



Deceptive Dishes: Seafood Swaps Found Worldwide Appendix

September 2016

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1. How Map Sources were Found:

Google Scholar was used to search the English language literature for relevant studies, using the following search terms: seafood mislabelling, seafood mislabeling, seafood labelling, seafood labeling, seafood fraud, seafood testing, seafood authenticity, seafood allergies, fish (crab, shrimp, etc.) mislabelling, fish mislabeling, fish labelling, fish labeling, fish fraud, fish testing, fish authenticity, fish allergies. Both spellings of “mislabeling” were needed to capture UK English spellings. Each search term was used separately. Google news alerts for “seafood fraud OR traceability” were used to track media stories and reported legal cases on seafood mislabeling. Legal cases involving seafood fraud in the United States were searched for in NOAA Law Enforcement¹ or Department of Justice press releases and archives.²

2. Global Seafood Mislabeling and Species Substitution Tables

Table A1: The Most Common Types of Seafood Misabeled in the United States			
Mislabeled seafood type	Number of studies	Number of samples	Bibliography #
Snapper	29	476	1, 2, 17, 30, 47, 67, 70, 73, 79, 84, 86, 87, 95, 96, 97, 102, 108, 115, 123, 133, 155, 163, 166, 170, 186, 192, 200, 205, 206
Grouper	20	94	2, 47, 95, 134, 139, 140, 141, 142, 153, 155, 163, 167, 174, 177, 182, 184, 192, 194, 200, 205
Salmon	17	121	1, 31, 43, 46, 47, 104, 105, 108, 151, 163, 179, 180, 185, 187, 190, 198, 200

¹ NOAA (National Oceanic and Atmospheric Administration) Office of Law Enforcement. Retrieved 8/2/16 at http://www.nmfs.noaa.gov/stories/2012/11/11_15_12seafood_fraud_enforcement.html

² US DOJ (United States Department of Justice) Office of Public Affairs. Retrieved 8/2/16 from <https://www.justice.gov/justice-news>

Table A2: The Most Common Types of Seafood Mislabeled in Europe			
Mislabeled seafood type	Number of studies	Number of samples	Bibliography #
Cod	21	336	8, 22, 26, 28, 51, 54, 64, 68, 72, 91, 99, 112, 121, 122, 123, 127, 143, 144, 152, 164, 168
Hake	14	204	8, 64, 68, 76, 77, 78, 91, 119, 122, 130, 144, 150, 164, 169
Sole	11	108	4, 8, 60, 64, 68, 106, 122, 144, 146, 154, 169

Table A3: The Most Common Types of Seafood Mislabeled Elsewhere in the World			
Mislabeled seafood type	Number of studies	Number of samples	Bibliography #
Cod	8	77	34, 37, 42, 100, 110, 111, 113, 208
Shellfish	8	51	3, 9, 41, 74, 88, 90, 116, 203
Snapper	7	23	37, 39, 48, 81, 111, 132, 193

Table A4: The Most Common Types of Seafood Found Substituted Globally			
Type of substitute seafood	Number of studies	Number of samples	Bibliography #
Asian Catfish	42	187	1, 2, 32,34, 36, 47, 55, 64, 68, 75, 89, 91, 106, 108, 127, 128, 130, 132, 134, 139, 140, 141, 142, 144, 146, 152, 153, 163, 167, 174, 176, 177, 184, 186, 194, 200, 205, 206
Hake	28	180	1, 8, 28, 37, 56, 64, 68, 72, 76, 77, 78, 89, 91, 105, 107, 111, 119, 122, 130, 142, 144, 149, 150, 164, 166, 169, 200, 206
Escolar/Oilfish	21	238	1, 2, 17, 37, 38, 39, 66, 80, 82, 95, 100, 102, 113, 117, 120, 133, 138, 161, 163, 200, 210



