (2 species)	Dussumieriidae/ Clupeiformes		0	
		Anchoviella guianensis	Engraulidae/Clupeiformes		0	
		Cetengraulis edentulus			0	
		Ilisha elongata	Pristigasteridae/		0	
		Pellona ditchela	Clupeiformes		0	
		Alburnus alburnus	Leuciscidae/Cypriniformes		0	
		Rastrineobola argentea	Danionidae/Cypriniformes		0	
Snapper	1	*Aphareus* sp. (2 species)	Lutjanidae/Eupercaria	–	0	
		Aprion virescens		–	0	
		Etelis sp. (4 species)		–	0	
		Lipocheilus carnolabrum			0	
		Lutjanus sp. (48 species)		–	0	
		Macolor sp. (2 species)		–	0	
		Ocyurus chrysurus			0	

(*continued on next page*)

Table 3 (*continued*)

Trade name	No.	Expected species scientific name (FishBase.org)	Taxonomical ranking Family/Order	Molecular identification	No.	Products code
		Paracaesio sp. (3 species)			0	
		Parapristipomoides squamimaxillaris			0	
		Pinjalo pinjalo			0	
		Pristipomoides sp. (7 species)			0	
		Symphorichthys spilurus			0	
		Symphorus nematophorus			0	
		Pagrus auratus	Sparidae/Eupercaria		0	
		Sparus aurata		–	0	
		-		***Paragyrops edita***	**1**	**P31**
		Sebastes alutus	Sebastidae/Perciformes	-	0	
leatherjacket	1	*Oligoplites* sp. (2 species)	Carangidae/	–	0	
		Scomberoides tol	Carangiformes	–	0	
		Abalistes stellatus	Balistidae/	–	0	
		Balistapus undulatus	Tetraodontiformes	–	0	
		Balistes capriscus		–	0	
		Melichthys vidua		–	0	
		Pseudobalistes flavimarginatus		–	0	
		Aluterus sp. (2 species)	Monacanthidae/	–	0	
		Meuschenia scaber	Tetraodontiformes	–	0	
		Monacanthus chinensis		–	0	
		Paramonacanthus sulcatus		–	0	
		Pseudalutarius nasicornis		–	0	
		Rudarius minutus		–	0	
		Stephanolepis setifer		–	0	
		Thamnaconus degeni		–	0	
		-	**Liparidae/Perciformes**	***Liparis tanakae***	**1**	**P5**
Total	74				74	

et al., 2008; Lowell et al., 2015; Warner et al., 2019). Therefore, snapper was selected by Cawthorn et al. (2018) as a model for assessing the effects and implications of using umbrella terms on seafood supply chain transparency. They found evident implications in terms of consumers' deception for economic gain and environmental sustainability subsequent to the masking of IUU fishing practices. Therefore, authors emphasized the need to revise the use of this term and the absolute necessity of harmonizing the species naming at an international level by limiting the number of species to be associated with the umbrella terms in favor of more specific trade names (Cawthorn et al., 2018). In this regard, a pertinent example of the use of more informative trade names for snapper can be found in the latest standard issued by the FRDC in Australia, which proposes the use of adjectives referring to distinctive morphological characteristics of this species (Australian Fish Name Standard database, 2019). As regards the only one snapper product included in the study, it was molecularly identified as *Parargyrops edita* (Crimson seabream), from Sparidae family, a demersal fish species with a wide distribution in the South China Sea. By virtue of its commercial value in the latest decades the species has been significantly exploited leading to the need for the establishment of conservation strategies to protect fish stocks (Wang et al., 2019). This considered, the product would represent a fitting example of what Cawthorn et al. (2018) highlighted with respect to the use of the term snapper to designate too extensive number of species, particularly non-Lutjanids species, essentially concealing the identity of species with a high vulnerability to fishing. Thus, the not-matching result with the expected scientific names for the reported trade name, in this case, poses relevant issues in terms of environmental sustainability.

