Food Chemistry 185 (2015) 165–181

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Analytical Methods

Fish species substitution and misnaming in South Africa: An economic, safety and sustainability conundrum revisited

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ARTICLE INFO

Article history:
Received 10 September 2014
Received in revised form 16 March 2015
Accepted 29 March 2015
Available online 2 April 2015

Keywords:
Authentication
DNA barcoding
Fish species
Mislabelling
Seafood
Sustainability

ABSTRACT

While fish species mislabelling has emerged as a global problem, the tracking of improvements or deteriorations in seafood trading practices is challenging without a consistent basis for monitoring. The aim of this study was to develop a robust, repeatable species authentication protocol that could be used to benchmark the current and future incidences of fish mislabelling in South Africa. Using this approach, 149 fish samples collected from restaurants and retailers in three provinces (KwaZulu-Natal, Western Cape and Gauteng) were identified using DNA barcoding, supplemented in certain cases with mitochondrial control region sequencing. Overall, 18% of samples were incorrectly described in terms of species, with similar misrepresentation rates in restaurants (18%) and retail outlets (19%). While there appears to be some improvement in the transparency of local seafood marketing compared to previous studies, the results remain of concern and signal the need for enhanced seafood labelling regulations, monitoring and law enforcement.

1. Introduction

Modern consumers are increasingly aware of their health and social responsibilities and are seeking greater assurance on the origin, composition and environmental impacts of their food. Consumers have, however, also voiced concerns relating to the reliability of information received on product labels, with reports of 'food counterfeiting' likely fuelling such concerns (Eden, Bear, & Walker, 2008). Although 'food fraud" has been carried out since antiquity, these practices seem to have escalated in recent years. High-value, protein-rich foods are especially prone to substitution or mislabelling, as exemplified by the Chinese melamine saga of 2008 (Sharma & Paradakar, 2010), the 2013 meat scandals in South Africa and the EU (Cawthorn, Steinman, & Hoffman, 2013; Premanandh, 2013) and the many documented cases of seafood fraud. While the former two examples were generally sporadic, seafood mislabelling has been a persistent and widespread problem, apparently intensifying in synchrony with the ever-declining state of the world's fish stocks. Evidence for the latter derives from studies conducted over a broad geographic scale that have exposed high levels of fish mislabelling in, amongst others, the Americas, Europe and South Africa (Ardura et al., 2010; Cawthorn et al., 2012a; Filonzi et al., 2010; Hanner et al., 2011; Von der Heyden, Barendse, Seebregts, & Matthee, 2010; Warner et al., 2013). Factors appearing to contribute to the upsurge in fish mislabelling include the associated financial incentives, globalisation of seafood supply chains, the highly processed nature of fish products, as well as lax law enforcement. Regardless of the motives, the repercussions of fish mislabelling are manifold and include financial, health and conservation concerns.

South Africa is a nation largely defined by its productive oceans and diverse aquatic life, which in turn support a range of commercial and artisanal fishermen. The country's domestic marine harvest has averaged over 690,000 tonnes per annum over the last decade, placing its fisheries among the most important in Africa (FAO, 2013). However, the region has neither escaped the wrath of overexploitation nor has it evaded the burden of illegal seafood trade and corruption (Hauck & Kroese, 2006). Similar to the global trend of overexploited marine fisheries, many of South Africa's wild fish stocks are considered overfished, particularly within the inshore zone (DAFF, 2012).

Although fish mislabelling has been suspected in South Africa for decades (Smith & Smith, 1966), little was done prior to 2010 to elucidate its true prevalence. Between 2010 and 2012, a comprehensive DNA sequence library was established to facilitate the

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[1] South African Research Chair in Meat Science hosted by the University of Stellenbosch in partnership with the University of Fort Hare, funded by the Department of Science and Technology (DST) and administered by the National Research Foundation (NRF).

http://dx.doi.org/10.1016/j.foodchem.2015.03.113
0308-8146/

authentication of commonly-traded fish species in South Africa (Cawthorn, Steinman, & Witthuhn, 2011a, 2012b). Through this work, 'DNA barcoding' was shown to hold particular promise in explicitly distinguishing the species origin of raw, processed, whole or partial fish specimens (Cawthorn, Steinman, & Witthuhn, 2011a). DNA barcoding, based on the sequencing of a short, standardised region of the cytochrome *c* oxidase I (COI) gene, has garnered increasing attention as a broadly applicable tool for identifying an array of animal species, including fishes (Hebert, Cywinska, & Ball, 2003; Hebert, Ratnasingham, & deWaard, 2003). The utility of the method for fish species identifications is grounded on the premise that the COI sequence shows considerably greater inter- than intra-species variation, allowing for the differentiation of *ca.* 97% of fish species (Ward, 2009) and often being more discriminatory than alternative DNA markers used for this purpose (Cawthorn et al., 2011a, 2012b; Nicolè et al., 2012). Although some potential limitations of DNA barcoding have previously been recognised (Rubinoff, Cameron, & Will, 2006), the method has more recently been validated for use in forensic and regulatory fields (Dawnay et al., 2007; Handy et al., 2011). Momentum for the initiative has further been aided by, *inter alia*, the establishment of the Consortium for the Barcode of Life (CBOL) – an international alliance that promotes global standards for DNA barcoding, the development of the Barcode of Life Database (BOLD, www.barcodinglife.org) – an online data management system that serves as a global repository for barcode sequences (Ratnasingham & Hebert, 2007), as well as the emergence of numerous campaigns seeking to barcode all life on earth. The Fish Barcode of Life Initiative (FISH-BOL, http://www.fishbol.org) is one such campaign aiming to assemble a COI-reference library for all fishes (Ward, Hanner, & Hebert, 2009), with over 10 000 of the *ca.* 32 000 fish species being barcoded to date (2014).

