JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY ARTICLE

J. Agric. Food Chem. 2011, 59, 475–480 475
DOI:10.1021/jf103754r

High Level of Mislabeling in Spanish and Greek Hake Markets Suggests the Fraudulent Introduction of African Species

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DNA analysis of hake products commercialized in southern European (Spanish and Greek) market chains have demonstrated more than 30% mislabeling, on the basis of species substitution. Tails and fillets were more mislabeled than other products, such as slices and whole pieces. African species were substitute species for products labeled as American and European species, and we suggest it is a case of deliberate economically profitable mislabeling because real market prices of European and American hake products are higher than those of African in Spanish market chains. The presented results suggest fraud detection that disadvantages African producers. Government-mandated genetic surveys of commercial hakes and the use of subsequent statements of fair trade on labels of seafood products could help to reduce fraud levels in a global market of increasingly conscious consumers sensitive to ethical issues.

KEYWORDS: Seafood; hake; *Merluccius*; fraud detection; DNA analysis; PCR amplification

INTRODUCTION

Several studies have detected fraud in fish markets, mainly by substituting species by others of a different price or origin, such as in caviar (*1*), cod (*2*), shark (*3*), reef fish (*4*), Amazonian fish (*5*), etc. Seafood mislabeling reaches high levels in many countries, including Italy (*3*, *6*), Ireland (*2*), and the U.S.A. (*7*, *8*). In hake markets, cases of mislabeling have been reported (*9*−*11*) and have been principally attributed to misidentification of specimens caught in mixed fisheries, such as the overlapping North American offshore *Merluccius albidus* and silver *Merluccius bilinearis* hakes (*9*) or the south African cape species *Merluccius capensis* and *Merluccius paradoxus* (*10*).

The hake market is very important worldwide and has shown an accelerated decline throughout the past decade (*12*). More than 165 000 tons were imported in Europe during 2004 (only 42 000 tons exported) at an average price of 2.34 €/kg (*13*), with Spain accounting for 60% of total European Union (EU) imports, whereas Greece, the last country listed in the ranking of European hake trade, imported 1365 tons. Most European hake imports were of south African and South American species because Namibia, South Africa, and Argentina were the main exporter countries for the European hake market (*13*). However, South American exports as well as the global unit value are decreasing in recent years because of lower landings [−15% in 2009 with respect to 2008 (*14*)]. South African hake populations exhibited severe depletion 30 years ago, and their restoration has not been completely achieved because recovery was less rapid than predicted (*15*).

Given the background presented above and the global importance of hake species trade, a deeper look at the hake products actually present in European markets seems to be necessary. Species identification cannot be properly controlled unless genetic markers are employed, especially when the commercial product is not the whole specimen (slices, fillets, and tails), as is often the case with hake, where its main products in international trade are fillets (*16*). There are many genetic methodologies available for this purpose (*17*). Among them, polymerase chain reaction (PCR) amplification of the 5S rDNA and direct visualization of the products on agarose gels have been proven to be simple, cheap, and reliable (*18*−*20*). On the basis of this methodology, commercial hake products from markets located in the two European hake importer countries where mislabeling has already been detected were analyzed: Spain (*10*) and Greece (*21*). The level and direction of species mislabeling were investigated, to identify key areas where control should be reinforced in international hake trade.

MATERIALS AND METHODS

Samples. Reference samples for hake species (*Merluccius australis*, *M. bilinearis*, *M. capensis*, *Merluccius gayi*, *Merluccius hubbsi*, *M. paradoxus*, *Merluccius polli*, and *Merluccius senegalensis* and the Grenadier *Macruronus magellanicus*) were taken from the study by Campo et al. (*22*).

A total of 93 hake packages carrying labels with the scientific name of a species from the genus *Merluccius* (hakes) were purchased from Spanish

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Published on Web 12/22/2010

Table 1. Fragment Sizes (in Base Pairs) Obtained by PCR Amplification of the 5S rDNA for the Hake Species Surveyed in This Study

species	ocean	geographic location	fragment sizes
M. australis	Atlantic and Pacific	South America and New Zealand	400
M. bilinearis	Atlantic	North America	222 (+661 + 759)
M. capensis	Atlantic	south Africa	371
M. gayi	Pacific	South America	386 (+393)
M. hubbsi	Atlantic	South America	241 (+660)
M. merluccius	Atlantic	Europe	371
M. paradoxus	Atlantic and Indian	south Africa	371 + 492
M. polli	Atlantic	west and south Africa	371 + 501
M. senegalensis	Atlantic	north Africa	365
M. magellanicus	Atlantic and Pacific	South America	272

