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Almost never you get what you pay for: Widespread mislabeling of commercial "*zamburiñas*" in northern Spain.

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Highlights:

- The vernacular name of *Mimachlamys varia*, "*zamburiñas*", is erroneously used to refer to several species.
- Fresh, frozen, and canned products and dishes prepared in restaurants were analyzed.
- Taxonomic and genetic analyses with the 16S rRNA gene revealed very high levels of mislabeling.
- *Mimachlamys varia* was substituted with *Aequipecten opercularis* and cultured *Argopecten purpuratus*.
- Mislabeling results in incorrect scallop fisheries management and fraud to consumers.

Abstract:

Food fraud involves both financial and health problems for consumers as well as conservation problems for target species worldwide. In Spain, the common name "*zamburiña*", which officially only refers to the species *Mimachlamys varia* (the variegated scallop), is frequently mistakenly used to refer to other pectinid species, and this confuses consumers. In this study, we carried out the first assessment of the levels of fraud in samples from 12 supermarkets/small shops offering fresh, frozen, or canned pectinid products and in 20 restaurants offering "*zamburiñas*" in Asturias (northern Spain). Taxonomic and genetic identifications of the involved species (using 16S mitochondrial rRNA partial fragments) were conducted. Our results showed that 73 (49%) out of the 148 analyzed samples from the fifteen commercial products under study (4 fresh, 6 frozen and 5 canned products) were mislabeled (a global 60% of commercial products had substitutions). Moreover, the analysis of the dishes that were commercially labeled with the vernacular name "*zamburiñas*" from 20 restaurants sampled across the region revealed that in all of them (100%), the species detected was the Peruvian scallop (*Argopecten purpuratus*), known in Spanish as "*vieira del Pacífico*". These results imply intentional deceit and therefore violations of consumer rights. Moreover, this might result in economic damage and serious problems for correct marine resource management and exploitation plans.

Keywords: 16S rRNA; mislabeling; shellfish; traceability; bivalves; scallops

1. Introduction

Food fraud is the intentional deceptive misrepresentation of food for financial gain and usually can have significant implications and consequences for the economy and public health (Spink & Moyer, 2011; Spink, Ortega, Chen, & Wu, 2017). Some of the most obvious consequences are the increased revenue of the sellers due to the substitution of a higher value product for another one that is either cheaper or of lower quality (van Ruth, Huisman, & Luning, 2017), thus providing a financial advantage, which is known as economically motivated adulteration (EMA) (Spink & Moyer, 2011). Health problems can also result from the inadvertent consumption of allergenic species (Sheth et al., 2010; Triantafyllidis et al., 2010), which can produce serious cases of food-related illness (Cohen et al., 2009; Giusti et al., 2018). Furthermore, food fraud can undermine consumers' rights to make informed decisions, particularly those based on religious or ethical questions (Woolfe & Primrose, 2004), and affect the conservation status of overfished, endangered or protected species (Almerón-Souza et al., 2018; Iglésias, Toulhoat, & Sellos, 2010; Quinto, Tinoco, & Hellberg, 2016). Fish and fisheries products are at particular risk of fraud; the European Parliament identified them recently as the second highest-risk food category (European Parliament, 2013). To take action against illegal, unreported, and unregulated (IUU) fisheries and overfishing and with the aim of implementing sustainable management practices, accurate seafood identification and traceability seem to be crucial (Jacquet & Pauly, 2008). Moreover, each fish species should be referred to by a single name to avoid confusion (the *"one name, one fish"* rule), as asserted by consumers, researchers and nonprofit organizations such as Oceana (e.g., see the successive annual reports about the levels and implications of global seafood fraud available at https://eu.oceana.org/).

After Portugal, Spain has the second highest per capita consumption of fish products among the countries in the European Union, with almost double the average consumption in all member states (Spain: 45.6 kg/per capita/year; Portugal: 56.8 kg/per capita/year; EU: 24.3 kg/per capita/year) (EUMOFA, 2019). Among the fish products most consumed by Europeans, only two groups of marine invertebrates are found: mussels and squid (EUMOFA, 2019). However, Spain has a wide gastronomic tradition of the consumption of marine invertebrates including prawns and shrimp (Arrasate-López et al., 2012; Gorelli, Sardà, & Company, 2016; Yolanda Vila, Sobrino, & Jiménez, 2013), squids and octopuses (Fernández-Rueda & García-Flórez, 2007; Mauvisseau et al., 2017; Y. Vila, Silva, Torres, & Sobrino, 2010); mussels (Monfort, 2014), clams and cockles (Arias-Pérez et al., 2016; Borrell et al., 2014) and other mollusks and crustaceans. Although research concerning mislabeling and food fraud in fish is increasingly extensive at all levels (during fishing, at wholesalers, during processing (Muñoz-Colmenero, Blanco, Arias, Martinez, & Garcia-Vazquez, 2016); in end-user markets (Muñoz-Colmenero et al., 2015) and in restaurants (Horreo, Fitze, Jiménez-Valverde, Noriega, & Pelaez, 2019)), the number of available studies carried out on marine invertebrates is nowhere near comparable; the latter is much less common (Luque & Donlan, 2019), with only a few studies on single species (Armani et al., 2013; Harris, Rosado, & Xavier, 2016; Giusti et al., 2020).

More than 400 species of scallops belonging to the family Pectinidae have been described (Brand, 2016), of which approximately 30 species are potentially aquaculture-exploitable species. Most have high commercial importance and provide scallop meat worldwide (EUMOFA, 2019). In Spain, there are three species of scallops that are of commercial interest and whose production comes mainly from the exploitation of natural stocks: the great scallop (*Pecten maximus*; Linnaeus, 1758), the queen scallop (*Aequipecten opercularis*; Linnaeus, 1758) and the variegate scallop (*Mimachlamys varia*; Linnaeus, 1758) (Iglesias, 2012). In Spain, although there are no dense local populations of *M. varia* and no specific commercial fishery for this species, those caught with the queen scallop (*A. opercularis*) are commercialized (Arias et al., 2011). Like other bivalves, scallop species are filter-feeders and tend to accumulate heavy metals (Berik, Çankırılıgil, & Gül, 2017), specially cadmium (Bustamante & Miramand, 2004; Loaiza, Pillet, De Boeck, & De Troch, 2020), which can cause nephrotoxicity, oxidative stress, DNA damage or bone pathologies (Åkesson et al., 2014; Cabral et al., 2015). Therefore, in accordance with the Marine Strategy Framework Directive, cadmium (as well as other heavy metals such as lead and mercury) in fish and other shellfish for human consumption should be monitored to determine the good environmental status of the marine environment (Swartenbroux et al., 2010).

