Accepted Manuscript

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PII:	S0044-8486(18)30930-X
DOI:	doi:10.1016/j.aquaculture.2018.10.006
Reference:	AQUA 633597
To appear in:	*aquaculture*
Received date:	5 May 2018
Revised date:	17 September 2018
Accepted date:	5 October 2018

Please cite this article as: Richard Newton, Wenbo Zhang, Michael Leaver, Francis Murray, David C. Little , Assessment and communication of the toxicological risk of consuming shrimp in the EU. Aqua (2018), doi:10.1016/j.aquaculture.2018.10.006

Assessment and communication of the toxicological risk of consuming shrimp in the EU

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Keywords: Shrimp; risk assessment; food safety; antimicrobial; media; public perception

Acknowledgements

This study was funded by the Seafood Importers' and Producers' Alliance (SIPA).

Declaration of interest

None

Abstract

The numbers of alerts from the EU's Rapid Alert System for Food and Feed (RASFF) related to crustacean products were compared to numbers of mainstream media stories related to health concerns. An internet search of "farmed shrimp" was also conducted and the content of the websites assessed for subject matter and balance. The study found that the absolute number of RASFF alerts has fallen considerably since legislation controlling testing of food being traded into and within the EU was introduced in 2002 and tracked increasing stringency of EU procedures. There were 1512 alerts from 1980 to 2015 with 44.0% and 21.2% of alerts attributed to farmed and wild shrimp respectively. There were large numbers of alerts reporting antibiotic residues in wild shrimp, which raised questions about the source of the contamination, and natural occurrence of the antimicrobial residues was considered. The number of mainstream media stories closely followed the number of alerts, but 91.2% of media articles concerning the health aspects were concerned with consumption of farmed shrimp. The internet search revealed a much more negative view of farmed shrimp compared to the mainstream media. It is suggested that the internet generally follows an historic negative narrative on farmed seafood, often with little validation which narrows the discourse on seafood production rather than empowering consumers. According to the risk assessment of RASFF data, it was concluded that farmed shrimp does not possess any more risk than wild seafood choices but producers have not been able to communicate the benefits of farmed produce to the consumer.

1 Introduction

Farmed warm water shrimp, (mainly *Penaeus monodon* and *Litopenaeus vannamei*) is one of the most important traded seafood commodities in the world. The majority of production occurs in Asia and South America with large markets in the USA and the EU which import some US$5.6 billion and US$7.0 billion of crustacean products (FAO 2016) respectively. As shrimp production (from fisheries) in the EU has declined, trade in shrimp products has increased to make up the short fall, much of it farmed warm water shrimp from Asia and South America (figure 1).

