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Short communication

DNA barcode identification of fish products in Taiwan: Government-commissioned authentication cases

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ABSTRACT

Mislabeling of fish products not only impacts consumer finances, but can also be deleterious to public health. Fish products may be mislabeled for reasons including ambiguity of common fish names, challenging morphological identification, or willful intention to deceive. We reveal a high rate of mislabeling (70%) in 34 samples from 17 cases entrusted to us by three different Customs offices and one Coastal Patrol Office in Taiwan using DNA barcoding based on a partial segment of the mitochondrial cytochrome c oxidase subunit I gene (COI). In order to reduce the mislabeling of imported fish products, the authorities should take some actions into consideration, such as institutionalizating molecular authentication of fish products, standardizing the usage of common fish names, and legislating for penalties.

1. Introduction

Fish is considered to be healthier than other meat since it has been demonstrated that intake of fish is beneficial for preventing many diseases, such as type 2 diabetes, heart failure and metabolic syndromes (Baik, Abbott, Curb, & Shin, 2010; Djoussé, Akinkuolie, Wue, Dingg, & Gaziano, 2012; Wu et al., 2011). Moreover, fish, especially those obtained by aquaculture, have a lower carbon footprint than beef and pork (Nijdam, Rood, & Westhoek, 2012). So, as human health consciousness develops and concern about climate change increases, it can be expected that the exploitation of fish as a resource will grow concomitantly.

Species identification is critical to biological conservation, and it can be used to prevent illegal exploitation or to arrest smuggling of protected species (Chang, Jang-Liaw, Lin, Fang, & Shao, 2013; Chang et al., 2014; Ciavaglia, Tobe, Donnellan, Henry, & Linacre, 2015; Lee et al., 2013; Meganathan, Dubey, Jogayya, & Haque, 2013). In addition, species authentication is extremely important for the detection of commercial fraud. Commercial fraud has been found in investigations of meat, traditional medicines and spices (Doosti, Dehkordi, & Rahimi, 2014; Eurlings et al., 2013; Guo, Wang, Su, Zhang, & Zhou, 2011; Kane & Hellberg, 2016; Quinto, Tinoco, & Hellberg, 2016; Torelli, Marieschi, & Bruni, 2014; Xu et al., 2016), and fish products are very vulnerable to adulteration. In previous studies it has been demonstrated that 24% of seafood samples in South Brazil, 33.3% of sampled fish fillets in Egypt, 50% of sampled common sole in German, 82% of sampled fish fillets in Italy, 22% of seafood samples in India, and 25% of seafood samples from North America were mislabeled (Carvalho, Palhares, Drummond, & Frigo, 2015; Galal-Khallaf, Ardura, Mohammed-Geba, Borrell, & Garcia-Vazquez, 2014; Kappel & Schröder, 2016; Nagalakshmi, Annam, Venkateshwarlu, Pathakota, & Lakra, 2016; Pinto et al., 2015; Wong & Hanner, 2008). Two types of harmful consequences arise from mislabeling of fish products, namely economic fraud and health hazards (Galimberti et al., 2013). Economic fraud involves substituting high value fish with less expensive ones; for instance, replacing cod (*Gadus* spp.) with Gadiformes, Perciformes, Pleuronectiforems or Tetraodontiformes fishes (Xiong et al., 2016), and snapper (*Lutjanus* spp.) with tilapia (Khaksar et al., 2015). Retailers are inclined to mislabel fish products as either higher-priced fish species or ones with more appetizing names, since doing so increases their profit margins (Jacquet & Pauly, 2008). The health hazards associated with mislabeling include substitution with species that are allergenic or toxic, or with species whose aquaculture and processing chains are compromised by high pollution

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and/or microbiological contamination (C.-H. Hsieh et al., 2010; Pappalardo & Ferrito, 2015; Triantafyllidis et al., 2010).