The common organization of the markets in fishery and aquaculture products is laid down in Regulation (EU) No. 1379/2013 of the European Parliament. In Article 35, the commercial designation of the species and its scientific name (among other pertinent information) are included as compulsory information on the relevant labeling. In addition, Article 37 stipulates that Member States shall draw up and publish a list of the commercial designations accepted in their respective territories, together with their scientific names (Regulation (EU) No 1379/2013). Spanish legislation listing the commercial and scientific names of fish and aquaculture species states that the vernacular name for *A. opercularis* is "*volandeira*", that for *M. varia* is "*zamburiña*" and that for *P. maximus* is "*vieira*" (Ministerio de Agricultura, Pesca y

Alimentación, 2019; Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente, 2018). Despite this, there is still some confusion with respect to the vernacular name of *A. opercularis* since it is sometimes also called "*zamburiña*", although in reality it should be referred to by the name "*volandeira*" (Iglesias, 2012). Although the legislation is clear, the widespread use of the term "*zamburiña*" seems to even include other nonnative species produced mainly by aquaculture, such as the Peruvian scallop (*Argopecten purpuratus*; Lamarck, 1819) (Mendo, Wolff, Mendo, & Ysla, 2016; von Brand, Abarca, Merino, & Stotz, 2016). This deceives consumers but can also negatively affect the estimates of the stock sizes, especially if it influences the recording of catch data used in fisheries management, which contributes to the scarcity of the resource and further degradation of the fisheries (Jacquet & Pauly, 2008; Marko et al., 2004). All these pectinids have been subjected for years to intense fishing pressure, resulting in a very consequential reduction in natural stocks. In the case of *M. varia*, the reduction in the natural stock has been particularly dramatic (Iglesias, 2012). Moreover, later attempts to culture queen and variegated scallop were still uncommon (from only one to 4 tons in Galicia (Iglesias, 2012)), and they were heavily affected by several oil spill events in the area (Strand, Louro, & Duncan, 2016). In 2019, the prices in fish markets for these pectinids ranged from 6.92€/kg for *M. varia* to 2.67€/kg for *A. opercularis* (Xunta de Galicia, 2019). Scallops are an attractive target for fraud because they naturally absorb and retain large quantities of water and can be forced to keep excessive volumes, resulting in inaccurate and illegal weights (FAO, 2011). Moreover, there are previous reports of scallop being replaced by other species or products as skate wings or surimi (Jacquet & Pauly, 2008; FDA, 2018) and notorious errors have occurred in the labeling of imported products, e.g. the labeling of Japanese scallop imports as US national production has been reported and fraudulently used to obtain higher prices or to replace lack of supply (FAO, 2011).

The usual methodology for species identification is based on their distinctive morphological characteristics. However, in recent years, molecular biology techniques (based on DNA and sequencing) have gained notoriety in the study of mislabeling and food fraud, allowing the identification of species even if the product under suspicion is highly processed (Lo & Shaw, 2018; Woolfe & Primrose, 2004). In cases where the product susceptible to food fraud is a highly processed product (subjected to high increases in temperature, pressure or other methodologies used by the food industry), the use of molecular markers based on mitochondrial DNA is highly recommended for numerous reasons, including the small size of the required sample, acceptable levels of polymorphism, the higher number of copies in a cell and the greater stability in response to exposure to high temperatures or denaturing agents

(Lo & Shaw, 2018; Woolfe & Primrose, 2004). Moreover, this method has previously been reported to be effective in the identification of scallop species (López-Piñón, Insua, & Méndez, 2002; Feng, Li, Kong, & Zheng, 2011; Wen et al., 2017).

The main aim of this study was to use genetic and taxonomic methods to conduct a combined assessment of the levels of seafood fraud in the marketing of fresh and processed scallops (Pectinidae) products in large supermarkets/small shops, as well as in restaurants. The data obtained in this work could help to define the levels of replacements of the species *M. varia* with other scallops with clear lesser economic value in northern Spain.

2. Materials and Methods

2.1. Sample collection and taxonomical procedures

To screen as much as possible the scallop (Pectinidae) products offered to consumers, the supermarket chains with the highest sales volumes in Spain were identified through the internet. From these supermarket major chains, nine different stores along the Cantabrian coast were selected after checking that the distribution of products was similar in different stores within the same supermarket chain. Two other small fish shops and a gourmet product store were assessed, resulting in a total of 12 stores offering fresh, frozen or canned pectinids products, including those labeling the product as "*zamburiñas*" (the common name for the variegated scallop (*M. varia*)). Sampling of fresh products was conducted in March 2019 and the sampling of frozen and canned products was conducted in April 2019 (Table 1). In addition, 18 restaurants along the coast and in the main cities of Asturias, one in the neighboring region of Galicia and another restaurant in Segovia (a landlocked region of inland Spain) that offered "*zamburiñas*" on the menu were also sampled (Fig. 1) between December 2019 and January 2020 (Table 2). In each of the restaurants, a sample was taken at random to carry out subsequent genetic analyses in the laboratory. In addition, photos were taken of the dish, the menu, and the prices of the seafood portions (Fig. 2). The shell was stored for taxonomic identification whenever possible (Fig. 3). In summary, fresh/frozen (125 samples) and canned samples (158 samples from twelve cans of twelve different brands of canned food) and prepared dishes from 20 restaurants (20 samples) were analyzed.

