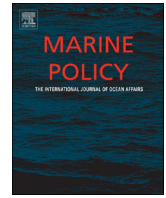




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# A systematic analysis across North Atlantic countries unveils subtleties in cod product labelling



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## ABSTRACT

Over the last decade, the mislabelling of seafood products has come to prominence in the fields of food science and marine conservation. This study aims to determine whether differences in fish labelling accuracy can be explained by factors associated with governance, legislation and product availability, using cod (*Gadus* spp.) as a case study. A total of 401 cod products from a range of different supermarket retailers in each of nine countries bordering the North Atlantic Ocean were purchased and genetically identified. The countries sampled were grouped into primarily cod-importing or cod-producing states, and belonging/not-belonging to the European Union. They comprised the United Kingdom, Belgium, the Netherlands, Denmark, Estonia, Iceland, Norway, Sweden and Canada. Estonia showed the highest incidence of mislabelling, with 59.4% samples mislabelled, followed by Denmark with 18.6%, Canada with 7.3%, Sweden with 4.4% and finally the United Kingdom with 2.4%. Substitute species included species within the Gadidae and Merlucciidae, such as haddock (*Melanogrammus aeglefinus*), Alaskan pollock (*Gadus chalcogrammus*) and Argentine hake (*Merluccius hubbsi*), respectively, but also included species more distantly-related to cod, such as snailfish (*Liparis* spp.), spotted wolffish (*Anarhichas minor*) and yellow perch (*Perca flavescens*), the latter a freshwater species. The remaining countries showed no mislabelling. Neither EU affiliation, production nor the type of product, i.e. fresh or processed, had a significant effect on mislabelling. It is suggested that other factors, such as country-specific differences at social, cultural or legal levels, may be the greater drivers of mislabelling.

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## 1. Introduction

The increase in seafood supply, international trade and progress in food processing have created the potential for species substitution, which has become a major concern both in domestic and international markets (reviewed in [1]). Products that are traded internationally are generally processed to some extent, thereby removing the morphological characteristics required for species authentication and making products vulnerable to mislabelling [2]. Furthermore, seafood supply chains are getting progressively longer and processing steps are often carried out in different countries, increasing the opportunity to mislabel food.

The United Nations Food and Agriculture Organization (FAO) *Codex alimentarius* requires the country of origin of all food products to be identified, except when food has undergone processing in another country; in this case, the country where processing took place is

considered country of origin [3]. In Europe, the principles for traceability and food safety are laid down by a plethora of regulations and directives [4–8]. These pertain to the requirements that all fish and fishery products must be traceable throughout all stages of production, processing and distribution and accurate labelling must be present on all food products, including: the commercial and scientific name of the species, the method of production (wild or farmed), and the catch area [5,8]. Furthermore, seafood must not be sold under a name that could mislead the consumer as to its true identity [4]. In contrast, in both Canada and the USA, the labels of packaged fresh seafood products are only required to include an appropriate common name, compiled in the CFIA Fish List and Food and Drug Administration (FDA) Seafood List, respectively. Additionally, in some cases, the “country of origin” may be required, however this may just be the last country in which part of the product processing has taken place [9–11]. Furthermore, the country of origin of seafood products imported into Canada must be declared on all imported fish products, but only on the container in which they are imported, not necessarily on the retail package [11].

Mislabelling is the process of substituting one species for another. There is widespread evidence of seafood mislabelling,

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otherwise known as species substitution, occurring on a range of species and geographical scales, despite the existence of seemingly adequate and specific policies relating to product traceability. This phenomenon holds implications for the conservation and management of marine resources and human health [12–14], causes economic losses [15] and harms consumer perception [16] and eco-campaigns [17].

Mislabelling can have dire consequences for overfished species or those that are under protection. Nearly 80% of smooth-hound products (“palombo”) sold in Italy did not belong to *Mustelus* spp., which are the only permitted to be sold under this vernacular name [18]. In fact, many of the species identified are listed on the IUCN Red List, rated as vulnerable and near threatened. The US FDA Seafood List designates 13 species of rockfish that can be sold under the common name “Pacific red snapper”, however, an investigation found that > 60% of “Pacific red snapper” products contained species that were not included in the list, some of which were listed as overfished [19]. Furthermore, a study of seafood fraud in the USA by the conservation group Oceana found one in three samples to be mislabelled [20]. Market substitution appears to be consistently more conspicuous in North America [21,22] than in Europe [23,24], although recent surveys of restaurants have revealed considerably greater levels of substitution than found in the retail sector [25].