Mislabeling can be so injurious to health, finances and conservation that accurate methods to verify species found in fish products are critical. Although traditional methods of morphological identification offer a straightforward solution for recognizing fish species (Bottero & Dalmasso, 2011), it is not possible to use them on certain fish products such as fish fillets and fish eggs, because either processing eliminates diagnostic characteristics or, in the case of fish eggs, sufficient morphological characters do not exist to allow identification. Fortunately, DNA-based methods offer an alternative solution. Hebert, Cywinska, Ball, and deWaard (2003) first comprehensively proposed the concept of DNA barcoding as a reliable, cost-effective and accessible solution for identifying species based on a particular segment of the cytochrome *c* oxidase subunit 1 (COI), noted for having lower within-species than between-species variation (Ward, Hanner, & Hebert, 2009). COI sequences could therefore be used as taxon "barcodes", serving as a core element of a bioidentification system for all animals on earth. Many researchers have applied this DNA barcoding method to differentiate species from various fish products, including caviar, surimi, packaged frozen products, fillets and dried products (Boscari et al., 2014; Galal-Khallaf, Ardura, Borrell, & Garcia-Vazquez, 2016; Keskin & Atar, 2012; Pinto et al., 2015; Pinto et al., 2016; Wen et al., 2015; Zhao et al., 2013). In addition, a publicly-accessible database—the Barcode of Life Data system (BOLD)—provides a tool to compare a query sequence with an extensive set of reference sequences (Ratnasingham & Hebert, 2007).

In this article, we report the DNA barcoding results of 17 government-commissioned authentication cases from three different Customs offices and one Coastal Patrol Office between 2009 and 2015. Taiwan has instituted different import tariffs for fish products made from different species, so mislabeling of imported fish products can cause considerable losses in tax revenue. Also, importation of some fish species and their products is banned by the Taiwanese government, particularly for those species that are of concern for reasons of conservation or invasiveness. The molecular authentication of suspected mislabeling would greatly assist in the conservation of biodiversity by acting as a deterrent to illegal trade in protected species.

2. Materials and methods

2.1. Sample collection

Between 2009 and 2015, 17 molecular identification cases were entrusted to us by three different Customs offices of the Customs Administration under the Ministry of Finance, Taiwan, and one Coastal Patrol Office under the Coast Guard Administration, Taiwan. Since these four government entities did not request a particular sample size, for the 17 cases if the subject was a whole fish or a fish fillet, such as cases No. 3 and No. 11 (Table 1), only one piece of tissue was sampled from each subject. However, if the subject constituted more than one individual, such as several dried fish, fish eggs, or fish larva (cases No. 1, No. 15 and No. 16), sample size depended on the morphological similarity of subject components. DNA was extracted from more than one individual from these latter collective samples when they displayed morphological heterogeneity. In total, we tested 34 specimens taken from these 17 cases (see Table 1).

2.2. DNA barcoding

DNA was extracted from each of the 34 samples using Quick Gene DNA Tissue Kit S (Fujifilm, Tokyo, Japan). PCR amplifications of the partial mitochondrial COI gene (approximately 650 bp) were performed in a mixture with a final volume of 50 μL containing 5 ng template DNA, 12.5 μmol of each forward and reverse primer, forward: FishF1+2 (5′-TCR ACY AAY CAY AAA GAY ATY GGC AC-3′); reverse: FishR1 (5′- TAG ACT TCT GGG TGG CCA AAG AAT CA-3′) and FishR2 (5′-ACT TCA GGG TGA CCG AAG AAT CAG AA-3′). The protocol for these universal primers was modified based on the method of Robert D Ward, Zemlak, Innes, Last, and Hebert (2005), using 25 μL of Fast-Run™ Advanced Taq Master Mix (ProTech, Taipei, Taiwan), and distilled water. Thermal cycling began with one cycle at 94 °C for 4 min; followed by 35 cycles of denaturation at 94 °C for 0.5 min, 45–50 °C (to effect the best balance between PCR productivity and specificity) for 0.5 min, and 72 °C for 0.5 min; and finally, a single extension step at 72 °C for 7 min. PCR products were purified using a PCR DNA Fragment Extraction Kit (Geneaid, Taipei, Taiwan). Approximately 50 ng of the purified PCR product was employed as template for sequencing, which we performed following the protocol of the ABI PRISM BigDye terminator v3.1 Cycle Sequencing Kit (PE Applied Biosystems, Foster City, CA, USA) with the primers used for PCR (by Mission Biotech Inc., Taipei, Taiwan). The beginnings and ends of the contiguous sequences from both directions of the COI gene from each sample were trimmed, and then we constructed the contig sequence using the program BioEdit ver. 7.1.9. COI sequences are given in Supplementary Material 1, but they have not been submitted to GenBank since they are neither from voucher samples or expertly-identified fish specimens. In some of the earlier cases, the results of species identification with DNA barcoding were documented, but the COI sequences were not saved, so only 20 sequences are shown in Supplementary Material 1.