All samples were separated into individuals at the lab, labeled, and preserved in absolute ethanol. In the case of samples coming from fresh and frozen products, the shells were removed, washed and stored with the corresponding label to be morphologically identified in the zoology unit of the Organisms and Systems Biology Department of the University of

Oviedo (Fig. 3). The main taxonomic features analyzed were related to the shell characteristics (e.g., shell sculpture and shape, auricle morphology, color pattern, etc.), especially those of the right valve, since it was frequently the only valve present in the commercial presentation of several species. The systematics and taxonomy of the species described herein follow MolluscaBase (2020).

2.2. DNA extraction

DNA extraction from fresh/frozen products and from those individuals sampled in restaurants was conducted using the E.Z.N.A. Mollusc DNA kit (Omega Biotek; Norcross, GA, USA) following the manufacturer's instructions. For the canned samples, initial testing with the E.Z.N.A. Mollusc DNA kit (Omega Biotek; Norcross, GA, USA) was unsuccessful. The DNeasy mericon Food Kit (QIAGEN; Verlo, Netherlands), which is specific for processed or cooked products, was subsequently used for the DNA extractions, following the manufacturer's instructions. The classical DNA extraction phenol/chloroform method (Sambrook and Russell, 2006) and the use of the OneStep PCR Inhibitor Removal Kits (Zymo Research, California, USA) were also attempted on the problematic samples. Finally, the aliquots of DNA were frozen at -20 °C for storage.

2.3. PCR amplification

The 16S mitochondrial rRNA partial fragments were amplified by polymerase chain reaction (PCR) using the universal primers (16Sbr and 16Sar) described by Palumbi (1996). A 40 µL reaction mixture was prepared containing 1x Go Taq Flexi Buffer (Promega; Madison, WI, USA), 0.5 mM dNTPs (EURx; Gdańsk, Poland), 2.5 mM $MgCl_2$ (Promega; Madison, WI, USA), 0.2 µM of each primer, 50 ng of template DNA and 0.5 U of Go Taq G2 Flexi Polymerase (Promega; Madison, WI, USA). The mixture was run in an Applied Biosystems™ 2720 Thermal Cycler (Applied Biosystems; Foster City, CA, USA) with the following PCR program: the initial denaturation was run at 95 °C for 5 min, followed by 35 cycles of denaturation at 95 °C for 1 min, primer annealing at 55 °C for 1 min and extension at 72 °C for 2 min. A final extension step was run at 72 °C for 7 min. After the reaction, the amplicons were separated by horizontal gel electrophoresis on a 2% agarose gel stained with SimplySafe™ (EURx; Gdańsk, Poland). The amplicons with an expected fragment of 620 bp were sent for purification and sequencing at Macrogen Spain Inc., which uses the Sanger sequencing method (Sanger, Nicklen & Coulson, 1977).

2.4. Species identification

The sequences of the obtained PCR products were reviewed and edited manually using BioEdit (Hall, 1999). For species identification, the revised sequences were compared to reference sequences in the GenBank database using the BLAST algorithm (http://www.ncbi.nlm.nih.gov/genbank/). The cut-off values for the percentage identity higher than 97% (Stackebrandt & Goebel, 1994) and the alignment value E of 0 were used for identification at the species level. All DNA sequences were aligned using the Clustal W alignment explorer integrated in MEGA version 7.0 (Kumar, Stecher, & Tamura, 2016). The haplotypes were determined using the DnaSP5 program (Librado & Rozas, 2009).

3. Results and Discussion

This paper reports for the first time irregularities in the labeling and the levels of fraud by ingredient substitutions in the central area of the Bay of Biscay (Asturias, Spain) in the commercialization of pectinids and specifically of the "*zamburiñas*" (the variegated scallop, *M. varia*). A total of 303 individual samples were analyzed as follows: 50 fresh, 75 frozen, 158 canned products and 20 samples from dishes bought in 20 restaurants.

The morphological analysis revealed that all studied whole specimens were conchologically consistent with the diagnosis of the following four species: *P. maximus*, *M. varia, A. opercularis* and *A. purpuratus*. The first species can be rapidly separated from the other three by its larger size (more than 120 mm) and by its markedly unequivalve shell; the right valve is convex or dome-shaped and slightly overlaps the left valve, which is flat. Likewise, *M. varia* can be easily distinguished from the remaining two species by the anterior auricles of each valve, which are markedly longer than the posterior ones (Fig. 3a), while in *A. opercularis* and *A. purpuratus,* both the anterior and posterior auricles are equal or nearly equal (Fig. 3b and 3c). Furthermore, *M. varia* has spatulate spines on the radiating ribs of the shell, while these spines are absent in the other two species (Fig. 3). *A. opercularis* and *A. purpuratus* differ in the number of radiating ribs on the shell sculpture and in shell length; the queen scallop has 19-22 radiating ribs, and large specimens measure up to 8.9 cm, while the Peruvian scallop presents 23-26 ribs and has a maximum length of 12 cm (this study; Tebble, 1966; Palomares & Pauli, 2019). Furthermore, the inner shell coloration of *A. purpuratus* differs significantly from those of the other species, with intense reddish to dark purple color (Fig. 3b). Alternative shell color patterns are commonly exhibited by members of the family Pectinidae. Here, we have selected the most common patterns, which have been traditionally considered the more 'typical' coloration. The sampled *A. purpuratus* specimens occurred at two distinctive morphs regarding the external shell color: the ‘typical’ dark purple-reddish with whitish patches (Fig. 3b) and a uniform orange color (not shown). The ‘typical’ morph was ten times more abundant than the orange morph. Of the total of fresh, frozen and restaurant samples (145 samples), 107 were identified taxonomically using the available shells. For the remaining 38 samples, shells were not available.