The increased use of molecular genetic markers should protect both consumers and producers from fraud and safeguard species from over-exploitation and illegal trafficking [26,27]. In recent years, DNA barcoding has emerged as a broadly applicable tool for species identification [28]. The DNA barcoding gene *cytochrome oxidase 1* (*COI*) has been validated as a diagnostic marker for species-level identification in birds, fish and invertebrates [29–32]. DNA barcoding makes use of an inexpensive and high throughput technology and can be used to identify whole or parts of specimens to enable the identification of species that are protected and/or harvested illegally [26,27,33]. Given the background presented above and the global importance of cod fisheries, a deeper understanding of cod products in international markets is of particular interest. This study expands on recent investigations [16,24,34,35] and assesses the prevalence of Atlantic cod (*Gadus morhua*) mislabelling, both across EU and non-EU member states, and in relation to a country's provision of cod products, be it primarily through internal landings or imports. Mislabelling is compared across countries, and the influence of legal, political and social factors that could either be permitting or preventing its proliferation is examined.

## 2. Methods

### 2.1. Selection of countries

To examine the incidence of cod mislabelling across Europe and to assess whether legislation and/or national cod production

influences seafood fraud, countries were selected based on their geographical location (bordering the North Atlantic and adjacent seas), on their EU affiliation (EU/non-EU) and national cod production (Table 1).

The Total Allowable Catch (TAC) of cod for each country was used as a proxy for production. TAC values for 2011 and 2012 were collated from European Commission publications [36,37] and the mean was obtained. Countries with an annual TAC > 15,000t were considered as ‘cod-producing’ (P<sup>+</sup>), while a TAC of < 4000t/annum, determined a low production (‘cod-importing’, P<sup>-</sup>) country (Table 1). Cod quotas for Atlantic Canada were sourced from Fisheries and Oceans Canada (<http://www.dfo-mpo.gc.ca>).

Packaged cod products were selected for sample collection due to their consistent availability throughout many countries, including those investigated. Packaged products also enable the identification of the supplier of a particular sample, when an EU approval barcode is present. The latter is required on all packaged fresh fish products sold in the EU to meet traceability requirements [38]. This approval number is a code that allows identification of the processing factory that handled the product prior to its delivery to the retailer. A list of these codes and associated processing companies, as well as their locations within the EU can be accessed online [39].

Large supermarket chains were selected in order to maximise sampling standardisation. Countries were chosen based on EU affiliation and national cod production for the following reasons: i) EU countries are subject to exhaustive, overarching regulations in terms of fishery trade and management, ii) the manner in which legislations are implemented and the quality of enforcement are the member states' responsibility and thus may vary between countries; iii) many cod stocks in EU waters are subject to quota partitioning among member and associate states, and some have been seriously depleted [40]. Overall, EU membership was employed as a predictor to assess whether belonging to a nation under transnational governance could influence the prevalence of mislabelling.

With regard to production, it may be hypothesised that the economic incentive to mislabel seafood in exporting countries is lower compared to countries that may not have such a thriving industry (importer), or it could be that importing seafood adds steps to the supply chain which may not be strictly regulated and may increase the opportunity for substitution as a result.

### 2.2. Sample collection

Between 43 and 53 cod products were obtained from different large supermarket chains in a major city in each of nine countries: the United Kingdom, UK; the Netherlands, NL; Belgium, BE; Denmark, DK; Norway, NO; Sweden, SE; Estonia, EE; Iceland, IS, Canada, CA. For Canada and the UK, Guelph and Reading, two smaller towns in the vicinity of Toronto and London, respectively, were sampled in addition to the latter in order to target a higher

**Table 1**

Description of countries sampled and number of stores visited. Abbreviation P<sup>-</sup> denotes low cod production, P<sup>+</sup> denotes high production.

Country and city	EU affiliation, Production	Number of supermarket chains sampled	Number of individual stores sampled	Total number of samples
United Kingdom, London	EU, P <sup>+</sup>	7	19	43
Denmark, Copenhagen	EU, P <sup>+</sup>	6	31	43
Sweden, Stockholm	EU, P <sup>+</sup>	5	19	45
Norway, Bergen	Non-EU, P <sup>+</sup>	6	20	43
Iceland, Reykjavik	Non-EU, P <sup>+</sup>	6	6	53
Canada, Toronto	Non-EU, P <sup>+</sup>	8	18	44
Estonia, Tallinn	EU, P <sup>-</sup>	8	16	43
The Netherlands, Rotterdam	EU, P <sup>-</sup>	7	26	44
Belgium, Brussels	EU, P <sup>-</sup>	5	18	43

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