2.3. Data analysis

Edited COI sequences were compared to the Barcode of Life Database (BOLD) (http://www.boldsystems.org/) for species identification using the Species Level Barcode Records tool. If the Species Level Barcode Records function failed to authenticate a sample, BOLD's All Barcode Records tool was adopted to find the nearest match. The best match result for each COI sequence is shown in Table 1.

3. Results and discussion

PCR amplification efficiency can be diminished or eliminated by food processing conditions, such as physical stress, high temperature, pH and exposure to enzymatic activities, which can destroy the primary structure of DNA (Kharazmi, Bauer, Hammes, & Hertel, 2003; Meyer, 1999), or by using inappropriate primers or PCR conditions. In this study, although the tested samples may have undergone some food processing conditions, e.g. cases No. 1 and No. 5 (see Table 1), the universal primers we employed exhibited a high success rate of PCR amplification; only one out of 34 samples did not amplify (Specimen 1 of case No. 9). Of the 33 COI sequences obtained, the BOLD identification system identified a best match (with more than 99% sequence similarity) for 32 sequences; the remaining sequence (case No. 17, Table 1) having a 98% homology match in BOLD. Following Ratnasingham and Hebert (2007), we adopted the barcoding threshold of 1% for species delimitation, so that the species of 32 query sequences could be identified. Although the BOLD platform has been utilized in many molecular authentication studies (Asis, Lacsamana, & Santos, 2016; Chang et al., 2014; Ko et al., 2013; Lamendin, Miller, & Ward, 2015; Landi et al., 2014), this study reveals three shortcomings of the current BOLD platform. First, not all submitted sequences in the BOLD database indicate the scientific name to species level. Some

Table 1
List of all samples authenticated by DNA Barcoding.