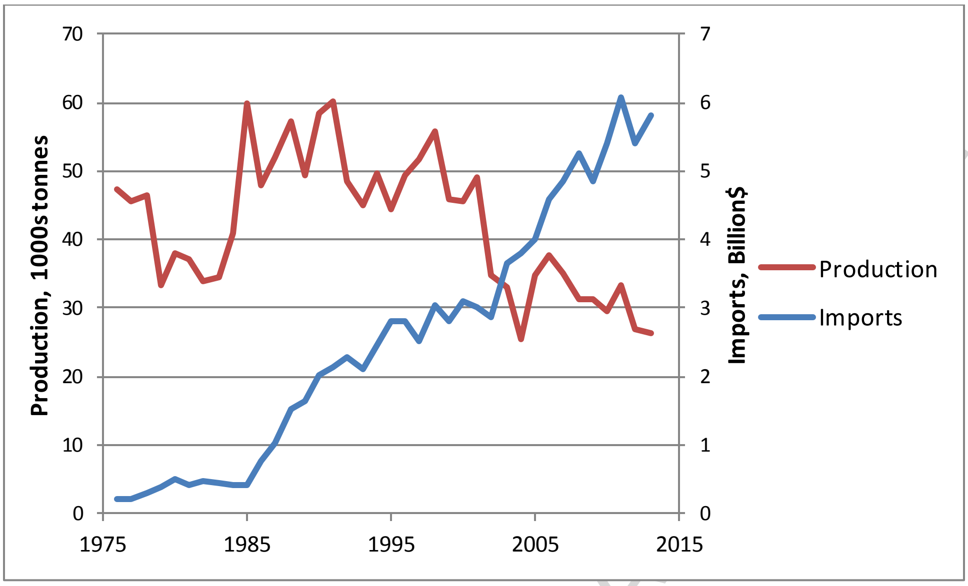

Figure 1. Trends in EU28 shrimp fishery production volume and value of imported shrimp trade within and to the EU (data from FAO fishstat 2016).

The shrimp industry has received criticism for environmental and social impacts in a number of contexts, notably mangrove clearance, salinisation, soil and water contamination, displacement of traditional livelihoods and labour abuses (Hossain et al 2013, Tran 2013, Belton 2016). However, it has also contributed to significant economic growth, often in poorer regions of Low and Medium Income Countries (LMIC), and supports improved infrastructure investment and livelihoods throughout its value chains (Hatje et al 2016, Tran 2013). Despite a very mixed picture of success and failure, the public perception of tropical farmed shrimp and other aquaculture species tends to be broadly negative, perpetuated by negative mainstream and internet based media stories, blogs and information outlets which can filter through to policy initiatives at the highest level (Murk et al 2016, Little et al 2012). There is a perception that has been perpetuated by interest groups, especially NGOs and portions of the media, that shrimp producers, particularly in Asia, have not improved production practices since negative stories first surfaced decades ago. Therefore the perception is that producers continue to contribute to global environmental damage, social malpractice and are still utilising chemical and pharmaceutical substances which have been banned in the West, with little regard for the consequences on human health (Little et al 2012). These perceptions and their effect on policy create suspicion in producer countries of the motives of importing countries, resulting in a lack of transparency and hindering collaboration between stakeholders, preventing progress in sustainable and responsible production development (Vandergeest and Unno 2012). Multistakeholder dialogues often highlight incompatible differences between industry, NGOs and academia, and may exclude the voices of particularly developing world and small scale producers, relegating them to targets for action rather than participants within an improvement process, whereas some NGOS refuse to engage in a process which they regard as legitimisation of an industry that they regard as unsustainable (Havice and Iles 2015, Anh et al 2011, Vandergeest and Unno 2012). In some circumstances the motives of researchers or NGOs are considered an imposition of the Global North's values on developing nations that displaces the sovereignty of their own laws, traditions and culture (Vandergeest and Unno 2012). Conversely some NGOs and Global North stakeholders consider the regulations of shrimp producing countries to be comparatively weak (Vandergeest and Unno 2012, Vandergeest et al 2015).

Many consumer based internet sites and blogs focus on negative claims over environmental degradation and poor social responsibility in the value chain but they also raise concerns over the use of pharmaceuticals and chemicals for disease management, unsanitary production conditions, and bacterial contamination with little supporting evidence. Such sites claim that imported tropical shrimp are therefore unsafe and should be avoided, often in favour of local wild alternatives (e.g. https://www.pccmarkets.com/sound-consumer/2008-08/sc0808-shrimp/ accessed 23/8/18). This article is based on a systematic analysis of data from the EU Rapid Alert System for Food and Feed (RASFF) and scientific literature, as empirical evidence of food-safety risks for shrimps, prawns and crawfish imported into Europe in comparison to media claims. The analysis is in two sections. Firstly a risk assessment of the consumption of imported shrimp is presented based on the contamination levels reported within the RASFF database over time, and secondly, trends in the numbers of alerts are compared to the frequency of published articles in the mainstream media (newspapers and magazines), and further contextualised with information available as web-based media.