This said, the attribution of specific trade names and the avoidance of the use of generic terms should be encouraged also for the labelling of fish products on the Chinese domestic market primarily in accordance with the general transparency requirements advocated by GB 7718-2011 standard. In this regard, the use of a trade names consisting of the common names associated with attributes relating to unique morphological features or to a reference to the geographical catching area (may be a valid approach for the improvement of the trade name's accuracy (Tinacci et al., 2019; Tinacci et al., 2022). Nonetheless, even though the one-species-one-name approach is still advocated internationally as a standard objective to ensure a fair and transparent seafood traceability system, the use of umbrella terms is currently permitted in the US, Canada, and the EU (Cawthorn et al., 2018, 2021; Tinacci et al., 2019).

4. Conclusions

The present study was addressed to the assessment of labeling compliance, trade names accuracy and molecular identity of grilled fish snacks sold on an e-commerce platform for the protection of a fair and informed consumer purchasing. The analysis conducted confirmed products' compliance to the national food labelling mandatory rules. However, the frequent use of umbrella and generic terms was found to potentially constitute an obstructive element to a fully informed purchase by the consumer. The trade names not-matching rate highlighted through the products' molecular identification, unveiled intentional or unintentional substitution phenomena that have a direct economic impact on the value of the product on sale. In addition, this can impact on the management of fish stocks as a result of untracked and uncontrolled overfishing. In this respect DNA barcoding was confirmed as a valid method to be potentially applied as routine analytical tool to guarantee the authenticity of products offered for sale on the various distribution chains.

CRediT authorship contribution statement

Xia Zhang: Investigation, Data curation, Writing – original draft. **Tinacci Lara:** Writing – review & editing. **Zhenzhu Sun:** Conceptualization, Data curation. **Yuan Li:** Conceptualization, Writing – review & editing. **Jing Guo:** Conceptualization, Data curation. **Weide Deng:** Conceptualization, Data curation. **Yanfei Chen:** Conceptualization, Data curation. **Ailan He:** Conceptualization, Data curation. **Hongyuan Peng:** Conceptualization, Data curation. **Andrea Armani:** Writing – review & editing, Supervision. **Wen Jing:** Conceptualization, Writing – review & editing, Funding acquisition.

Declaration of competing interest

None

Data availability

Data will be made available on request.

Acknowledgments

This work was supported by the National Natural Science Foundation of China (Nos. 31872571, 32272425), the Foundation of Department of Education of Guangdong Province (Nos. 2022ZDZX4045, 2019KZDXM018, 2020ZDZX1042) and the Foundation of Shaoguan University (No. SZ2020KJ11).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodcont.2023.110043.

References

Armani, A., Guardone, L., Castigliego, L., D'Amico, P., Messina, A., Malandra, R., Gianfaldoni, D., & Guidi, A. (2015). DNA and Mini-DNA barcoding for the identification of Porgies species (family Sparidae) of commercial interest on the international market. *Food Control, 50*, 589–596. https://doi.org/10.1016/j.foodcont.2014.09.025

Armani, A., Tinacci, L., Lorenzetti, R., Benvenuti, A., Susini, F., Gasperetti, L., Ricci, E., Guarducci, M., & Guidi, A. (2017). Is raw better? A multiple DNA barcoding approach (full and mini) based on mitochondrial and nuclear markers reveals low rates of misdescription in sushi products sold on the Italian market. *Food Control, 79*, 126–133. https://doi.org/10.1016/j.foodcont.2017.03.030

Armani, A., Tinacci, L., Xiong, X., Castigliego, L., Gianfaldoni, D., & Guidi, A. (2015). Fish species identification in canned pet food by BLAST and Forensically Informative Nucleotide Sequencing (FINS) analysis of short fragments of the mitochondrial 16S ribosomal RNA gene (16S rRNA). *Food Control, 50*, 821–830. https://doi.org/10.1016/j.foodcont.2014.10.018

Australian Fish Name. (2019). *Standard database*. https://www.frdc.com.au/knowledge-hub/standards/australian-fish-names-standard#toc-download-the-australian-fish-names-database. (Accessed 13 March 2023).