and Greek market chains (89 and 4 packages, respectively, roughly proportional to the hake imports of the two countries). The packages analyzed were sold under different presentations: whole piece, slice, fillet, and tail, with all of them frozen. They were obtained at random from five different Spanish cities located on different coasts (the Mediterranean, Barcelona and Alicante; the Atlantic south Spanish, Cadiz; the northwestern Atlantic, Vigo; and the center north, Gijon) and from Thessaloniki (Greece). Because the hake market is restricted in Greece and because of the fact that instead of the scientific name the word "bakaliaros" (*21*) is used on labeling the hake products (i.e., *Gadus morhua*, *Macruronus magellanicus*, *Melanogrammus aeglefinus*, and *Merluccius* spp.), a limited number of samples with scientific names could be used in our survey from Greek market chains. One package was purchased per store, and three pieces were analyzed per package to investigate the existence of multiple species in the same package.

Sampling was carried out in two different time periods: the years 2004–2006 and the year 2010, purchasing hake products at random from the same Spanish and Greek cities. This will allow us to compare the temporal evolution of commercial hake mislabeling, if any.

DNA Analysis. DNA extraction from hake muscle and PCR amplification followed that by Moran and Garcia-Vazquez (*19*). Fragment sizes of the PCR products were determined employing the following protocol: 1 μL of PCR products was mixed with 10 μL of deionized formamide and 0.3 μL of GeneScan-500 LIZ Size Standard (Applied Biosystems); the number of nucleotides (base pairs, bp) of each fragment was established using the GeneScan 3.7 Analysis Software (Applied Biosystems). Fluorescent fragment detection was performed by capillary electrophoresis in a 3100 Genetic Analyzer (Applied Biosystems). Species identification was made by a comparison of the pattern of fragments obtained from each sample to reference samples, as described in the study by Campo et al. (*22*) for all *Merluccius* species and by Perez and Garcia-Vazquez (*11*) for *M. magellanicus*. 5S rDNA fragment sizes typical of these species appear in **Table 1**. To distinguish *M. merluccius* and *M. capensis*, which yield similar 5S rDNA fragments, the protocol described by Perez and Garcia-Vazquez (*11*) based on the restriction fragment length polymorphism (RFLP) at the cytochrome *b* gene was followed.

Survey of Market Hake Prices. In June–July 2010, 11 seafood shops from Spain that represented three different commercial seafood chains distributed at national and international levels were visited. Four shops representing two seafood chains were visited from Greece on the same dates. The market chains and the geographical distribution of sampling localities was the same in 2004–2006. Prices per kilogram of hake products that contained information on the fishing area on the label were recorded, as well as the product presentation (whole piece, slice, fillet, and tail). For internal consistency of the study and to facilitate comparisons, we limited our study to raw frozen hakes (different presentations) with white labels of commercial chains and excluded products with added value, such as famous expensive labels or precooked seafood, of high variance in price. For confidentiality reasons, the names of the visited market chains were omitted in the Results. The survey of prices carried out in these Spanish and Greek markets revealed an enormous variation in hake products, species, and prices among the five market chains (three Spanish and two Greek) explored. The results, however, did not allow for comparisons between continents for all types of hake presentations. European hakes are sold, when frozen, mostly as whole pieces. We did not find frozen slices and fillets of European origin in the five market chains considered, where those types of processed hake were principally of African or American origin. Although the scientific name of the species was not always marked on the label, the geographic origin was clearly indicated on all labels as well as Food and Agriculture Organization (FAO) fishing area and country of origin or continent, and thus, we classified hake products by continent.

International trade data, such as quantity and values, by country and species, were taken from the international database Sea Around Us Project (SAUP; http://www.seaaroundus.org/eez/; accessed on June 2010). Data indicating the quantity, price, and market trends of Spanish hake imports were obtained from the EU Statistics COMEXT at http://www.ine.es/prodyser/infoeuropea/comerproeu.htm (file DS-045409-EU27; accessed on June 2010).

Statistics. Contingency χ^2 was applied whenever relevant for comparison between real and indicated quantity of lots of the different species in commercial markets. A comparison of prices was performed employing *t* tests for evaluating the statistical significance of differences in average price between groups of hake products (i.e., from different continents). The SSPS software (version 8.0 for Windows; SPSS, Inc., Chicago, IL) was employed for statistical tests.

RESULTS

Positive PCR amplification and species identification were achieved for all hake packages based on 5S rDNA fragment sizes. All of the three fish pieces analyzed per same package were always of the same species. No differences were found among market chains or regions within each country; therefore, the results were pooled by presentation and species (**Table 2**). Genetic analysis revealed that in 2004–2006 all but one of the Greek hake packages (75%) analyzed were mislabeled as *M. hubbsi* (Argentinean hake). The identified species contained was of African origin, such as *M. capensis*, *M. paradoxus*, or *M. senegalensis*. During the same years, in the Spanish market chains, 28 hake packages of 89 were mislabeled (31.5%). Taking the two countries together, 33.3% hake products were mislabeled (**Table 2**). Tails and fillets were more mislabeled than other products, such as slices and whole pieces (**Figure 1a**). Differences in mislabeling levels among presentations were statistically significant [Yates's contingency $\chi^2 = 18.28$; 3 degrees of freedom (df); $p < 0.001$].