2. European food safety

The safety of food and animal feed in the EU is regulated by national competent authorities based on sampling regimes mandated by EU law under the technical guidance of the European Food Safety Authority (EFSA). EFSA was instituted through Regulation (EC) N° 178/2002 (European Commission (EC) 2002) which also established the general principles of food law for the EU, largely in response to various food scares that had caused economic losses and reduced consumer confidence . The RASFF, is a system initiated in 1979 for testing food and animal feed products for contamination and relaying the results within member states, but sampling procedures and communication protocol were initially non-standardised. In principle all member states are responsible for ensuring that food is fit for human consumption by testing a number of randomly collected samples from food consignments for a range of contaminants. Consignments which violate EU regulations, whether due to exceeding limits of contaminants or other violations such as inadequate documentation, are flagged on RASFF, following notifications by health officials in accordance with the RASFF Standard Operating Procedures (EC 2016) and subsequently removed from the supply chain. Improved standardisation was stimulated by the consolidation of the consumer and health services under one Directorate General and the implementation of European Council Directive 96/23/EC (EC 1996), that established regulations concerning monitoring of harmful substances and residues in livestock.

The RASFF was systematically modified after 2002 (Regulation (EC) N° 178/2002), reflecting the introduction of better testing methodology and improved data sharing between EU States. These regulations were further enshrined in European law by Regulation (EC) N° 178/2002 which provided a complete hygiene package for both food and feed. Legislation to establish Maximum Residue

Limits (MRLs) for pharmacologically active substances preceded these developments with implementation of regulation 2377/90 (EEC 1990) categorising substances according to whether MRLs had been established or were necessary. MRLs were updated in subsequent amendments and regulations as better testing procedures were developed but they could not be established for a number of substances of importance to aquaculture, particularly genotoxic chloramphenicol and nitrofurans, and their metabolites. Consequently, any detection of chloramphenicol or nitrofuran residues has resulted in the rejection of that consignment (FAO accessed 5/11/16). Initially, despite the MRLs set by EEC 2377/90, it was not obligatory for member states to test aquaculture products for substances, whether produced in the EU or 3rd countries. A subsequent regulation (96/23/EC) made it obligatory for 3rd countries to submit monitoring plans for approval but the first list of countries with approved plans was only published in 2000 (EC decision 2000/159). Since the establishment of monitoring plans, many notifications have actually been raised by exporting countries. Regulations that standardised sampling regimes across the EU were not published until Commission Decision (98/179/EC) and the laboratories were only required to obtain accreditation (according to ISO 17025) by early 2002. Despite standardisation of sampling regimes, analytical techniques for detecting certain substances, particularly nitrofuran metabolites were not developed until the EU FoodBRAND project (2002 to 2003: Vass et al 2008). Following this, analytical methods and their interpretation were standardised under regulation 2002/657/EC. This regulation introduced the concept of minimum required performance limits (MRPLs) which serve as a reference point for detection of substances for which no MRL has been set. MRPLs for both nitrofurans and chloramphenicol were subsequently amended (EC Decision 2003/181/EC) to levels deemed reliable for detection (0.3µg/kg and 1µg/kg for chloramphenicol and nitrofurans respectively), rather than a threshold of risk to the consumer.

The current RASFF system details when a consignment of food or feed has violated EU regulations such that it poses a threat to human health. Alerts are triggered based on the presence of banned substances, detection of controlled substances above the maximum residual limit (MRL), evidence of spoilage, or invalid documentation. It also details the date of the violation, the notifying country, the source of the imported goods and the species in most cases.

3. Materials and methods

3.1 Risk Assessment

The approach to risk assessment was to calculate the mass of shrimp with a given contaminant level that would be required to exceed the Acceptable Daily Intake (ADI) for a 70kg adult (WHO 1987). ADI is a measure of the amount of a specific substance (e.g. food additive, veterinary drug or pesticide) in food or drinking water that can be ingested on a daily basis over a lifetime without an appreciable health risk. In some cases, for some contaminants, these may be expressed as weekly or monthly acceptable intakes. For foodstuffs with ADI (or equivalent weekly or monthly intake levels) it is simple to estimate the amount of shrimps required to exceed safe levels (as defined by JECFA 2000), based on a typical adult of 70kg, the ADI, and the levels of contaminant measured in shrimps as indicated on RASFF. This can be done either for the maximum exceedance on the RASFF database, or on the average or median exceedance over a set period.