Total genomic DNA was successfully isolated from all fresh and frozen products and from samples purchased in restaurants. However, out of the 158 canned samples from 12 brands of canned food, only 24 PCR products of sufficient quality from five commercial brands were obtained. The amplification of the other canned samples failed, and they were not considered for the subsequent analyses. Sometimes the canning process, which requires heating, high pressure, sterilization and long-term exposure to extreme conditions during the industrial practice, tends to degrade DNA into very short fragments, resulting in low-quality DNA extractions (Cawthorn, Steinman, & Witthuhn, 2012; Chin, Adibah, Danial Hariz, & Siti Azizah, 2016; Lin & Hwang, 2007). In addition, all canned products used in this work are accompanied by sauces and the use of additives, which in seafood inhibit PCR amplification (Ram, Ram, & Baidoun, 1996). Previous protocols using primers which amplify shorter fragments were effective in identifying degraded DNA samples of different fishery products (Tinacci et al., 2018). Moreover, family-specific and species-specific primers that amplify smaller fragments (610 bp and 228 bp respectively) have been designed in the past for the species *A. purpuratus* (Marín, Fujimoto, & Arai, 2015; Marín, Villegas-Llerena, Fujimoto, & Arai, 2017). In our case, the design of specific primers that amplify very small fragments, similar to those used in environmental DNA (eDNA) techniques (Godlberg et al., 2016) and that serve for the identification of *A. opercularis* and *M. varia* would be very useful.

The image on the packaging of the cans was that of *A. opercularis* in all cases instead of the real “*zamburiñas*” (Fig 2c). These actions mislead or cause the consumer to continue to believe incorrect information by associating the picture of the “*volandeira*” with the name “*zamburiña*”. Similar practices have previously been reported in the packaging of canned products labeled as “abalone" (*Haliotis* sp.) that were substituted with *Concholepas* sp. in Mexico (Aranceta-Garza, Perez-Enriquez, & Cruz, 2011) or in the consumption of different species of scallops under the term “*itayagai*” in Japan, which may cause confusion among consumers (Marín, Fujimoto, & Arai, 2013).

The 16S rRNA primers generated PCR products that, after trimming, resulted in size lengths between 392 and 551 base pairs for the obtained sequences. A total of 169 sequences were obtained, of which 98.8% exhibited high levels of quality after being edited and therefore allowed the species identification through BLAST in the GenBank genetic database with percentages of similarity above 97% (Stackebrandt & Goebel, 1994). Thirty different haplotypes were obtained and identified as *A. opercularis* (4), *A. purpuratus* (13), *M. varia* (5) and *P. maximus* (8), respectively. These haplotypes were submitted to the GenBank database with the access numbers MT123899-MT123902 (*A. opercularis*), MT126344-MT126356 (*A. purpuratus*), MT126358-MT126362 (*M. varia*) and MT157397-MT157402 (*P. maximus*). The genetic analysis of the samples carried out in this study allowed the identification at the species level of 167 out of the 169 samples that were identified commercially as "*zamburiñas*", "*volandeiras*", "*vieiras*" and "*vieiras del Pacífico*" (Tables 1 and 2). The taxonomic and genetic results were fully coincident in this work (when possible).

Globally, the analyses of four fresh products revealed that in nineteen out of the 50 samples analyzed in which the declared species was "*zamburiña* (*Chlamys* sp.)", the species detected was *A. opercularis* (38% fraud by substitution in the samples and 25% in terms of the commercial products) (Table 1). In the frozen products, a total of 75 samples from 6 products were analyzed, and 74 of them could be identified at the species level. Out of 31 samples, the species identified was different from that declared (41.3%) in 3 products (50% fraud) (Table 1). In all but one case, species homogeneity was detected in the individuals analyzed within the same commercial product. A single substitution was found in a frozen product where *A. purpuratus* (most individuals) and *A. opercularis* (a single specimen) were mixed; it is not possible that the two species were caught together in the same fishing grounds and that small individuals were inadvertently mislabeled because both species do not share the same catch area (South America in the case of *A. purpuratus* and Europe in the case of *A. opercularis*). Studies conducted on mussels have shown similar ranges of mislabeling fraud, with 50% mislabeling rate in products labeled as *Mytilus chilensis* in which *Aulacomya atra* was instead found (Colihueque, Espinoza & Parraguez, 2019). Finally, 23 samples from 5 cans were analyzed and genetically identified. All samples, labeled "*zamburiñas*" (variegated scallops; *M. varia*), were identified as *A. opercularis* (100% fraud by substitution). Previous studies in the neighboring region of Galicia, identified *A. opercularis* in canned samples labeled as "small scallops" (López-Piñón, Insua, & Méndez, 2002). Although "small scallop" is a vague term, we could deduce that these substitution practices have a long temporal continuity. The same impressive substitution percentage was obtained by analyzing highly processed DNA from canned fish-based cat food (Armani, Tinacci, et al., 2015). It seems clear that the processed products are, as can be expected, more likely to be mislabeled compared to the whole products, as morphological features that might be useful for identification (such as shells, in this case) are not present (Armani et al., 2015; Garcia-Vazquez et al., 2011; Muñoz-Colmenero et al., 2015). In summary, 148 samples from 15 commercial products were analyzed, and 73 samples (49%) and 9 (60%) out of the 15 commercial products studied were adulterated.

In the case of the 20 samples purchased from 20 restaurants, all specimens were assigned to the Peruvian scallop (*A. purpuratus*), resulting in a 100% fraud by substitution in the analyzed samples and restaurants. The scallop fisheries are subject to a closure (which depends of the locality, occurring between June and September for "*volandeira*" and "*zamburiña*" in the case of Vigo estuary, from December to April for "*zamburiña*" in Ferrol, Mugardos and Barallobre and from March to October for "*vieira*") in northern Spain (Iglesias, 2012; Xunta de Galicia, 2018a; Xunta de Galicia, 2018b). However, "*zamburiñas*" appear on restaurant menus throughout the year. The true is that taking into account that in summer, the national fisheries are closed and restaurants still have high demand for "zamburiñas", we suspect that substitutions of the real "*zamburiñas*" on their menus for other products such as Peruvian scallop have gradually become a common and generalized practice. Unfortunately, consumers are uninformed and are unaware of this reality. The common presentation of the dish named as "*zamburiñas*" (Fig 2d) invites consumers to erroneously think they are consuming a fresh and local product. Doing resamplings from time to time, with no need of fishery closing could give an idea of whether the level of substitutions found in this work is maintained throughout the year. Previous studies conducted in restaurants measuring fraud by establishments rather than for single species have reported fraud percentages varying from 29% to 36% (Horreo et al., 2019; Hu, Huang, Hanner, Levin, & Lu, 2018). In those reports, some of the species/genera names appearing on the menu were consistently wrong and were thus also fraudulent in all sampled cases (Horreo et al., 2019).