Australian Fish Names Standard As 5300-2019. Australian Standard prepared by the Fisheries Research and Development Corporation (FRDC) Fish Names Committee, the standards reference body responsible for the technical content of the Australian Fish Names Standard; approved by the FRDC on 12 June 2019 and published on 24 June 2019 by FRDC, PO Box 222, Deakin West Act 2600. https://www.frdc.com.au/sites/default/files/2023-02/as_5300-2019-final_approved_pdf_download_version.pdf. (Last access 13 March 2023).

Bénard-Capelle, J., Guillonneau, V., Nouvian, C., Fournier, N., Le Loët, K., & Dettai, A. (2015). Fish mislabelling in France: Substitution rates and retail types. *PeerJ, 2*, e714. https://doi.org/10.7717/peerj.714

Betancur-R, R., Wiley, E. O., Arratia, G., Acero, A., Bailly, N., Miya, M., Lecointre, G., & Orti, G. (2017). Phylogenetic classification of bony fishes. *BMC Evolutionary Biology, 17*, 1–40. https://doi.org/10.1186/s12862-017-0958-3

Burgener, M., & Hübner, P. (1998). Mitochondrial DNA enrichment for species identification and evolutionary analysis. *Zeitschrift für Lebensmittel-Untersuchung und-Forschung A, 207*(4), 261–263. https://doi.org/10.1007/s002170050329

Cawthorn, D. M., Baillie, C., & Mariani, S. (2018). Generic names and mislabeling conceal high species diversity in global fisheries markets. *Conservation Letters, 11*(5), Article e12573. https://doi.org/10.1111/conl.12573

Cawthorn, D. M., Murphy, T. E., Naaum, A. M., & Hanner, R. H. (2021). Vague labelling laws and outdated fish naming lists undermine seafood market transparency in Canada. *Marine Policy, 125*, Article 104335. https://doi.org/10.1016/j.marpol.2020.104335

Cawthorn, D. M., Steinman, H. A., & Corli Witthuhn, R. (2011). Establishment of a mitochondrial DNA sequence database for the identification of fish species commercially available in South Africa. *Molecular Ecology Resources, 11*(6), 979–991. https://doi.org/10.1111/j.1755-0998.2011.03039.x

Cawthorn, D. M., Steinman, H. A., & Witthuhn, R. C. (2012). DNA barcoding reveals a high incidence of fish species misrepresentation and substitution on the South African market. *Food Research International, 46*(1), 30–40. https://doi.org/10.1016/j.foodres.2011.11.011

CFIA Fish List. (2022). Canada food inspection agency, fish list, last update 2022/09/08. https://inspection.canada.ca/active/scripts/fssa/fispoi/fplist/fplist.asp?lang=e. (Accessed 13 March 2023).

Chen, C., Ding, Y., Jiang, Z., Jiang, H., Lu, C., Zhang, L., Chen, Z., & Zhu, C. (2021). DNA barcoding of yellow croakers (*Larimichthys* spp.) and morphologically similar fish species for authentication. *Food Control, 127*, Article 108087. https://doi.org/10.1016/j.foodcont.2021.108087

Chen, Y., Shan, X., Han, Q., Gorfine, H., Dai, F., & Jin, X. (2022). Long-term changes in the spatio-temporal distribution of snailfish *Liparis tanakae* in the Yellow Sea under fishing and environmental changes. *Frontiers in Marine Science, 9*, 1–13. https://doi.org/10.3389/fmars.2022.1024086

Chen, Y., Shan, X., Jin, X., Johannessen, A., Yang, T., & Dai, F. (2018). Changes in fish diversity and community structure in the central and southern Yellow Sea from 2003 to 2015. *Journal of Oceanology and Limnology, 36*, 805–817. https://doi.org/10.1007/s00343-018-6287-6

Clark, L. F. (2015). The current status of DNA barcoding technology for species identification in fish value chains. *Food Policy, 54*, 85–94. https://doi.org/10.1016/j.foodpol.2015.05.005

Dou, S. (2013). Eels in China: Species, fisheries, stock management and culture. In K. Tsukamoto, & M. Kuroki (Eds.), *Eels and humans. Humanity and the Sea* (pp. 117–128). Tokyo: Springer. https://doi.org/10.1007/978-4-431-54529-3_8.