In 2010 (**Table 3**), the level of mislabeling was similar in Spain (7 of 18 packages mislabeled, 38.9%), as well as the type of species substitution, because of mislabeling of African hakes. Four packages labeled as *M. capensis* really contained *M. paradoxus*. Two packages of *M. capensis* were labeled as *M. merluccius*. One package of *M. polli* was labeled as *M. hubbsi*. In Greece (**Table 3**), one of the four lots analyzed was mislabeled (25%): the label was *M. merluccius* but contained *M. hubbsi*.

Concerning species substitution, some instances were likely unintentional probably because of phenotypic similarities. Such is the case of *M. capensis* and *M. paradoxus* (both cape hakes, distributed in southern African waters; **Tables 2** and **3**) because they are of very similar phenotype and caught together in mixed fisheries. However, other types of mislabeling are likely deliberate, such as in cases of species substitution with fish from different

Table 2. Genetic Identification of 93 Commercial Hake Packages Labeled as Six Different Hake Species in Southern European Market Chains in 2004−2006[a]

country of origin	product presentation	species name indicated on packages	genetically identified species	N
Spain	fillet	*M. capensis*	*M. capensis*	2
	fillet	*M. capensis*	*M. paradoxus*	4
	fillet	*M. hubbsi*	*M. hubbsi*	1
	fillet	*M. hubbsi*	*M. magellanicus*	2
	fillet	*M. merluccius*	*M. australis*	1
	fillet	*M. merluccius*	*M. paradoxus*	2
	slice	*M. australis*	*M. australis*	3
	slice	*M. capensis*	*M. paradoxus*	4
	slice	*M. hubbsi*	*M. hubbsi*	4
	slice	*M. hubbsi*	*M. polli*	2
	slice	*M. merluccius*	*M. merluccius*	2
	slice	*M. paradoxus*	*M. paradoxus*	2
	tail	*M. australis*	*M. capensis*	1
	tail	*M. capensis*	*M. paradoxus*	4
	tail	*M. hubbsi*	*M. hubbsi*	3
	whole piece	*M. australis*	*M. australis*	1
	whole piece	*M. bilinearis*	*M. bilinearis*	14
	whole piece	*M. capensis*	*M. capensis*	4
	whole piece	*M. hubbsi*	*M. hubbsi*	3
	whole piece	*M. merluccius*	*M. capensis*	2
	whole piece	*M. merluccius*	*M. merluccius*	21
	whole piece	*M. merluccius*	*M. paradoxus*	6
	whole piece	*M. paradoxus*	*M. paradoxus*	1
Greece	slice	*M. hubbsi*	*M. capensis*	1
	slice	*M. hubbsi*	*M. hubbsi*	1
	slice	*M. hubbsi*	*M. senegalensis*	1
	whole piece	*M. hubbsi*	*M. paradoxus*	1

[a] N = number of packages correctly labeled or mislabeled per species and product presentation.

continents. This is the case of African hakes (*M. capensis* and *M. polli*) labeled as European *M. merluccius* or South American *M. hubbsi* and *M. australis* (**Tables 2** and **3**). Genetic identification revealed that European hake *M. merluccius* and Argentine hake *M. hubbsi* (**Table 4**) were less abundant in market chains than indicated on the labels, whereas South African hakes were more abundant than reported on labels. If mislabeling is grouped by continents, it can be seen that the least indicated species on labels were African hakes (**Figure 2**), while American and especially European species were over-reported. The difference among continents for levels of under-reporting was tested comparing correctly and mislabeled hake packages for each continent (Africa, America, and Europe) and was statistically significant (Contingency $\chi^2 = 29.284$; 2 df; $p < 0.001$).

In the real markets analyzed here, most products were not labeled with the scientific name of the species but only with the continent of origin. Because the final price is largely influenced by the presentation (in general, slices are more expensive than fillets, and whole frozen pieces are less expensive than processed pieces for the same origin), standardized prices per kilogram of the same product between labeled continents of origin were compared, grouping the species and products by fishing area. The price paid in 2010 by Spanish and Greek consumers for whole European hake was higher than that paid for African and American hakes (**Table 5a**) ($p = 0.023$ and 0.044 for differences between European and African and American species, respectively, in Spanish shops), which makes substitution of European hake by species from other continents highly profitable for the defrauder. Slices and fillets of European hake were not found in the shops surveyed, only South American (in Spain and Greece) and African (in Spain) species. For frozen slices (**Table 5b**), the average price for the Spanish consumer was 11.72 versus 6.79 €/kg for South American and African hakes, respectively, in 2010 ($p = 0.0186$); therefore, replacing American hake slices by African species seems to be also economically advantageous. For fillets (**Table 5b**), however, the difference was not significant, although South American species were sold, in each market chain, at higher prices than African species (5.42 versus 4.48 € on average for American and African species; $p = 0.09$).