The Peruvian scallop (*A. purpuratus*) is native to the coasts of Peru and Chile, and it is an aquaculture species worldwide demanded and a relatively expensive product, which is exported from Peru to over 16 different countries yearly (Mendo, Wolff, Mendo, & Ysla, 2016). Moreover, this fishery is the first in the world to offer scallops under the ASC (Aquaculture Stewardship Council) certification label (ASC, 2017). A review of seafood distributors' websites pointed out that there is confusing and erroneous wording in the identification of species, such as "*Vieira del Pacifico tipo zamburiñas*" (Peruvian scallop, variegated scallop style) and "*zamburiña: Chlamys opercularis*", with the latter being an unaccepted name for the species *A. opercularis* (*volandeira*, queen scallop) or by referring to a completely wrong capture area: "*Zamburiña atlántica. Chlamys varia. Zona de captura: Pacífico Sureste FAO 87*" (Atlantic variegated scallop. *Chlamys varia*. Fishing area: Pacific Southeast FAO 87). It is likely that the restaurants buy the product frozen, with or without confusion about the labeling of the species, and use the vernacular name "*zamburiña*" on their menus, sometimes even under the heading of the specific geographical origin ("*Mariscos del Cantábrico*", shellfish from the Cantabrian Sea) that is synonymous with proximity and quality for the consumer (Fig. 2e). Similar practices have been previously reported in Galicia (Spain) where a company was fraudulent selling cans of foreign mussels (*Perna* spp.) as if they were produced in Galicia (FAO, 2011). Moreover, previous studies with scallops in the US reported errors in the labeling of imported products, for example, the labeling of Japanese scallop imports as US national production (FAO, 2011). In Italy, the substitution of *A. opercularis* by the smooth scallop, *Flexopecten glaber* (a species distributed along the Mediterranean Sea has been reported (Marčeta, Da Ros, Marin, Codognotto, & Bressan, 2016)), with the intention of financial gain, especially when processed foods are involved (Abbadi et al., 2017). In Mexico, fraud has been reported in canned products labeled as abalone, which actually contained the muricid *Concholepas concholepas*, which is commonly called "*loco*" in Chile (Aranceta-Garza et al., 2011). There have also been several reported cases of fraud in fish species where, for example, the native hake (*Merluccius merluccius*) captured in the Cantabrian Sea, which is highly appreciated and has high commercial value, has been replaced by other species of hake that are native to Argentina and South Africa (*M. hubsi, M. capensis, M. paradoxus*) and have much lower commercial value (Garcia-Vazquez et al., 2011; Muñoz-Colmenero et al., 2015) and are difficult to market in Europe due to their high parasite content (Lloris, D.; Matallanas, 2005). Accurate knowledge of the geographic origin of seafood products is necessary, not only for fair trade but also for the health of the consumer and the future of the fisheries (Garcia-Vazquez et al., 2011). Since the case in study also implies substitution of wild-caught species by aquaculture products, stricter controls over the scallop import process in Spain are indeed recommendable.

The variegated scallop (*M. varia*) has a great reputation in northern Spain for its quality and rarity (which indicate some risk for the maintenance of its stocks), and it is considered a gourmet food in Spain and France (Iglesias, 2012). In contrast, the queen scallop (*A. opercularis*), which is from the same extraction and marketing area, is much more abundant but cheaper. Although the substitutions found may not be remarkable from a nutritional point of view, the economic implications may be significant. The differences in price may be significant between products such as "*zamburiñas*" (variegated scallop, *M. varia*): 6.92 €/kg in the first-sale market in 2019 and approximately 30 €/kg in fish shops; "*volandeiras*" (queen scallop, *A. opercularis*): 2.67 €/kg in the first-sale market in 2019 and approximately 25 €/kg in fish shops (Xunta de Galicia, 2019). Products from other geographical areas that are imported into Spain, such as the "*vieira del Pacífico*" (Peruvian scallop, *A. purpuratus)* from Peru and Chile, are harvested at much lower prices, making the profit much higher: 13 €/kg in a shop**.** In any case, it is difficult to economically quantify the global damage represented by the substitutes found in this work, but one can presume the intention to deceive the consumer from the general use of the term "*zamburiñas*". Actually, as stated in the Spanish legislation and consistent with the rule *"one name, one fish"*, this name only designates one specific species (*M. varia*) (Ministerio de Agricultura Pesca y Alimentación, 2019; Ministerio de Agricultura y Pesca Alimentación y Medio Ambiente, 2018). In this study, similar to those for other seafood species, more meticulous control measures throughout the market chain have been revealed as necessary to avoid consumers' confusion, mislabeling, and potential health problems. The government authorities should play that fundamental role, not only for preventing intentional deceit, but also to guarantee correct reporting of the catch data to be used in fisheries management (Marko et al., 2004).

4. Conclusion

This study found that the term "*zamburiñas*" is used as a commercial claim due to the prestige and scarcity of the species *M. varia*. However, taxonomic and genetic analyses with the 16S rRNA gene showed that 9 (60%) out of the 15 fresh, frozen, and canned products analyzed and 100% of the products purchased in restaurants used "*zamburiñas*" as the commercial name but offered other species (mainly "*volandeiras*" (*A. opercularis*) and "*vieira del Pacífico*" (*A. purpuratus*)). Therefore, these results imply a worrying willingness to deceive consumers through commercial fraud, which suggests economic damages, violations of consumer rights and negative effects on the correct management and planning of marine resource exploitation.

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Figures.