EU Commission, Commercial designations. Commercial designations of fishery and aquaculture products database including all information related to commercial designations of fishery and aquaculture products marketed in the European Union. https://fish-commercial-names.ec.europa.eu/fish-names/home_en. (Last access 13 March 2023).

FAO & WHO. (2020). *Code of practice for fish and fishery products. Rome*. https://doi.org/10.4060/cb0658en. . (Accessed 13 March 2023)

FDA-1994-D-0221. (2012). FDA's guide to acceptable market names for seafood sold in interstate commerce. In *Issued by the center for fod safety and applied nutrition*. last revision July https://www.fda.gov/regulatory-information/search-fda-guidance-documents/guidance-industry-seafood-list. (Accessed 13 March 2023).

Fernandes, T. J., Amaral, J. S., & Mafra, I. (2021). DNA barcode markers applied to seafood authentication: An updated review. *Critical Reviews in Food Science and Nutrition, 61*(22), 3904–3935. https://doi.org/10.1080/10408398.2020.1811200

Fox, M., Mitchell, M., Dean, M., Elliott, C., & Campbell, K. (2018). The seafood supply chain from a fraudulent perspective. *Food Security, 10*, 939–963. https://doi.org/10.1007/s12571-018-0826-z

GAIN. (2020). *China: China releases draft general standard for the labeling of prepackaged foods for domestic comments*. https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=China%20Releases%20Draft%20General%20Standard%20for%20the%20Labelling%20of%20Prepackaged%20Foods%20for%20Domestic%20Comments%20_Beijing_China%20-%20Peoples%20Republic%20of_03-01-2020. (Accessed 13 March 2023).

GB7718-2011. General rules for the labeling of prepackaged food. Issued by the Ministry of Health on April 20, 2011. Implemented on April 20, 2012. Standard press of China (in Chinese). English version GAIN report number CH 13001. https://www.fsis.usda.gov/sites/default/files/media_file/2021-02/gb-7718-2011-part-i.pdf (Last access 13 March 2023).

Giusti, A., Malloggi, C., Tinacci, L., Nucera, D., & Armani, A. (2023). Mislabeling in seafood products sold on the Italian market: A systematic review and meta-analysis. *Food Control, 145*, Article 109395. https://doi.org/10.1016/j.foodcont.2022.109395

Handy, S. M., Deeds, J. R., Ivanova, N. V., Hebert, P. D., Hanner, R. H., Ormos, A., Weigt, L. A., Moore, M. M., & Yancy, H. F. (2011). A single-laboratory validated method for the generation of DNA barcodes for the identification of fish for regulatory compliance. *Journal of AOAC International, 94*(1), 201–210. https://doi.org/10.1093/jaoac/94.1.201

Kocher, T. D., Thomas, W. K., Meyer, A., Edwards, S. V., Pääbo, S., Villablanca, F. X., & Wilson, A. C. (1989). Dynamics of mitochondrial DNA evolution in animals: Amplification and sequencing with conserved primers. *Proceedings of the National Academy of Sciences, 86*(16), 6196–6200. https://doi.org/10.1073/pnas.86.16.6196

List, F. D. A. S. (2023). *Seafood list database*. updated January 2023 https://www.cfsanappsexternal.fda.gov/scripts/fdcc/?set=SeafoodList. (Accessed 13 March 2023).

Li, N., Wang, J., Li, F., & Jiang, T. (2021). Rapid identification of pufferfish in roast fish fillet by real-time PCR. *Food Additives & Contaminants: Part A, 38*(6), 1028–1033. https://doi.org/10.1080/19440049.2021.1891301

Loeffler, C. R., Spielmeyer, A., Friedemann, M., Kapp, K., Schwank, U., Kappenstein, O., & Bodi, D. (2022). Food safety risk in Germany from mislabeled imported fish: Ciguatera outbreak trace-back, toxin elucidation, and public health implications. *Frontiers in Marine Science, 9*, 355. https://doi.org/10.3389/fmars.2022.849857

Logan, C. A., Alter, S. E., Haupt, A. J., Tomalty, K., & Palumbi, S. R. (2008). An impediment to consumer choice: Overfished species are sold as Pacific red snapper. *Biological Conservation, 141*(6), 1591–1599. https://doi.org/10.1016/j.biocon.2008.04.007

Lowell, B., Mustain, P., Ortenzi, K., & Warner, K. (2015). One name, one fish: Why seafood names matter. *Ocean*, 1–12. https://oceana.org/wp-content/uploads/sites/18/onenameonefishreport.pdf.