Case no.	Client	Date	Import customs declaration entry no. or issue no.	Description of goods	Specimen no.	Expected species	COI sequence name	BOLD database	Match similarity	Mislabeled?
1	Kaohsiung Customs, Ministry of Finance	APR/17/2009	AE/98/1338/0056	Dried Japanese anchovy cooked with salt (*Engraulis japonicus*)	1	*Engraulis japonicus*	–	*Stolephorus holodon*	>99%	YES
2	Kaohsiung Customs, Ministry of Finance	JUL/25/2009	基六試委字第001號	Dried salted anchovy	1	Clupeiformes	–	*Stolephorus holodon*	>99%	NO
				Dried silver anchovies	2	Clupeiformes	–	*Spratelloides gracilis*	>99%	NO
3	Kaohsiung Customs, Ministry of Finance	OCT/14/2009	高前驗字第0981000895號	Swordfish fillet	1	*Xiphias gladius*	–	*Istiompax indica*	>99%	YES
4	Taipei Customs, Ministry of Finance	NOV/24/2009	北遞機一字第(098)001號	Fertilized fish egg	1	–	–	Acipenseridae	>99%	–
5	Kaohsiung Customs, Ministry of Finance	MAR/19/2010	BC/97/WS92/1503	Frozen surimi (bullseye fish)	1	Priacanthidae	–	*Priacanthus hamrur*	>99%	NO
6	Kaohsiung Customs, Ministry of Finance	JUL/20/2012	BG/01/PG38/0001	*Etrumeus teres*	1	*Etrumeus teres*	–	*Sardinella lemurus*	>99%	YES
7	Keelung Customs, Ministry of Finance	JAN/30/2013	AA//02/0227/0042	Frozen snapper fillet	1	Lutjanidae	–	*Oreochromis niloticus*	100%	YES
8	Keelung Customs, Ministry of Finance	MAY/15/2013	AA//02/1468/0028	Frozen fish chin meat	1	–	–	*Oreochromis aureus*	100%	–
9	Keelung Customs, Ministry of Finance	OCT/08/2013	AA/02/1646/0026	Frozen *Sardinella*	1	*Sardinella* sp.	–	NA[a]	–	–
				Frozen small whole round mackerel	2	Scombridae	–	*Decapterus macrosoma*	>99%	YES
10	Keelung Customs, Ministry of Finance	OCT/08/2013	AA/02/AA20/0044	Frozen small whole round mackerel	1	Scombridae	–	*Decapterus macrosoma*	>99%	YES
11	Keelung Customs, Ministry of Finance	NOV/18/2013	AA/BC/02/V404/8016	Frozen whole round mackerel	1	Scombridae	C11S1[c]	*Scomber scombrus*	100%	NO
12	Taipei Customs, Ministry of Finance	FEB/21/2013	CY/03/613/00355	Live *Oxyeleotris marmoratus*	1	*Oxyeleotris marmoratus*	–	*Acipenser schrenckii*	99.85%	YES
13	Taipei Customs, Ministry of Finance	FEB/23/2014	CN/03/629/05028	*Neosilurus ater*	1	*Neosilurus ater*	–	*Acipenser baerii*	100%	YES
14	Kaohsiung Customs, Ministry of Finance	MAR/07/2014	BC/03/U561/0601	Frozen oilfish fillet (*Ruvettus pretiosus*)	1	*Ruvettus pretiosus*	C14S1[c]	*Lepidocybium flavobrunneum*	100%	YES
15	Taipei Customs, Ministry of Finance	DEC/10/2014	CY/03/613/02829	Siberian sturgeon egg	1	*Acipenser baerii*	C15S1[c]	*Huso dauricus*	99.80%	YES
				Siberian sturgeon egg	2	*Acipenser baerii*	C15S2[c]	*Huso dauricus*	99.80%	YES
				Siberian sturgeon egg	3	*Acipenser baerii*	C15S3[c]	*Huso dauricus*	99.80%	YES
				Siberian sturgeon egg	4	*Acipenser baerii*	C15S4[c]	*Huso dauricus*	99.80%	YES
				Siberian sturgeon egg	5	*Acipenser baerii*	C15S5[c]	*Huso dauricus*	99.80%	YES
				Siberian sturgeon egg	6	*Acipenser baerii*	C15S6[c]	*Huso dauricus*	99.80%	YES
				Siberian sturgeon egg	7	*Acipenser baerii*	C15S7[c]	*Acipenser schrenckii*	100%	YES
				Siberian sturgeon egg	8	*Acipenser baerii*	C15S8[c]	*Acipenser schrenckii*	100%	YES
				Siberian sturgeon egg	9	*Acipenser baerii*	C15S9[c]	*Acipenser schrenckii*	100%	YES
				Siberian sturgeon egg	10	*Acipenser baerii*	C15S10[c]	*Acipenser schrenckii*	100%	YES
				Siberian sturgeon egg	11	*Acipenser baerii*	C15S11[c]	*Acipenser schrenckii*	100%	YES
				Siberian sturgeon egg	12	*Acipenser baerii*	C15S12[c]	*Acipenser schrenckii*	100%	YES
16	Northern Coastal Patrol Office, Coast Guard Administration	MAY/06/2015	宜蘭機字第1040006601號	Sturgeon	1	Acipenseriformes	C16S1[c]	*Acipenser naccarii, A. gueldenstaedtii, and Huso huso*[b]	100%	NO
				Sturgeon	2	Acipenseriformes	C16S2[c]	*Acipenser naccarii, A. gueldenstaedtii, and Huso huso*[b]	100%	NO
				Sturgeon	3	Acipenseriformes	C16S3[c]	*Acipenser naccarii, A. gueldenstaedtii, and Huso huso*[b]	100%	NO
				Sturgeon	4	Acipenseriformes	C16S4[c]	*Acipenser schrenckii*	99.84%	NO
				Sturgeon	5	Acipenseriformes	C16S5[c]	*Acipenser schrenckii*	99.84%	NO
17	Keelung Customs, Ministry of Finance	SEP/17/2015	AA/04/AH29/0029	Dried salted small fish	1	–	C17S1[c]	*Engraulis*	98.18%	–

[a] NA = not amplified by the polymerase chain reaction (PCR).
[b] The Basic Local Alignment Search Tool (BLASTn) from GenBank demonstrated that *Acipenser gueldenstaedtii* was the most likely species.
[c] The sequences can be found in the Supplementary Material 1.

are only recorded to genus or family level so, even though a query sequence can have a 100% match in the BOLD database, the species name of this query sequence may not be available, such as occurred for case No. 4 (Table 1). Second, the failure to find a matching sequence with more than 99% homology, such as case No. 17, may result from a deficiency in reference sequences in the BOLD database. Indeed, according to the Catalog of Fish (Eschmeyer, 2013), there are 148 species in the Family Engraulidae, but only 76 species with barcode sequences have been deposited in BOLD. Third, since BOLD does not verify the accuracy of the voucher specimen species names for each submitted barcode sequence, these barcodes may be incorrectly named, as vouchers are identified by different specialists. This problem arose for our sequences C16S1, C16S2 and C16S3 in case No. 16, which were unambiguously matched to *Acipenser naccarii*, *Acipenser gueldenstaedtii*, and *Huso huso,* by BOLD despite coming from the same specimen (Table 1).