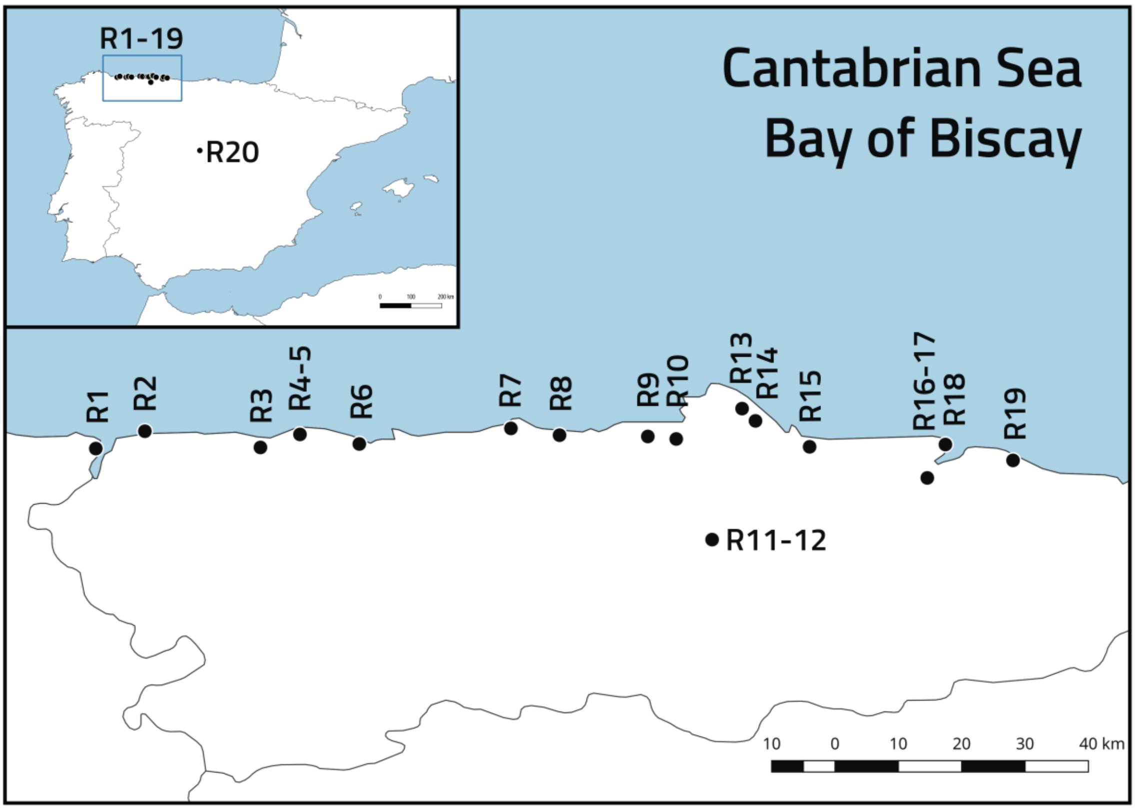

Figure 1: Map representing the 20 sampling points in restaurants offering "*zamburiñas*" for pectinid dishes. R1 is located in the region of Galicia; R2-R19 are located in the region of Asturias and R20 is located in Spain inland.