Lu, H. (2020). Marketing network of marine products under e-commerce mode. *Journal of Coastal Research, 106*(SI), 267–271. https://doi.org/10.2112/SI106-063.1

Luque, G. M., & Donlan, C. J. (2019). The characterization of seafood mislabeling: A global meta-analysis. *Biological Conservation, 236*, 556–570. https://doi.org/10.1016/j.biocon.2019.04.006

Nijman, V., & Stein, F. M. (2022). Meta-analyses of molecular seafood studies identify the global distribution of legal and illegal trade in CITES-regulated European eels. *Current Research in Food Science, 5*, 191–195. https://doi.org/10.1016/j.crfs.2022.01.009

Orr, J. W., Spies, I., Stevenson, D. E., Longo, G. C., Kai, Y., Ghods, S. A. M., & Hollowed, M. (2019). Molecular phylogenetics of snailfishes (Cottoidei: Liparidae) based on MtDNA and RADseq genomic analyses, with comments on selected morphological characters. *Zootaxa, 4642*(1), 1–79. https://doi.org/10.11646/zootaxa.4642.1.1

Pardo, M.Á., Jiménez, E., & Pérez-Villarreal, B. (2016). Misdescription incidents in seafood sector. *Food Control, 62*, 277–283. https://doi.org/10.1016/j.foodcont.2015.10.048

Ratnasingham, S., & Hebert, P. D. (2007). Bold: The barcode of Life data system. *Molecular Ecology Notes, 7*(3), 355–364. https://doi.org/10.1111/j.1471-8286.2007.01678.x. http://www.barcodinglife.org

Regulation (EU) No 1379/2013 of the European Parliament and of the Council of 11 December 2013 on the common organisation of the markets in fishery and aquaculture products, amending Council Regulations (EC) No 1184/2006 and (EC) No 1224/2009 and repealing Council Regulation (EC) No 104/2000. *Official Journal L, 354*, (2013), 1–21, 28.12 http://data.europa.eu/eli/reg/2013/1379/oj.

Reilly, A. (2018). Overview of food fraud in the fisheries sector. FIAM/C1165, FAO. In *Fisheries and aquaculture circular*. Rome: Italy. https://www.fao.org/3/I8791EN/i8791en.pdf.

Richards, J. L., Sheng, V., Yi, C. W., Ying, C. L., Ting, N. S., Sadovy, Y., & Baker, D. (2020). Prevalence of critically endangered European eel (*Anguilla anguilla*) in Hong Kong supermarkets. *Science Advances, 6*(10), Article eaay0317. https://doi.org/10.1126/sciadv.aay0317

Shi, R., Huang, M., Wang, J., He, C., Ying, X., Xiong, X., & Xiong, X. (2020). Molecular identification of dried squid products sold in China using DNA barcoding and SYBR green real time PCR. *Food Additives & Contaminants: Part A, 37*(7), 1061–1074. https://doi.org/10.1080/19440049.2020.1746411

Shokralla, S., Hellberg, R. S., Handy, S. M., King, I., & Hajibabaei, M. (2015). A DNA mini-barcoding system for authentication of processed fish products. *Scientific Reports, 5*(1), 1–11. https://doi.org/10.1038/srep15894

Silva, A. J., Hellberg, R. S., & Hanner, R. H. (2021). Chapter. 7: Seafood fraud. In R. S. Hellberg, K. Everstine, & S. A. Sklare (Eds.), *Food fraud. A global threat with public health and economic consequences* (pp. 109–137). Academic Press, 10. 1016/B978-0- 12- 817242- 1.