COI barcoding (Cawthorn et al., 2012a) and other DNA markers (Von der Heyden et al., 2010) have recently been used to reveal disturbing rates of fish mislabelling (21–50%) in South Africa, with both studies generating considerable media attention (Joseph, 2009; Yeld, 2012) and likely leaving some industry role players infuriated and even humiliated. Such responses, however, typify those surrounding any major food scandal, where the immediate effects are often perceived as negative but the ensuing ones are largely positive. Research of this kind raises awareness around pertinent concerns, compelling the entire industry to resolve the issues. While weaknesses are exposed that are inherent to modern food supply chains (e.g. complexity, traceability), areas are highlighted that need improvement, prompting authorities to step up checks and revise regulations.

Apart from this media attention, several other developments have emerged of late with the potential to alter local seafood marketing transparency. For one, new food labelling regulations came into effect in South Africa in 2012 (DoH, 2010), urging suppliers to re-assess the accuracy of their product marketing. In response to observed cases of confounded fish naming, Von der Heyden et al. (2010) and Cawthorn et al. (2012a) advised the compilation of a 'standardised seafood naming list' in South Africa (as used in the US, UK, Canada), which is currently under development. A further factor relates to the efforts of the Southern African Sustainable Seafood Initiative (WWF-SASSI, www.wwfsassi.co.za), a World Wide Fund for Nature programme established in 2004 with the aim of fostering public awareness around marine conservation issues and driving responsible fishing through a market-based approach. This programme now works across the seafood supply chain with key suppliers and retailers to address shortcomings in traceability systems and to revise seafood labelling to include more comprehensive species information.

In order to gauge the success of the abovementioned initiatives and to understand if enhanced consumer and industry awareness are being translated into tangible improvements, it is critical to consistently monitor the operating of the seafood supply chain. To this end, the aim of this study was to assess the current extent of fish misnaming or mislabelling in South Africa at the final supply chain link (consumer level) and to reconcile the results with previous studies. Further, the study aimed to benchmark the present state with a rigorous, statistically relevant protocol that can be repeated on a pre-determined basis to aptly track changes in seafood trading practices.

2. Materials and methods

2.1. Study and sampling design

The overall research design was to survey restaurants and retail outlets in three South African provinces to evaluate the extent of fish misnaming or mislabelling prevailing on the market. A chi-square (χ^2) test power analysis was used to estimate the number of samples required from each outlet type and province to ensure the statistical relevance of results.

2.1.1. Selection of geographic regions

The regions chosen for sample collection included the coastal provinces of KwaZulu-Natal (KZN) and the Western Cape (WC), as well as the Gauteng province (GP). KZN and WC were selected as these are among the most populated South African provinces, are both major fishing provinces in the country and have been shown to have access to a wide variety of locally-caught fish species (Cawthorn, Steinman, & Witthuhn, 2011b). Gauteng was included to assess commercial fish trading practices in an inland province, since it represents a principal seafood market in South Africa and has the largest population density and highest per capita income of all the country's provinces.

2.1.2. Selection of outlets

Restaurants and retail outlets were selected for sample collection since these represent the main channels through which consumers obtain fish products in South Africa. Outlets in each province were designated for the study prior to sample collection, with the intent to balance the sample sizes from high and low income regions. The basis for selection of restaurants was that these should have a dedicated seafood section on the menu and/or serve at least three different fish species. Where seafood restaurant franchises were chosen for sample collection, efforts were made to include the same outlets in each province to promote result comparability. The retail outlets selected included predominantly supermarkets (stores selling a range of food and grocery products) and to a lesser extent fish markets (outlets selling primarily fish), with the prerequisite being that these sell at least three different fish species. In order to standardise the sampling protocol for supermarkets, six established supermarket chains were identified in South Africa that market fresh and frozen fish products and similar sample numbers were collected from each chain in each province.

2.1.3. Priority fish species

This study focused on the species authentication of finfish (teleost spp.). Samples were collected only from those specimens that could not be visually confirmed as the species being sold, whether this was due to processing or suspected mislabelling. A minimum of one and a maximum of two samples were obtained from each outlet in each province.

Two categories were defined for fish sample collection. For 'category A' samples, the following four 'priority' species were selected for collection: (i) kingklip (*Genypterus* spp.); (ii)