Prices of African and American species reported on international databases and EU statistics were opposite to the trend detected in real Spanish markets: African hakes were more expensive than South American hakes. In 2009, the last year with data in the COMEXT database, African *M. capensis* and *M. paradoxus* and American *M. hubbsi* were imported to Spain at 195.37 and 147.15 €/ton, respectively. Although prices oscillated annually, the trend was the same in previous years. For example, in 2006, export value per ton of *M. hubbsi* from Argentina was 456 €, while prices per ton of South African and Namibian hakes (*M. capensis* and *M. paradoxus*, sold together) were 591 and 749 €, respectively.

DISCUSSION

The results obtained in this study, although on the basis of somewhat limited sample sizes, reveal a high level of product mislabeling in European hake markets, recurrent in different years, already revealed by previous studies (*11*) and higher than ever reported (*10*). The mislabeling of hake detected until now suggested species misidentification on landings (*9*, *10*), but the mislabeling detected in this study has new elements for considering it a deliberate fraud. African hakes are sold as European or South American hakes, and this confusion cannot be originated at landings but elsewhere in the commercial chain.

In a global study of ex-vessel fish price, Sumaila et al. (*23*) have found concentrations of high catch value in the productive coastal areas of Europe and Asia, as well as along some areas of South America. Although the west and south African marine waters are heavily fished, no African country appears in the list of the 15 top fishing countries for total real landed values, occupied by 6 Asian, 6 European (including Spain), and 3 American countries.

This could be interpreted as relatively cheap fishery products in African countries, at least if compared to other continents. Real prices in Spanish markets were consistent with Sumaila et al. (*23*) observations, indicating a relatively reduced value of African species (may be due to the low salaries of African fishermen), and contribute to the understanding of the direction of fraud. In Spain, both European and American hakes are sold, on average, at higher prices than African hakes (**Table 5**); therefore, the substitution of a European or an American species by an African one is economically advantageous for the seller.

Our data are limited to some Spanish and Greek markets and, therefore, cannot be generalized worldwide, but we feel it is appropriate to suggest some possible broader consequences. Discrepancy between real market prices and official trade prices of American and African species suggests introduction in Spain of unrecorded or undeclared (may be product of illegal catch) African hakes. In international markets, the distribution of seafood prices changes depending upon the availability of different species to fishermen and to fish markets (*24*). However, if the species are inadvertently introduced in the system, such mechanisms of compensation are no longer feasible. Although African hakes were more available, if they were sold as American hakes, the apparent availability of American hakes would increase artificially, causing a reduction of their price in the commercial market as a feedback. Illegal catch, however, can be sold at any price and not subjected to the normal market rules. This type of fraudulent substitution is unfair for the consumers because they pay for a product that they are not buying in reality. It is also unfair for African producers (fishermen), who are deprived of economic benefits derived from the final price of the fish caught by them; those benefits are retained by the defrauder only.

A remark is necessary concerning health aspects of seafood mislabeling. After the Food Allergen Labeling and Consumer Protection Act (U.S.A.) and the application of the EU directive 2003/89/EC amending 2000/13/EC on November 2005 were implemented, the ingredient statement on packaged food labels now contains more information than ever before (*25*). However, there are still allergy problems concerning labeling (*21*,*26*), because accidental exposure to allergens can occur if the consumer is unaware of the real species contained in seafood. Allergens are not the only concern. Pollutants, toxins, and other harmful substances can be specific of a geographical region (*27*−*29*); for