Stein, F. M., Frankowski, J., Nijman, V., Absil, C., Kranendonk, I., & Dekker, W. (2021). Chinese eel products in EU markets imply the effectiveness of trade regulations but expose fraudulent labelling. *Marine Policy, 132*, Article 104651. https://doi.org/10.1016/j.marpol.2021.104651

Sun, S. E., Zhang, X., Kong, L., & Li, Q. (2021). Molecular identification of dried shellfish products sold on the market using DNA barcoding. *Journal of Ocean University of China, 20*, 931–938. https://doi.org/10.1007/s11802-021-4682-7

Tamm, E. E., Schiller, L., & Hanner, R. H. (2016). Seafood traceability and consumer choice. In A. M. Naaum, & R. H. Hanner (Eds.), *Seafood authenticity and traceability* (pp. 27–45). Academic Press. https://doi.org/10.1016/B978-0-12-801592-6.00002-4, 2016.

Tang, Q., Luo, Q., Duan, Q., Deng, L., & Zhang, R. (2022). DNA barcode identification of fish products from Guiyang markets in southwestern People's Republic of China. *Journal of Food Protection, 85*(4), 583–590. https://doi.org/10.4315/JFP-21-258

Tinacci, L., Giusti, A., Guardone, L., Luisi, E., & Armani, A. (2019). The new Italian official list of seafood trade names (annex I of ministerial decree n. 19105 of September the 22nd, 2017): Strengths and weaknesses in the framework of the current complex seafood scenario. *Food Control, 96*, 68–75. https://doi.org/10.1016/j.foodcont.2018.09.002

Tinacci, L., Guidi, A., Toto, A., Guardone, L., Giusti, A., D'Amico, P., & Armani, A. (2018). DNA barcoding for the verification of supplier's compliance in the seafood chain: How the lab can support companies in ensuring traceability. *Italian Journal of Food Safety, 7*(2). https://doi.org/10.4081/ijfs.2018.6894

Tinacci, L., Stratev, D., Strateva, M., Zhelyazkov, G., Kyuchukova, R., & Armani, A. (2022). New official Bulgarian list of seafood trade names: Coping with EU labelling requirements and market trends to enhance consumers' informed choice. *Journal of Consumer Protection and Food Safety, 17*, 395–406. https://doi.org/10.1007/s00003-022-01397-7

Vandamme, S. G., Griffiths, A. M., Taylor, S. A., Di Muri, C., Hankard, E. A., Towne, J. A., Watson, M., & Mariani, S. (2016). Sushi barcoding in the UK: Another kettle of fish. *PeerJ, 4*, Article e1891. https://doi.org/10.7717/peerj.1891

Wang, L., Wang, X., Li, C., & Jia, X. (2019). Seasonal distribution and habitat preferences of crimson seabream *Parargyrops edita*: Implications for a marine protected area in beibu gulf, northern South China sea. *Marine and Coastal Fisheries, 11*(3), 258–270. https://doi.org/10.1002/mcf2.10075

Wang, N., Xing, R. R., Zhou, M. Y., Sun, R. X., Han, J. X., Zhang, J. K., Zheng, W., & Chen, Y. (2021). Application of DNA barcoding and metabarcoding for species identification in salmon products. *Food Additives & Contaminants: Part A, 38*(5), 754–768. https://doi.org/10.1080/19440049.2020.1869324

Ward, R. D., Hanner, R., & Hebert, P. D. (2009). The campaign to DNA barcode all fishes, FISH-BOL. *Journal of Fish Biology, 74*(2), 329–356. https://doi.org/10.1111/j.1095

Warner, K., Roberts, W., Mustain, P., Lowell, B., & Swain, M. (2019). Casting a wider net: More action needed to stop seafood fraud in the United States, 10.31230/osf.io/sbm8h https://usa.oceana.org/wp-content/uploads/sites/4/march_2019_oceana_seafood_fraud_report_final.pdf.