The terms 'anchovy' 'sardine' and 'herring' are all used in the Taiwanese market to refer to the order Clupeiformes, unless the specimen is also labeled with a specific scientific name. The term 'mackerel' is mainly, but not exclusively, applied to the Family Scombridae. Of the five clupeiform products (cases No. 1, 2, 6 and 9, Table 1), except for the non-amplification of DNA in case No. 9, DNA barcoding indicated that two of four products were mislabeled (case No. 1 and 6, Table 1), while two of the three mackerel products was mislabeled. These mislabeling cases do not seem to have been motivated by commercial profit since the market price of the substituting species were roughly equal to the labeled species. However, in such cases, profits may still be eroded if the nutritional composition of expected and fraudulent fish differs (Leonardo et al., 2016). We speculate that there are two reasons for the mislabeling of these products: first, the Customs Administration provides common names rather than scientific ones in the tariff database and, in many cases, a common vernacular name may refer to a group of phylogenetically-unrelated species (Galimberti et al., 2013); secondly, even though these fishes are economically important and clupeiform taxonomy has been well-studied (Collette & Nauen, 1983; Whitehead, 1985; Whitehead, Nelson, & Wongratana, 1988), import traders are not trained taxonomists capable of accurately identifying the species over which they bargain. Xiong et al. (2016) mentioned that the absence of a standardized nomenclature, along with unfamiliarity amongst Chinese food business operators and consumers of marine fishes, creates the ideal scenario for mislabeling. Currently, a Latin-Chinese dictionary of fish names is available on the website of the Fish Database of Taiwan (http://fishdb.sinica.edu.tw/), and Lamendin et al. (2015) suggested that standardizing fish names could contribute to eliminating the mislabeling of fish products. Therefore, we encourage the Taiwanese authorities to standardize the common names in the tariff database by adding their scientific (binomial Latin) counterparts in order to inhibit mislabeling. Interestingly, mislabeling may not only impact consumers' finances, but also retailers' earnings. In this study, we found import traders had used black marlin (*Istiompax indica*) as a replacement for swordfish (*Xiphias gladius*) (case No. 3, Table 1), but the price of black marlin is actually higher than that of swordfish in Taiwan, leading us to suppose that the trader misunderstood the common names of these istiophorid billfishes. This latter case emphasizes how crucial standardization of common fish names is, resulting in a "win–win" situation for both clients and retailers.

Many studies have reported snapper products being replaced by tilapia (Galal-Khallaf et al., 2014; Khaksar et al., 2015; Logan, Alter, Haupt, Tomalty, & Palumbi, 2008; Wong & Hanner, 2008). In this study, two specimens were demonstrated to be tilapia (cases No. 7 and 8, Table 1), and a case of tilapia being substituted for snapper was detected (case No. 7, Table 1). Currently, Taiwanese authorities are enforcing a ban against the import of many agricultural products from China in accordance with Paragraph Three, Article 35 of the Act Governing Relations between the People of the Taiwan Area and the Mainland Area, and tilapia is one of these banned items. Therefore, mislabeling of tilapia may be due to intentional smuggling and/or be motivated by financial profit. Moreover, beyond economic consequences, tilapia substitution could also bring about health concerns since several studies have reported heavy metal contamination in tilapia from different areas (Abumourad, Authman, & Abbas, 2013; Cheung, Leung, & Wong, 2008; M.-P. Ling, Hsu, Shie, Wu, & Hong, 2009; Low, Zain, Abas, Salleh, & Teo, 2015). Even if snapper products are not fraudulent, some snapper species, such as *Lutjanus bohar* and *L. monostigma*, contain ciguatoxin (Gaboriau, Ponton, Darius, & Chinain, 2014; Lin, Lyu, Wu, Lu, & Hwang, 2012; Oshiro et al., 2010), which is mainly generated by unicellular dinoflagellate algae (genus *Gambierdiscus*) and accumulates in fish through the food chain (Bagnis et al., 1980). Ciguatoxin not only causes cardiovascular, gastrointestinal and neurological symptoms, but also results in hallucinations and paralysis (Oh, Kim, Seo, & Shin, 2012). Thus, besides testing for accurate labeling, DNA barcoding can also assist customers in picking the safer snapper species, specifically those produced by means of aquaculture, e.g. *L. campechanus* and *L. argentimaculatus* (Bariche et al., 2015; De Brito, Schneider, Sampaio, & Santos, 2015).