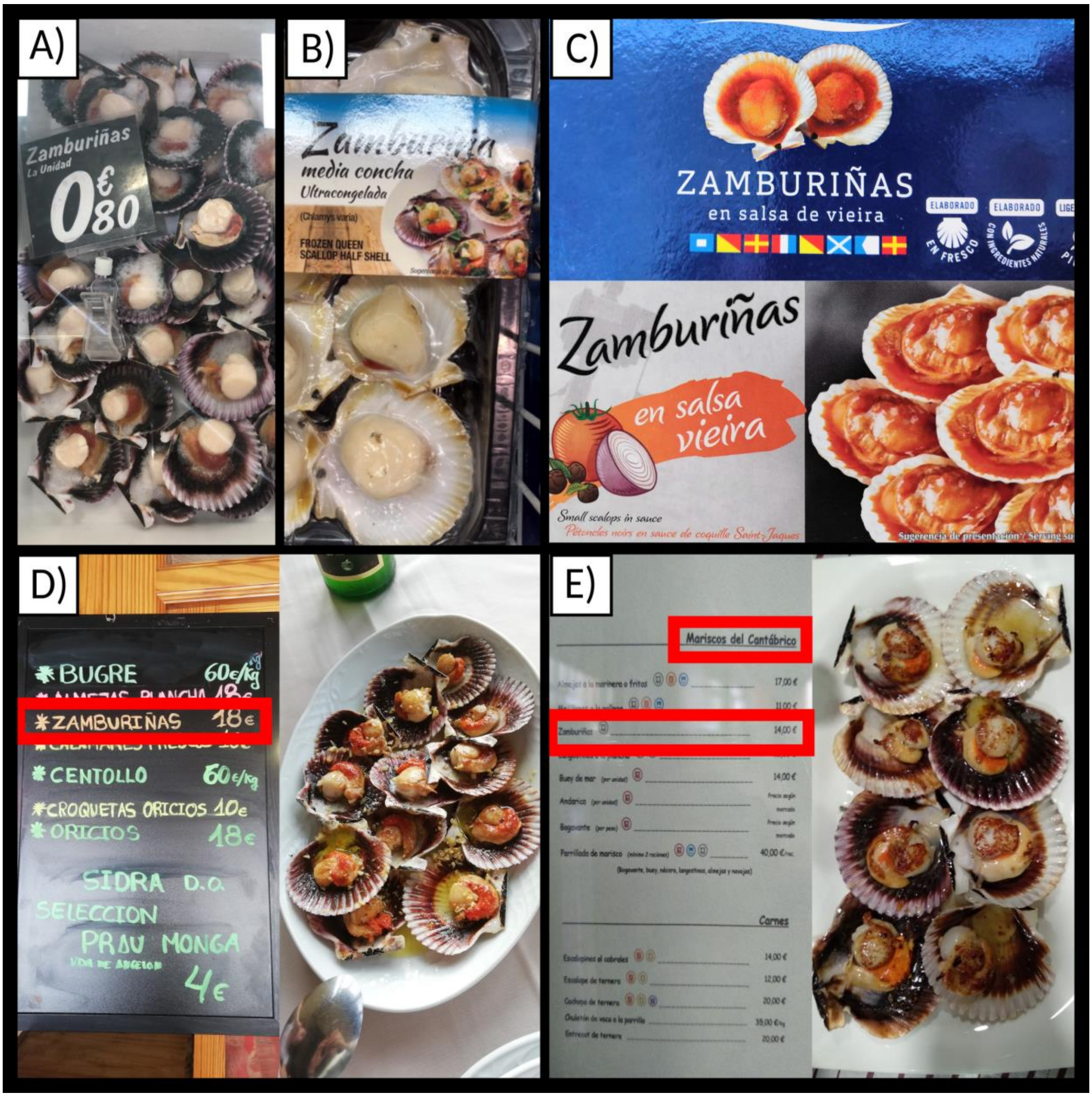

Figure 2: Examples of fresh (A), frozen (B), canned (C) and restaurant samples (D and E) used for this study. The common name "*zamburiñas*" is used to sell *A. purpuratus* (A). The common name "*zamburiñas*" and the species "*Chlamys varia*" (now *M. varia*) mistakenly designate individuals of *A. opercularis* (B).Two examples of canned products in which the common name "*zamburiñas*" and the image of *A. opercularis* can be seen (C). Captures of menus and prices and corresponding "*zamburiñas*" dishes (D and E) under study in this work. The vernacular name "*Zamburiñas*" is shown in red. In addition, the heading "*Mariscos del Cantábrico*" can be seen (E), referring to a specific geographical area: the Cantabrian Sea, south of the Bay of Biscay.

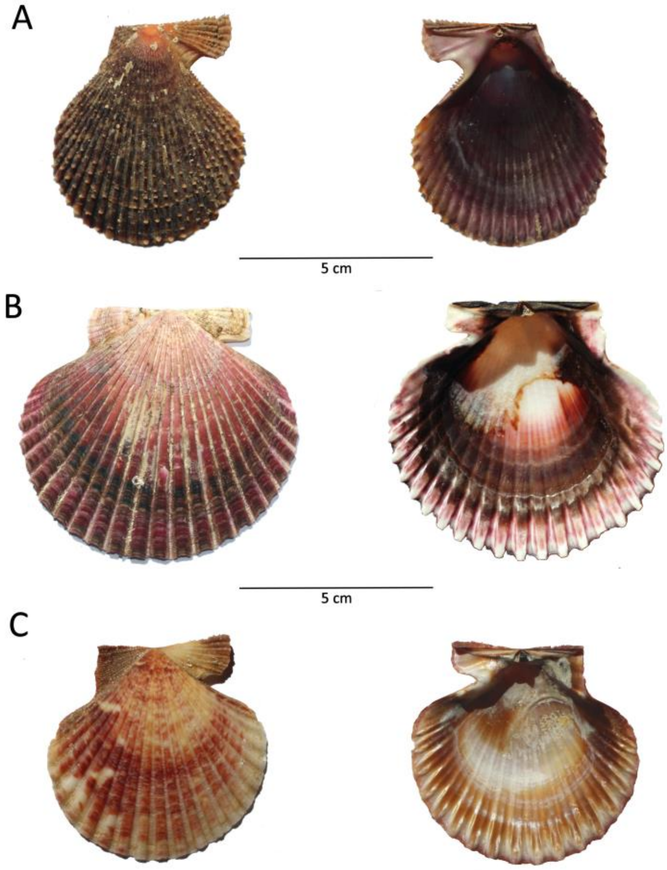

Figure 3: Pictures of exterior and interior of right valve of A) ‘typical’ colour morph of *Mimachlamys varia*; B) ‘typical’ colour morph of *Argopecten purpuratus*; C) common morph of *Aequipecten opercularis*.

Tables.

Table 1. Scallop samples obtained from fresh, frozen, and canned products (Processing method). The table shows the code for different products bought at the supermarket and gourmet/small shops, the sampling date and the number of samples (N). The Spanish (Label name) and scientific name (Label taxa) of the scallops taxa mentioned on the label, the prices of each product, the species identified by taxonomic experts (Tax. Id.) and BLAST, and the presence of mislabeling (Mislab).

Processing method	**Product code**	**Sampling Date (D/M/Y)**	**N**	**Label name**	**Label taxa**	**Price**	**Tax. Id.**	**BLAST**	**Mislab**
Fresh	FH1	04/03/2019	20	Zamburiña (*Chlamys sp.*)	*Mimachlamys varia*	12.44€/kg	*A. opercularis*	*A. opercularis*	Yes
	FH2	14/03/2019	9	Volandeira (A*equipeten opercularis*)	*Aequipecten opercularis*	11€/kg	*A. opercularis*	*A. opercularis*	No
	FH3	06/03/2019	11	Zamburiña (*Chlamys varia*)	*Mimachlamys varia*	29.95€/kg	*M. varia*	*M. varia*	No
	FH4	19/03/2019	10	Volandeira (Aequipecten opercularis)	*Aequipecten opercularis*	9.45€/kg	*A. opercularis*	*A. opercularis*	No
Summation Fresh samples	**4**		**50**						**2/4**
Frozen	FN1	15/04/2019	5	Zamburiñas	*Mimachlamys varia*	9.94€/kg	*A. purpuratus*	*A. purpuratus*	Yes
	FN2	17/04/2019	20	Zamburiñas	*Mimachlamys varia*	19.20€/kg	*A. purpuratus*	*A. purpuratus*	Yes
	FN3	15/04/2019	6	Vieira del Pacífico	*Argopecten purpuratus*	7.49€/kg	*A. purpuratus*	*Ar purpuratus*	No
	FN4	15/05/2019	12	Carne de Vieira	*Pecten maximus*	35.17€/kg	*P. maximus*	*P. maximus*	No
	FN5	18/04/2019	26	Carne de Vieira del Pacífico	*Argopecten purpuratus*	23.56€/kg	*A. purpuratus / A. opercularis*	*A. purpuratus / A. opercularis*	Yes
	FN6	16/04/2019	6	Volandeira	*Aequipecten opercularis*	27.96€/kg	*A. opercularis*	*A. opercularis*	No