For other contaminants such as genotoxic compounds, although JEFCA and the EU are of the opinion that there is either no safe level, or that there is insufficient toxicological information, alternative methods can be suggested. The current system uses so-called Reference Points for Action (RPA; European Food Safety Authority 2005) for some compounds. The setting of RPAs considers factors such the Threshold of Toxicological Concern (TTC) approach, which classifies contaminants quite broadly according to structure/chemistry (e.g. genotoxins) and sets a maximum safe intake level for all members of the class. For some genotoxic compounds such as chloramphenicol and nitrofurans an RPA has been defined based on consideration of TTC and on the sensitivity of analytical detection techniques. These RPAs indicate a maximum permitted residue level in any foodstuff. RPAs have been proposed for chloramphenicol and for nitrofuran residues and in this study were used to back-calculate a daily intake to give an amount of shrimp consumption that would pose a theoretical health risk for a 70kg adult based on maximum, median and mean contamination levels found in the RASFF database. The purpose of this step was to estimate ADIs for compounds with Maximum Residue Limits (MRLs) comparable with compounds for which ADIs are not available, but where other thresholds of toxicological concern are defined.

3.2 RASFF Contamination Data

Data from the RASFF database was downloaded under the category "crustaceans and products thereof". This data includes the source (but not necessarily the place of production), the violation, including concentrations of contaminants and the species of crustacean, in most cases, but not whether it was farmed or wild. Notifications were sorted by date, species and country of origin. Each violation was then then classified as either farmed or wild, where possible according to production data in FAO FishStat database (FAO 2016), or unknown where species was undeclared or the origin was ambiguous[1]; violation type was re-categorised into 7 separate categories (bacterial, antimicrobial, heavy metals, persistent organic pollutants (POPs), additives, spoilage and traceability). Spoilage included alerts from mould, poor organoleptic properties, infestations and breakages in the cold chain, whereas traceability related to incorrect or missing documentation. The trends in different alerts were identified between 2000 (when MRL limits and procedures were

[1] For example, *Penaeus monodon* is both farmed, as well as being produced from wild capture in India, in similar annual quantities of between 70 thousand and 130 thousand tonnes over the last ten years, and therefore alerts of *P. monodon* from India could not be attributed to either production method.

standardised (Section 1.2)) and 2015 the last complete year of records. In addition to the RASFF database a literature review was carried out to identify articles and grey literature detailing contaminant levels in shrimp of farmed origin.

3.3 Media analysis

The media analysis was conducted using the content analysis approach (e.g. Ban 2016, Pasquaré et al 2012) to assess the purpose and discourse characteristics of a media article and how it may be understood by the reader. A search of European newspaper and magazine articles was conducted using the Nexis® database using the terms “shrimp” or “prawn” in the headline and equivalent terms in French, Spanish and German, including the words e.g.“crevette”, “cameron”, “gamba”, “quisquilla” and “garnele”. Key messages were identified and categorised into an *a priori* defined list of themes so that numbers of articles could be compared. All articles were framed by the primary subject matter and headline of the article according to the following categories; public health, traceability, economics, the environment or social responsibility according to author perception. All content analysis was performed by one investigator to ensure consistency of perception (Lombard et al 2002). Articles were also characterised by whether they referred primarily to farmed or wild production and whether the article was considered to be positive, negative or neutral. Articles concerning employment were classified as “economic”, whereas articles concerning working conditions were classified as “social”. Although articles concerning public health generally do not specifically mention the concentration of banned substances, they usually mention the presence of banned or harmful substances in generic terms. Therefore, this study set out to compare numbers of RASFF alerts vs number of articles of public health nature and where possible, to link media claims on risk to a risk assessment determined from RASFF contamination data. However, as declarations of contamination levels within media sources are relatively rare, the numbers of alerts vs numbers of health related articles proved the most practical basis for comparison. Furthermore, contamination levels become less meaningful in the context of substances with a zero tolerance threshold. The media analysis included articles on other aspects such as economics or the environment for context whilst articles concerning recipes for shrimp and prawn dishes were not considered to be relevant. The full text from all articles included in the analysis can be seen in supporting information.