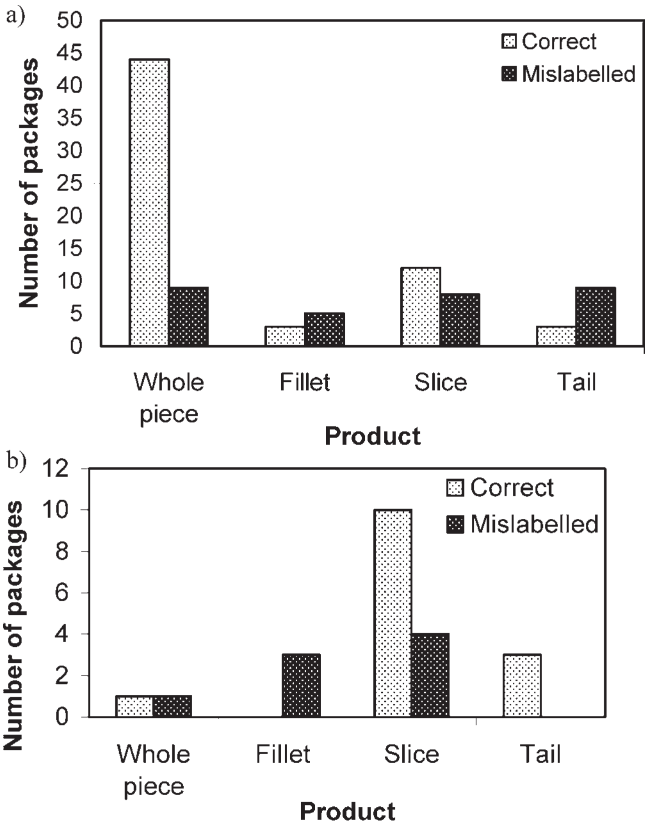

Figure 1. Mislabeling in different hake products, as the number of correct and wrong labels in whole pieces, fillets, slices, and tails revealed by DNA analysis of Spanish and Greek commercial seafood: (a) 2004−2006 and (b) 2010.

Table 4. Percentage of Hake Species Indicated (on the Labels) and Real Proportion of Each Species in South European Market Chains as Revealed by Genetic Analysis in (a) 2004−2006 and (b) 2010

species	origin	indicated on labels	real proportion
	(a) 2004−2006		
M. merluccius	Europe	34 (36.6%)	23 (24.7%)
M. bilinearis	North America	14 (15.1%)	14 (15.1%)
M. australis	South America	5 (5.4%)	5 (5.4%)
M. hubbsi	South America	19 (20.4%)	12 (12.9%)
M. magellanicus	South America	0	2 (2.2%)
M. senegalensis	north Africa	0	1 (1.1%)
M. capensis	south Africa	18 (19.3%)	10 (10.8%)
M. paradoxus	south Africa	3 (3.2%)	24 (5.8%)
M. polli	south Africa	0	2 (2.2%)
	(b) 2010		
M. merluccius	Europe	4 (18.2%)	1 (4.5%)
M. australis	South America	4 (18.2%)	4 (18.2%)
M. hubbsi	South America	10 (45.4%)	10 (45.4%)
M. capensis	south Africa	4 (18.2%)	2 (9.1%)
M. paradoxus	south Africa	0 (3.2%)	4 (18.2%)
M. polli	south Africa	0	1 (4.5%)

Table 3. Genetic Identification of 22 Commercial Hake Packages Labeled as Four Different Hake Species in Southern European Market Chains in 2010[a]

country of origin	product presentation	species name indicated on packages	genetically identified species	*N*
Spain	fillet	*M. capensis*	*M. paradoxus*	2
	fillet	*M. hubbsi*	*M. polli*	1
	slice	*M. australis*	*M. australis*	4
	slice	*M. capensis*	*M. paradoxus*	2
	slice	*M. hubbsi*	*M. hubbsi*	3
	slice	*M. merluccius*	*M. capensis*	2
	slice	*M. merluccius*	*M. merluccius*	1
	tail	*M. hubbsi*	*M. hubbsi*	3
Greece	slice	*M. hubbsi*	*M. hubbsi*	2
	whole piece	*M. hubbsi*	*M. hubbsi*	1
	whole piece	*M. merluccius*	*M. hubbsi*	1

[a] *N* = number of packages correctly labeled or mislabeled per species and product presentation.