3. Details of the European Union Analysis

The European Union (EU) began legal provisions aimed at tracing seafood and providing more consistent information to consumers in 2000.³ After these early legal provisions were enacted, academic and government-sponsored seafood identification investigations revealed weaknesses in the rules and their consistent implementation and enforcement.⁴ These studies, which gained attention in the media, likely helped sway the public and policymakers to strengthen rules governing the EU seafood market.⁵ In 2008, the EU established measures for combating illegal fishing that included, among others, requirements for catch documentation for all imported seafood in the EU market. These measures went into effect in January 2010.⁶ Since 2012, mandatory information available to consumers about their seafood purchase at the retail level has included member country-designated commercial name and scientific name of seafood, catch area, wild or farmed production method, and whether the product is fresh, frozen or previously frozen.⁷ Since December 2014, when Regulation (EU) No. 1379/2013 went into effect, fishing gear type and more precise fishing area names were included in the mandatory information.⁸

Given the EU's efforts in increased transparency and traceability in the seafood supply chain paired with measures to combat IUU fishing, Oceana examined the data on seafood mislabeling in the EU to see if any changes in the level of fraud could be detected over time. The EU data set includes 75 studies, comprised from peer-reviewed literature (63), government (5), non-governmental organizations (3), media (3), and data from one review study. Five of these sources did not contain quantitative data (i.e. media or governments reports of fraud or outbreak cases). The remaining 70 studies contained quantitative data that were used in the analyses in this review (Table A5).

³ See EC (European Commission). 2001. Commission Regulation (EC) No 2065/2001 of 22 October 2001 laying down detailed rules for the application of Council Regulation (EC) No 104/2000 as regards informing consumers about fishery and aquaculture products. *Off J Eur Communities* L278: 6–8. ;

⁴ Miller, D. C., & Mariani, S. (2010) Smoke, mirrors, and mislabeled cod: poor transparency in the European seafood industry. *Frontiers in Ecology and the Environment*, 8(10). doi: 10.1890/090212; Miller & Mariani (2012)

⁵ Mariani et al. (2014); Mariani et al. (2015); Nuwer, R. (May 22, 2012) Fish Forensics Gets an Upgrade, *Science Magazine*. Retrieved from <http://www.sciencemag.org/news/2012/05/fish-forensics-gets-upgrade>

⁶ EC (European Commission) (2008) Council Regulation No 1005/2008 of 29 September 2008 establishing a Community system to prevent, deter and eliminate illegal, unreported and unregulated fishing, amending Regulations (EEC) No 2847/93, (EC) No 1936/2001 and (EC) No 601/2004 and repealing Regulations (EC) No 1093/94 and (EC) No 1447/1999

⁷ Commission Implementing Regulation (EU) No. 404/2011 laying down detailed rules for the implementation of Council Regulation (EC) No. 1224/2009 establishing a Community control system, for ensuring compliance with the rules of the Common Fisheries Policy. *OJEU* 2011; L112.

⁸ EC (European Commission) (2013) EU Regulation No 1379/2013 on the common organisation of the markets in fishery and aquaculture products. *Official Journal of the European Union* L354 28.12.2013, p. 1–21

Table A5. Quantitative Studies Used in the EU Analyses and Estimated Year of Studies. Red Text Indicates that the Authors Did Not State Year(s) of Sample Collection

EU Reference	Study year	Point estimated study year
Armani et al. (2011)	<2010	2009
Armani, D'Amico et al. (2012)	<2011	2010
Armani, Castigliego et al. (2012)	<2011	2010
Armani et al. (2013)	<2013	2012
Armani et al. (2015a)	<2013	2012
Armani et al. (2015b)	2014	2014
Asensio et al. (2008b)	< 2008	2007
Asensio et al (2008a)	<2007	2008
Aursand et al. (2009)	<2009	2008
Barbutto et al. (2010)	<2009	2008
Bénard-Capelle et al. (2015)	2013	2013
Boucher (2011)	<2011	2010

Bréchon et al. (2013)	<2012	2011
Bréchon et al. (2016)*	<2015	2014
Carrera et al. (2014)	<2013	2012
Crego-Prieto et al. (2010)	< 2010	2009
Cutarelli et al. (2014)	<2013	2012
Di Pinto et al. (2015)	<2014	2013
Di Pinto et al. (2016)	2014	2014
Di Pinto et al. (2013)	<2012	2011
Espineira & Vieites (2012a)	<2012	2011
Espineira & Vieites (2012b)	< 2012	2011
Espineira et al. (2008)	<2008	2007
Espineira et al. (2008b)	<2008	2007
Espineira et al. (2009)	<2008	2007
European Commission (2015)*	2015	2015
Filonzi et al. (2010)	2008	2008
Food Safety Authority of Ireland (FSAI) (2011)	2010	2010