Wei, Y. D., Lin, J., & Zhang, L. (2020). E-commerce, Taobao villages and regional development in China. *Geographical Review, 110*(3), 380–405. https://doi.org/10.1111/gere.12367

Wen, J., Tinacci, L., Acutis, P. L., Riina, M. V., Xu, Y., Zeng, L., Ying, l., Chen, Z., Guardone, L., Chen, D., Sun, Y., Zhao, J., Guidi, A., & Armani, A. (2017). An insight into the Chinese traditional seafood market: Species characterization of cephalopod products by DNA barcoding and phylogenetic analysis using COI and 16SrRNA genes. *Food Control, 82*, 333–342. https://doi.org/10.1016/j.foodcont.2017.07.011

Xing, R. R., Hu, R. R., Wang, N., Zhang, J. K., Ge, Y. Q., & Chen, Y. (2021). Authentication of sea cucumber products using NGS-based DNA mini-barcoding. *Food Control, 129*, Article 108199. https://doi.org/10.1016/j.foodcont.2021.108199

Xiong, X., Guardone, L., Cornax, M. J., Tinacci, L., Guidi, A., Gianfaldoni, D., & Armani, A. (2016). DNA barcoding reveals substitution of Sablefish (Anoplopoma fimbria) with Patagonian and Antarctic Toothfish (*Dissostichus eleginoides* and *Dissostichus mawsoni*) in online market in China: How mislabeling opens door to IUU fishing. *Food Control, 70*, 380–391. https://doi.org/10.1016/j.foodcont.2016.06.010

Xiong, X., Guardone, L., Giusti, A., Castigliego, L., Gianfaldoni, D., Guidi, A., & Andrea, A. (2016). DNA barcoding reveals chaotic labeling and misrepresentation of cod (鳕, Xue) products sold on the Chinese market. *Food Control, 60*, 519–532. https://doi.org/10.1016/j.foodcont.2015.08.028

Xiong, X., Yao, L., Ying, X., Lu, L., Guardone, L., Armani, A., Guidi, A., & Xiong, X. (2018). Multiple fish species identified from China's roasted Xue Yu fillet products using DNA and mini-DNA barcoding: Implications on human health and marine sustainability. *Food Control, 88*, 123–130. https://doi.org/10.1016/j.foodcont.2017.12.035

Xiong, X., Yuan, F., Huang, M., Cao, M., & Xiong, X. (2020). Comparative evaluation of web page and label presentation for imported seafood products sold on Chinese e-commerce platform and molecular identification using DNA barcoding. *Journal of Food Protection, 83*(2), 256–265. https://doi.org/10.4315/0362-028X.JFP-19-309

Xiong, X., Yuan, F., Huang, M., Lu, L., Xiong, X., & Wen, J. (2019). DNA barcoding revealed mislabeling and potential health concerns with roasted fish products sold across China. *Journal of Food Protection, 82*(7), 1200–1209. https://doi.org/10.4315/0362-028x.jfp-18-514

Yuan, Y., Yuan, Y., Dai, Y., Gong, Y., & Yuan, Y. (2022). Development status and trends in the eel farming industry in Asia. *North American Journal of Aquaculture, 84*(1), 3–17. https://doi.org/10.1002/naaq.10187

Zeng, L., Armani, A., Wen, J., Lin, H., Xu, Y., Fan, S., Sun, Y., Yang, C., Chen, Z., Chen, D., Zhao, J., & Li, X. (2019). Molecular identification of seahorse and pipefish species sold as dried seafood in China: A market-based survey to highlight the actual needs for a proper trade. *Food Control, 103*, 175–181. https://doi.org/10.1016/j.foodcont.2019.04.007

Zhang, X., Tinacci, L., Xie, S., Wang, J., Ying, X., Wen, J., & Armani, A. (2022). Caviar products sold on Chinese Business to customer (B2C) online platforms: Labelling assessment supported by molecular identification. *Food Control, 131*, Article 108370. https://doi.org/10.1016/j.foodcont.2021.108370

Zhang, J. J., Wang, X., & Shi, W. (2019). Odor characteristics of white croaker and small yellow croaker fish during refrigerated storage. *Journal of Food Biochemistry, 43*(10), Article e12852. https://doi.org/10.1111/jfbc.12852