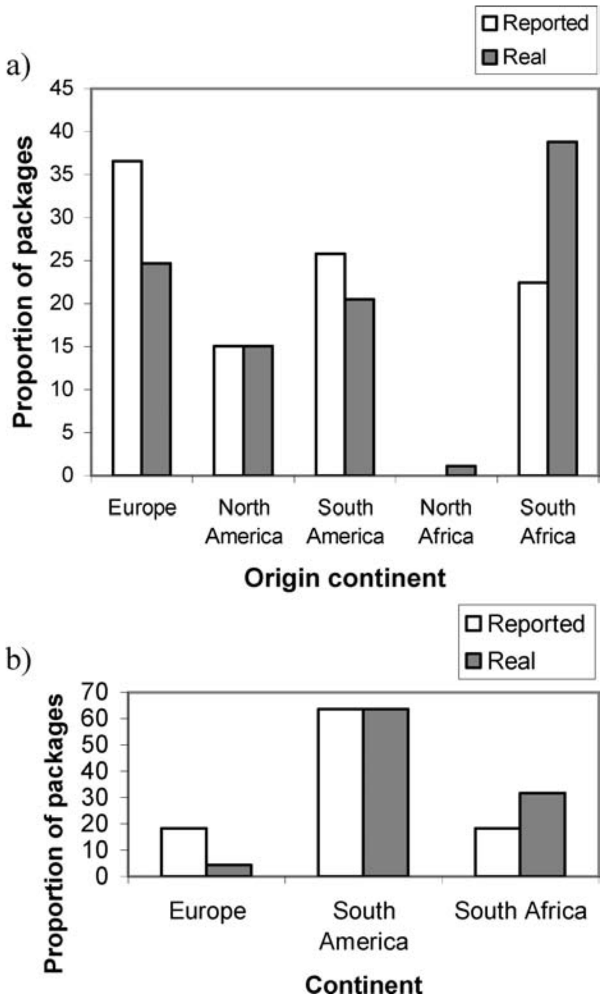

Figure 2. Declared and real (from DNA analysis) proportion of commercial hakes from different origin continents found in Spanish and Greek commercial markets: (a) 2004−2006 and (b) 2010.

example, heavy metals have been found in different species caught from African marine waters (*30*), whereas ciguatera outbreaks are more commonly associated with ingestion of fish caught from American waters (*31*). Hake parasites, such as *Anisakis*, are also region-specific (*32*). Therefore, accurate knowledge of the geographic origin of a fish product is very important for not only fair trade at the global level but also the health of the consumer.

The consequences of the fraud described here are particularly serious because the African producers inhabit developing countries. They not only deserve fair trade but urgently need the economic revenue of their products. Regulatory compliance issues facing producers are driven by both science-based concerns over product safety and politics (*33*). There is an international framework for fish safety and quality, and in the developing world, efforts for capacity building have focused mainly on the export sector (*34*). A global mandate to label species, country of origin, and catching or production method on all seafood has been recommended (*7*), with high penalties for infractions. We propose here that the socioeconomic perspective (i.e., warranty of fair trade) should also be considered, for information of consumers from importer countries. Increased consumer concern for ethical issues has been recognized (*35*), with more consumers willing to pay more for socially responsible products, especially if they are imported from developing countries (*36*). Traders could be more directly influenced by shifts in consumer demand rather than by limits on supply (harvest or trade restrictions) or

Table 5. Average (Standard Deviation) Market Prices (in €) of Raw and White-Label Hake in Three Spanish (A, B, and C) and Two Greek (D and E) Commercial Seafood Chains in 2010: (a) Whole Hakes from South America, Africa, and Europe and (b) Slices and Fillets from South America and Africa[a]

(a) Whole Hakes from South America, Africa, and Europe

market chain	South America	Africa	Europe
A (n = 5)	4.99 (0.00)	4.39 (0.36)	5.99 (0.00)
B (n = 3)	5.32 (0.00)	2.78 (0.38)	6.50 (0.00)
C (n = 3)	5.15 (0.00)	5.99 (0.00)	6.89 (1.42)
D (n = 1)	6.08		
E (n = 1)			7.02

(b) Slices and Fillets from South America and Africa

	slices		fillets	
market chain	South America	Africa	South America	Africa
A (n = 5)	12.50 (0.00)	8.45 (2.12)	7.95 (0.00)	5.37 (0.53)
B (n = 3)	10.30 (5.20)	9.13 (0.00)	4.91 (0.22)	4.69 (0.05)
C (n = 3)	13.75 (0.00)	4.92 (0.94)	4.45 (0.00)	4.35 (1.18)
D (n = 1)	6.87			
E (n = 1)	5.70			

[a] n = number of shops visited for each seafood chain.

voluntary self-regulation (*37*). A label indicating authentication of imported products aimed at benefiting producers from developing countries will surely be well-accepted and demanded by an increasing sector of consumers. Additionally, it would encourage traders to avoid fraudulent commercialization of products from developing countries, even if they have to pay for authentication certificates. Genetic tools for application in seafood traceability are abundant and affordable even for modest budgets (*17*), and now it is time to enforce their use in routine controls of international hake trade. From our results, importers and distributors of imported hakes, as gates for entry of foreign products in Europe, could be considered key areas where control should be reinforced in international hake trade. Another point where species authentication would be convenient could be at landings, at least in the case of mixed fisheries, such as south African hakes *M. capensis* and *M. paradoxus*, for a better control of the real exploitation of each species. Undeclared and under-reported catches can lead to harvesting of endangered populations, possible concealed depletion of named species, and other negative consequences for fish populations (*4*, *5*, *9*).

ACKNOWLEDGMENT

Ivan G. Pola helped in laboratory tasks. Prof. Costas Triantaphyllidis is acknowledged for his help in this work.