Food Standards Agency, UK (2008)	2007-2008	2007
Food Standards Agency, UK (2007)	2005-2006	2005
Galal-Khallaf et al. (2016)	2013	2013
Garcia-Vazquez et al. (2012)	2005-2010	2007
Garcia-Vazquez et al. (2011)	2010	2010
Garcia-Vazquez et al. (2009)	<2008	2007
Griffiths et al. (2013)	2010-2013	2012
Helyar et al.(2014)	<2013	2012
Herrero et al. (2011a)	<2011	2010
Herrero et al. (2011b)	<2011	2010
Herrero et al. (2011c)	< 2010	2009
Huxley-Jones et al. (2012)	2008-2009	2008
Infante et al. (2004)	<2004	2003
Kappel & Schröder (2016)	2013	2013
Lago et al. (2012)	<2011	2010
Lawrence (2014)	2014	2014

Ludwig et al. (2015)	2011-2012	2011
Machado-Schiaffino et al (2008)	<2008	2007
Mariani et al. (2016)	2013-2014	2013
Mariani et al. (2014)	2011	2011
Miller & Mariani (2012)	<2011	2010
Mottola et al. (2014)	<2014	2013
Anderson (2016)*	2015	2015
Muñoz-Colmenero et al. (2015)	2011-2013	2012
Muñoz-Colmenero et al. (2016)	2012-2014	2013
Nebola et al. (2010)	<2010	2009
Oceana (2014)	2014	2014
Oceana Europe (2015)	2015	2015
Pappalardo & Ferrito (2015b)	<2014	2013
Pappalardo & Ferrito (2015a)	2013-2014	2013
Pappalardo et al. (2011)	<2011	2010
Pascoal et al. (2008)	<2007	2006

Pepe et al. (2007)	<2007	2006
Perez & Garcia-Vasquez (2004)	<2004	2003
Rehbein & Oliveira (2012)	2009	2009
Santaclara et al.(2007)	<2007	2006
Santaclara et al. (2015)	<2013	2013
Stamatis et al. (2015)	2010-2013	2012
Taboada et al. (2014)	<2014	2013
Tantillo et al. (2015)	2014-15	2014
Trocchia et al. (2015)	<2015	2014
Vandamme et al. (2016)	2014-2015	2014

* Non-EU samples excluded from the EU analyses. For studies that did not state the year(s) of sample collection, an approximate (latest) year of sample collection was estimated to be one year earlier than the date of publication or the date of first submission to be published, if provided. For multi-year investigations, the mid-year or earlier year was generally used as point estimate.

Study sample sizes ranged from eight to 3,906 samples, but the average and median sample sizes are 169 and 58, respectively. Two very large, multi-country studies have been published since 2015, one with more than 1,400 samples taken from supermarkets in six western EU countries bordering the Atlantic,⁹ and another 2015 European Commission survey with over 3,900 fish products representing 150 species taken from importers, seafood traders, processors, cold stores and mass caterers, as well as retail in every EU member state except Cyprus.¹⁰

The published dates of the 70 quantitative studies span from 2004-2016. To determine if seafood mislabeling rates changed after the EU regulations went into effect, it is important to know when seafood

⁹ Mariani et al. (2015)

¹⁰ EC (2015)



samples were collected. Unfortunately, the dates of sample collection were not stated in 63 percent of the EU studies reviewed. In these cases, an approximate (latest) year of sample collection was estimated to be one year earlier than the date of publication or the date of first submission to be published, if provided. For multi-year investigations, the mid-year or earlier year was generally used as point estimate (Table A5).

Oceana calculated the weighted mean mislabeling rate of all the EU studies in each estimated year of sample collection and plotted results over time to see if any trends emerged. This analysis shows a decreasing rate of mislabeling since 2011 (Fig A1a). Because there was no apparent trend in fraud rates before 2011, Oceana next grouped the data to time periods before and after 2011. Data from 2013-2014 were combined to accommodate the time period of one large, 1400+ sample study.¹¹ What emerges is a more clear-cut apparent decrease in the rate of seafood mislabeling over time (Figure 3 in Deceptive Dishes report). This inference is supported by the larger number of samples collected since 2011 (Figure A1b) from multiple studies (Fig. A1c) and by the lack of any apparent trend prior to 2012 (Figure A1a).