DNA barcoding revealed that the species of oilfish fillet in case No. 14 (Table 1) was escolar (*Lepidocybium flavobrunneum*) rather than *Ruvettus pretiosus*; the meat of both these fishes contains abundant wax esters that can cause serious diarrhea (Gregory, 2002; Shadbolt, Kirk, & Roche, 2002; Yohannes, Dalton, Halliday, Unicomb, & Kirk, 2002). Both in Taiwan and Hong Kong, oilfish and escolar have been reported as substitutes for true cod (*Gadus* spp.); a phenomenon motivated by financial benefit (Hwang et al., 2012; K. H. Ling et al., 2008). Although oilfish and escolar have not been reported as being declared as cod at Taiwanese Customs, Kappel and Schröder (2016) pointed out that fraudulent substitution is frequently committed by restauranteurs rather than by fishermen or retailers. Hence, the authorities should pay more attention not only to the labeling of imported oilfish and escolar, but also to labeling after they are sold in the market.

This study found sturgeon mislabeled as sleeper and catfish (cases No. 12 and 13, Table 1) or labeled with the wrong scientific name (case No. 15, Table 1). Although all sturgeon species are listed under Appendix I or II by the Conservation on International Trade in Endangered Species (CITES) (www.cites.org), they have also become aquaculture species. The import of live sturgeon and sturgeon eggs is mainly used to seed sturgeon aquaculture in Taiwan. Previous studies have verified that DNA-based techniques can be used to identify sturgeon species from caviar (Doukakis et al., 2012; Fain, Straughan, Hamlin, Hoesch, & LeMay, 2013), and this study is consistent with previous ones in showing that the problems with identifying species of sturgeon eggs (cases No. 4 and No. 15, Table 1), which lack distinguishing morphological diagnostic characteristics, can be resolved by DNA barcoding. Nevertheless, hybrid sturgeon, such as hybrids between *A. gueldenstaedtii* and *Acipenser baerii*, between *A. naccarii* and *A. baerii*, and between *Acipenser schrenckii* and *Huso dauricus*, are also common in aquaculture (Bronzi, Rosenthal, & Gessner, 2011). Thus, due to the solely maternal transmission of mitochondrial COI, these sequences cannot indicate whether a sturgeon is purebred or hybrid. Thus, nuclear genetic markers should be utilized in conjunction with the mitochondrial COI barcoding marker in authentication testing where the genealogy of the test species may be in question (Boscari et al., 2014; Congiu et al., 2001).

Finally, though the rate of mislabeling found in this study (70%) is much higher than that found in investigations of seafood in other

counties (Carvalho et al., 2015; Cutarelli et al., 2014; Galal-Khallaf et al., 2014; Wong & Hanner, 2008), it does not reflect the real mislabeling rate of fish products imported into Taiwan as the tested specimens were already regarded as suspicious by Customs officers, so our dataset does not represent a random sample. Nevertheless, we confirm that fish product adulteration is an issue in the Taiwanese market (H.-S. Hsieh, Chai, & Hwang, 2007; Huang et al., 2014). Fraudulent labeling of fish products violates the Commodity Labeling Act of Taiwan. Not only is it a form of economic deception, but it also threatens public health. Since DNA barcoding has been established as a benchmark by the US Food and Drug Administration for seafood identification (Handy et al., 2011; Yancy et al., 2008), and given the confirmed cases of mislabeled fish products in Taiwan documented here, we suggest that the Taiwanese government should establish a formal DNA barcoding series to investigate the extent to which imported fish products are incorrectly labeled. Lamendin et al. (2015) asserted that there is no mislabeling in the Tasmanian seafood market owing to Australia's regulatory framework. Institutionalized molecular identification, the standardization of common names of fish, and legislation of penalties for mislabeling will contribute to reducing the rate of mislabeled imported fish products into the Taiwanese market, protecting public health as well as securing government revenue.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.foodcont.2016.01.034.

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