Summation Frozen samples	**6**		**75**						**2/6**
Canned	C1	23/04/2019	1	Zamburiñas en salsa de vieira con aceite de oliva (12%)	*Mimachlamys varia*	2.59€ (23.23€/kg)	*A. opercularis*	*A. opercularis*	Yes
	C2	20/04/2019	2	Zamburiñas en salsa de vieira. Receta tradicional	*Mimachlamys varia*	3.87€ (59,54€/kg)	*A. opercularis*	*A. opercularis*	Yes
	C3	20/04/2019	6	Zamburiña en salsa de vieira	*Mimachlamys varia*	1.20€ (14€/kg)	*A. opercularis*	*A. opercularis*	Yes
	C4	20/04/2019	3	Zamburiñas en salsa de vieira	*Mimachlamys varia*	2.10€ (35€/kg)	*A. opercularis*	*A. opercularis*	Yes
	C5	23/04/2019	12	Zamburiñas en salsa de vieira	*Mimachlamys varia*	2.91€ (42,79€/kg)	*A. opercularis*	*A. opercularis*	Yes
Summation Canned samples amplified	**5**		**24**						**5/12**
	C6	20/04/2019		Zamburiñas en salsa de vieira.	*Mimachlamys varia*	1.63€ (14,68€/kg)	Failed amplfication		
	C7	20/04/2019		Zamburiñas en salsa marinera con el 13% de aceite de oliva,	*Mimachlamys varia*	1.19€ (14€/kg)	Failed amplfication		
	C8	20/04/2019		Zamburiñas en salsa de vieira de las Rías Gallegas. Elaboradas a mano.	*Mimachlamys varia*	4.25€ (70€/kg)	Failed amplfication		
	C9	20/04/2019		Zamburiñas de las Rías Gallegas en salsa de vieira.	*Mimachlamys varia*	3.77€ (58€/kg)	Failed amplfication		
	C10	23/04/2019		Zamburiñas a la cazuela.	*Mimachlamys varia*	5.25€ (85€/kg)	Failed amplfication		
	C11	22/04/2019		Zamburiñas en salsa de vieira.	*Mimachlamys varia*	1.59€ (15.86€/kg)	Failed amplfication		
	C12	23/04/2019		Zamburiñas a la gallega.	*Mimachlamys varia*	12.50€ (147€/kg)	Failed amplfication		

Summation canned samples	**12**	**158**

Table 2. Scallop samples obtained from restaurants in different localities. The table shows the code for different samples bought for this study, the sampling date and the Spanish (Menu name) and scientific name (Menu taxa) of the scallops taxa mentioned on the menu, the prices of each product, the species identified by taxonomic experts (Tax. Id.) and BLAST, and the similarity between the amplified and the most similar sequence existing in GeneBank (SIM, in %) and the presence of mislabeling (Mislab).

Locality	Code	Sampling Date (D/M/Y)	Menu name	Menu taxa	Price	Tax. Id.	BLAST	SIM	Mislab
Ribadeo	R1	28/01/2020	Zamburiñas a la plancha	*M. varia*	14€	*A. purpuratus*	*A. purpuratus*	99.16	Yes
Tapia	R2	11/01/2020	Zamburiñas a la plancha	*M. varia*	15€	*A. purpuratus*	*A. purpuratus*	100	Yes
Navia	R3	11/01/2020	Zamburiñas	*M. varia*	14€	*A. purpuratus*	*A. purpuratus*	99.79	Yes
Puerto de Vega/Veiga	R4	10/01/2020	Zamburiñas	*M. varia*	14€	*A. purpuratus*	*A. purpuratus*	100	Yes
Puerto de Vega/Veiga	R5	10/01/2020	Zamburiñas	*M. varia*	14€	*A. purpuratus*	*A. purpuratus*	99.79	Yes
Lluarca	R6	12/01/2020	Zamburiñas	*M. varia*	16€	*A. purpuratus*	*A. purpuratus*	100	Yes
Ouviñana	R7	25/01/2020	Zamburiñas a la plancha	*M. varia*	12€	*A. purpuratus*	*A. purpuratus*	99.58	Yes
Cuideiru	R8	04/01/2020	Zamburiñas a la plancha	*M. varia*	16€	*A. purpuratus*	*A. purpuratus*	100	Yes
Piedrasblancas	R9	09/01/2020	Zamburiñas	*M. varia*	15€	*A. purpuratus*	*A. purpuratus*	100	Yes
Avilés	R10	30/12/2019	Zamburiñas	*M. varia*	14.5€	*A. purpuratus*	*A. purpuratus*	100	Yes
Oviedo/Uviéu	R11	18/01/2020	Zamburiñas	*M. varia*	18€	*A. purpuratus*	*A. purpuratus*	100	Yes
Oviedo/Uviéu	R12	23/01/2020	Arroz meloso de rape y zamburiña en salsa de	*L. piscatorius*	16€	*A. purpuratus*	*A. purpuratus*	99.58	Yes

			caldereta	*M. varia*					
Lluanco	R13	12/01/2020	Zamburiñas a la plancha	*M. varia*	19€	*A. purpuratus*	*A. purpuratus*	99.58	Yes
Candás	R14	12/01/2020	Zamburiñas	*M. varia*	14€	*A. purpuratus*	*A. purpuratus*	99.58	Yes
Gijón/Xixón	R15	11/01/2020	Zamburiñas	*M. varia*	18€	*A. purpuratus*	*A. purpuratus*	100	Yes
Villaviciosa	R16	18/01/2020	Zamburiñas a la sartén	*M. varia*	16€	*A. purpuratus*	*A. purpuratus*	100	Yes
Villaviciosa	R17	11/01/2020	Zamburiñas	*M. varia*	12€	*A. purpuratus*	*A. purpuratus*	99.78	Yes
Tazones	R18	11/01/2020	Zamburiñas a la plancha	*M. varia*	15€	*A. purpuratus*	*A. purpuratus*	99.57	Yes
Llastres	R19	18/01/2020	Vieiras a la plancha (Zamburiñas)	*P. maximus* *M. varia*	14€	*A. purpuratus*	*A. purpuratus*	99.58	Yes
Segovia	R20	04/01/2020	Zamburiñas a la plancha	*M. varia*	14€	*A. purpuratus*	*A. purpuratus*	99.58	Yes