¹¹ Mariani et al. (2015)

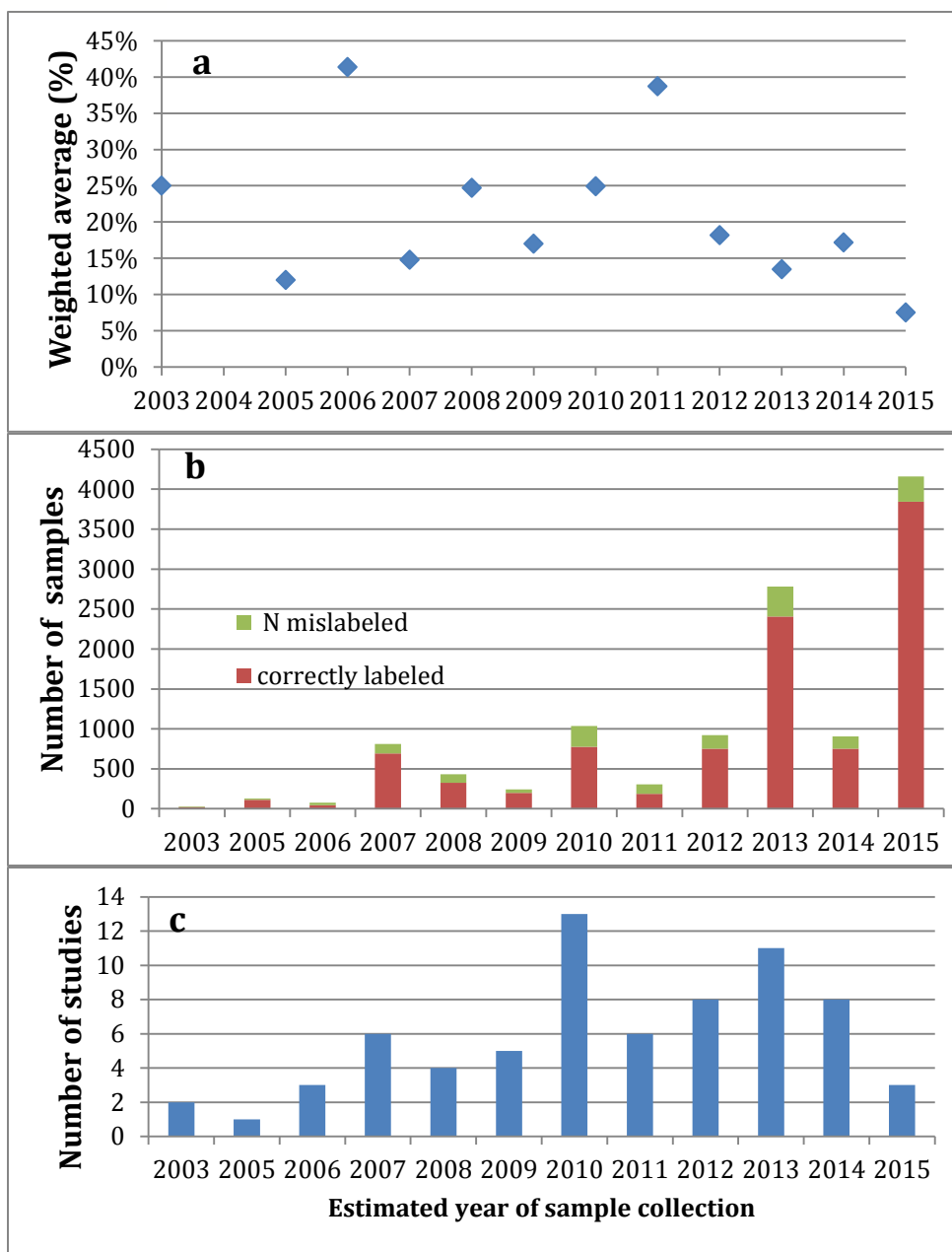


Figure A1. European Union Weighted Mean Mislabeling Rate (a), Number of Samples Analyzed in Each Time Period (b), and Number of Studies Undertaken in Each Estimated Year of Sample Collection (c)