LITERATURE CITED

(1) DeSalle, R.; Birstein, V. J. PCR identification of black caviar. *Nature* **1996**, *381*, 197−198.
(2) Miller, D. D.; Mariani, S. Smoke, mirrors, and mislabeled cod: Poor transparency in the European seafood industry. *Front. Ecol. Environ.* **2010**, *8*, 517−521.
(3) Barbuto, M.; Galimberti, A.; Ferri, E.; Labra, M.; Malandra, R.; Galli, P.; Casiraghi, M. DNA barcoding reveals fraudulent substitutions in shark seafood products: The Italian case of "palombo" (*Mustelus* spp.). *Food Res. Int.* **2010**, *43* (1), 376−381.
(4) Marko, P. B.; Lee, S. C.; Rice, A. M.; Gramling, J. M.; Fitzhenry, T. M.; McAlister, J. S.; Harper, G. R.; Moran, A. L. Mislabeling of a depleted reef fish. *Nature* **2004**, *430*, 309−310.
(5) Ardura, A.; Pola, I. G.; Ginuino, I.; Gomes, V.; Garcia-Vazquez, E. Application of barcoding to Amazonian commercial fish labelling. *Food Res. Int.* **2010**, *43*, 1549−1552.

(6) Filonzi, L.; Chiesa, S.; Vaghi, M.; Marzano, F. N. Molecular barcoding reveals mislabelling of commercial fish products in Italy. *Food Res. Int.* **2010**, *43*, 1383−1388.
(7) Jacquet, J. L.; Pauly, D. Trade secrets: Renaming and mislabeling of seafood. *Mar. Policy* **2008**, *32* (3), 309−318.
(8) Wong, E. H. K.; Hanner, R. H. DNA barcoding detects market substitution in North American seafood. *Food Res. Int.* **2008**, *41* (8), 828−837.
(9) Garcia-Vazquez, E.; Horreo, J. L.; Campo, D.; Machado-Schiaffino, G.; Bista, I.; Triantafyllidis, A.; Juanes, F. Mislabelling of commercial North American hakes suggests underreported exploitation of *Merluccius albidus*. *Trans. Am. Fish. Soc.* **2009**, *138* (4), 790−796.
(10) Machado-Schiaffino, G.; Martinez, J. L.; Garcia-Vazquez, E. Detection of mislabeling in hake seafood employing mtSNPs-based methodology with identification of eleven hake species of the genus *Merluccius*. *J. Agric. Food Chem.* **2008**, *56* (13), 5091−5095.
(11) Perez, J.; Garcia-Vazquez, E. Genetic identification of nine hake species for detection of commercial fraud. *J. Food Prot.* **2004**, *67*, 2792−2796.
(12) Lopez, J. *Hake Market Report*; Food and Agriculture Organization (FAO) GLOBEFISH: Rome, Italy, 2007; http://www.globefish.org/dynamisk.php4?id = 4374 (accessed on June 2010).
(13) Lien, K. *Hake Market Report*; Food and Agriculture Organization (FAO) GLOBEFISH: Rome, Italy, 2004; www.globefish.org/index.php?id = 2282 (accessed on June 2010).
(14) INFOPESCA. *Lower Landings of Hake in Argentina*; Food and Agriculture Organization (FAO) GLOBEFISH: Rome, Italy, 2010; http://www.globefish.org/dynamisk.php4?id = 4814 (accessed on June 2010).
(15) Butterworth, D. S.; Rademeyer, R. A. Sustainable management initiatives for the southern African hake fisheries over recent years. *Bull. Mar. Sci.* **2005**, *76* (2), 287−319.
(16) O'Sullivan, G. Mixed 2006 trends for European frozen hake fillet imports. *Food and Agriculture Organization* (*FAO*) *Fish Info Network Market Report*; Eurofish: Copenhagen, Denmark, 2007; http://www.eurofish.dk/index.php?id = 1523 (accessed on June 2010).
(17) Rasmussen, R. S.; Morrissey, M. T. DNA-based methods for the identification of commercial fish and seafood species. *Compr. Rev. Food Sci. Food Saf.* **2008**, *7*, 280−295.
(18) Carrera, E.; García, E.; Céspedes, A.; González, I.; Fernández, A.; Asensio, L. M.; Hernández, P. E.; Martín, R. Differentiation of smoked *Salmo salar*, *Oncorhynchus mykiss* and *Brama raii* using the nuclear marker 5S rDNA. *Int. J. Food Sci. Technol.* **2000**, *35* (4), 401−406.
(19) Moran, P.; Garcia-Vazquez, E. Identification of highly prized commercial fish using a PCR-based methodology. *Biochem. Mol. Biol. Educ.* **2006**, *34*, 121−124.