While this analysis normalizes the fraud rate of all studies in each time period to the number of samples collected, it does not distinguish between differences in EU country level or of type(s) of seafood analyzed, nor does it take into account seafood products or sectors of the supply chain excluded from the regulations or sampling bias. Indeed, even in the largest EU-wide study conducted by the government, certain countries (e.g. Malta, Estonia, Latvia and Spain) and types of seafood (such as grouper, redfish,



common sole and yellowfin sole) saw seafood mislabeling rates considerably higher than the overall average of 6 percent. This could suggest inconsistent implementation of the legal provisions among EU countries and a potentially higher risk of mislabeling in certain types of seafood (EC 2015). Factors affecting uneven implementation likely include culture differences, political will, economic situation, budget, and resources not being allocated in the same way between countries, all of which eventually affect the control, enforcement and compliance with EU rules. Differences in the specificity of commercial names of seafood adopted in each country is also a factor, with more general naming rules leading to apparent lower mislabeling rates.

A closer look at mislabeling rates over time in two of the most studied types of seafood—hake and cod—revealed fluctuating or weak decreasing trends in mislabeling rates (data not shown). Hake is a particularly prized fish in Spain, which commands the largest hake market in the world, and has been examined for mislabeling as far back as 2004 in published studies.¹² In fact, Spain recognizes 10 species-specific names for different hake species (*Merluccius* species) on their national fish list.¹³ Spain has been the focus of five of the eight studies in this review.¹⁴ In a case study restricted to Spain, Muñoz-Colmenaro et al. (2015) also found fluctuating trends in overall mislabeling rates over 10 years, but significantly higher levels of mislabeling in hake processed to the point of being unrecognizable (e.g. fileted). This study also found an increasing diversity of species substituted for European (*Merluccius merluccius*) and other hakes. It is important to note that in many countries outside of the U.S., whole fish are or were more prevalent in the marketplace, compared to the unrecognizable fillets or fish sections commonly marketed in the U.S. and increasingly more available in other countries.

Atlantic cod is another popular fish in many EU countries, particularly the U.K. and Ireland, where processed “fish and chips” is a popular dish. Cod mislabeling has been the focus of nine studies in more than 12 EU countries since 2009 (estimated year).¹⁵ The earliest cod mislabeling studies investigated products purchased from markets and take-out restaurants in Ireland and the U.K., which found the highest mislabeling among smoked and processed products (up to 86 percent), compared to 19 percent for all cod products.¹⁶ The heavy media attention following the release of these results was cited as a contributing factor in the lower cod mislabeling rate found a few years later in Ireland.¹⁷ Subsequently, lower cod mislabeling rates followed in the U.K. in 2014 (estimated date, Bréchon, 2016), but the rest of the countries reviewed here were not sampled over time to assess trends. One recent multi-country review of cod mislabeling in EU and non-EU countries found that country-specific differences, whether legal or cultural, were more important in driving fraud rates compared to EU affiliation.¹⁸ These findings highlight the importance of strong, consistent implementation (and enforcement) of legal provisions in fighting seafood fraud and illegal fishing.

¹² Muñoz-Colmenaro et al. (2015).

¹³ See <http://www.boe.es/boe/dias/2015/03/12/pdfs/BOE-A-2015-2653.pdf>

¹⁴ Spain studies are: Perez & Garcia-Vasquez (2004); Machado-Schiaffino et al. (2008); Garcia-Vazquez et al. 2009; Garcia-Vazquez et al. 2012; Muñoz-Colmenaro et al. (2015). The other three studies that sampled hake are: Mariani et al. (2016); Tantillo et al. (2015) and European Commission (2015).

¹⁵ Miller & Mariani (2010); Miller & Mariani (2012); Boucher (2011); Mariani et al. (2014); Di Pinto et al. (2013); Oceana (2014); Bréchon et al. (2016); Mariani et al 2016; European Commission (2015).

¹⁶ Miller & Mariani (2010); Miller & Mariani (2012)

¹⁷ Mariani et al. (2014)

¹⁸ Bréchon et al. (2016);

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