(20) Pinhal, D.; Gadig, O. B. F.; Wasko, A. P.; Oliveira, C.; Ron, E.; Foresti, F.; Martins, C. Discrimination of shark species by simple PCR of 5S rDNA repeats. *Genet. Mol. Biol.* **2008**, *31* (Supplement 1), 361−365.
(21) Triantafyllidis, A.; Karaiskou, N.; Perez, J.; Martinez, J. L.; Roca, A.; Lopez, B.; Garcia-Vazquez, E. Fish allergy risk derived from ambiguous vernacular fish names: Forensic DNA-based detection in Greek markets. *Food Res. Int.* **2010**, *43*, 2214−2216.
(22) Campo, D.; Machado-Schiaffino, G.; Horreo, J. L.; Garcia-Vazquez, E. Molecular organization and evolution of 5S rDNA in the genus *Merluccius* and their phylogenetic implications. *J. Mol. Evol.* **2009**, *68* (3), 208−216.
(23) Sumaila, R.; Mardsen, A. D.; Watson, R.; Pauly, D. A Global ex-vessel fish price database: Construction and applications. *J. Bioecon.* **2007**, *9*, 39−51.
(24) Pinnegar, J. K.; Hutton, T. P.; Placenti, V. What relative seafood prices can tell us about the status of stocks. *Fish Fish.* **2006**, *7* (3), 219−226.
(25) Taylor, S. L.; Hefle, S. L. Food allergen labeling in the USA and Europe. *Curr. Opin. Allergy Clin. Immunol.* **2006**, *6*, 186−190.
(26) Sheth, S. S.; Waserman, S.; Kagan, R.; Alizadehfar, R.; Primeau, M. N.; Elliot, S.; St. Pierre, Y.; Wickett, R.; Joseph, L.; Harada, L.; Dufresne, C.; Allen, M.; Allen, M.; Godefroy, S. B.; Clarke, A. E. Role of food labels in accidental exposures in food-allergic individuals in Canada. *Ann. Allergy, Asthma, Immunol.* **2010**, *104*, 60−65.
(27) Belfroid, A. C.; Purperhart, M; Ariese, F. Organotin levels in seafood. *Mar. Pollut. Bull.* **2000**, *40* (3), 226−232.
(28) Cao, H; Suzuki, N.; Sakurai, T.; Matsuzaki, K.; Shiraishi, H.; Morita, M. Probabilistic estimation of dietary exposure of the general Japanese population to dioxins in fish, using region-specific fish monitoring data. *J. Exp. Sci. Environ. Epidemiol.* **2008**, *18*, 236−245.
(29) Van Dolah, F. M. Marine algal toxins: Origins, health effects, and their increased occurrence. *Environ. Health Perspect. Suppl.* **2000**, *108*, S1.
(30) Sodoumou, Z.; Gnassia-Barelli, M.; Siau, Y.; Morton, V.; Roméo, M. Distribution and concentration of trace metals in tissues of different fish species from the Atlantic coast of western Africa. *Bull. Environ. Contam. Toxicol.* **2005**, *74* (5), 988−995.
(31) Swift, E. B.; Swift, T. R. Ciguatera. *Clin. Toxicol.* **1993**, *31* (1), 1−29.
(32) Mattiucci, S.; Abaunza, P.; Ramadori, L.; Nascetti, G. Genetic identification of *Anisakis* larvae in European hake from Atlantic and Mediterranean waters for stock recognition. *J. Fish Biol.* **2004**, *65*, 495−510.
(33) Rasco, B. Perceptions of seafood safety. *J. World Aquacult. Soc.* **2010**, *41* (2), 258−265.
(34) Ababouch, L. Assuring fish safety and quality in international fish trade. *Mar. Pollut. Bull.* **2006**, *53*, 561−568.
(35) Connolly, J.; Shaw, D. Identifying fair trade in consumption choice. *J. Strategic Mark.* **2006**, *14*, 353−368.
(36) Becchetti, L.; Rosati, F. C. Global Social Preferences and the Demand for Socially Responsible Products: Empirical Evidence from a Pilot Study on Fair Trade Consumers. Feb 2007; CEIS Working Paper 91, Social Science Research Network (SSRN), http://ssrn.com/abstract=962488 (accessed on June 2010).
(37) Clarke, S. Understanding pressures on fishery resources through trade statistics: A pilot study of four products in the Chinese dried fish market. *Fish Fish.* **2004**, *5*, 53−74.

Received for review June 28, 2010. Revised manuscript received November 30, 2010. Accepted December 7, 2010. The samples were obtained in the context of the EU RTD Contract MARINEGGS QLK5-CT1999-01157, and additional funding was provided by the Spanish Fundación para el Fomento en Asturias de la Investigación Aplicada y la Tecnología (FICYT) Project IB09-023.