In addition to the main media assessment, an internet search was conducted in English by typing "farmed shrimp" into the Google® search engine to gauge the information and perception of shrimp which is continuously available to consumers. The first fifty sites in the list were characterised according to their content in a similar way to the mainstream media search into the following categories; general, public health, the environment, economics, social responsibilities, business sites, forums, academic sites and others. Sites in each of these categories were then categorised based on their positive, negative or neutral content and compared to outcomes of the mainstream media search.

4. Results

4.1 Risk Assessment

Little detailed data on contaminant concentrations was given in early entries within the RASSF database but data became more extensive in later years. The RASFF data indicated that levels of any particular contaminant in shrimps could vary greatly (Table 1), and there was no evidence to suggest that contamination intensity had changed over the time period of the database for any substance. Some upper level figures for contaminant levels appeared to be unrepresentative of the rest of the data sets. For example for furazolidone (measured as AOZ nitrofuran metabolite) the highest figure was 1.2ppm (1.2mg/kg), whilst all 173 other values for shrimps exceeding limits were < 0.17ppm. Given the possibility that these outliers may represent technical errors in recording or analysis, the maximum safe level of daily intake of shrimps for a 70kg adult was calculated for both the median contaminant level and the highest (i.e. worst case contaminant level). Outliers of two magnitudes or more above the median were only present in chloramphenicol and nitrofuran data (14 each) and randomly distributed chronologically and geographically, but medians were unaffected after their removal.

Table 1 Indicates the maximum safe intake of shrimps based on ADI, ADI adjusted to monthly or weekly intake recommendations, or daily intakes based on back-calculation for RPAs. Levels of intake are given for median RASFF alert levels for each contaminant and for maximum alert level recorded since 2000.

Table 1 Maximum safe consumption for the six most frequent compounds flagged in RASFF alerts for shrimp and prawns since 2000

Shrimp Origin[a]	**Contaminant**[b]	**ADI**[c]	**Mean RASSF**[d]	**Median RASSF**[d]	**Max RASSF**[d]	**Max intake (g) Mean**[e]	**Max intake (g) Median**[e]	**Max intake (g) Max**[e]
Farmed	Chloramphenicol	RPA=0.3 μg/kg	0.0182	0.0006	0.91	24.8	750.0	0.495
Wild			0.0534	0.0024	1.4	8.4	187.5	0.321
Unknown			0.0761	0.0006	1.2	5.9	750.0	0.375
Farmed	Nitrofurans	RPA=1 μg/kg	0.1587	0.0045	11	9.5	333.3	0.136
Wild			0.1343	0.0115	1	11.2	130.4	1.500
Unknown			0.0194	0.0038	1.2	77.1	394.7	1.250
Farmed	Tetracyclins	ADI=0.03 mg/kg body weight	0.2139	0.158	2.065	9819.3	13291.1	1016.95
Wild			N/A		N/A	N/A	N/A	N/A
Unknown			0.2107	0.21	0.382	9966.8	10000.0	5497.38

Farmed	Cadmium	PTMI=25 µg/kg body weight	1.1400	0.86	1.8	51.2	67.8	32.407
Wild			1.3054	0.96	2.5	44.7	60.8	23.333
Unknown			1.0752	0.9	2.5	54.3	64.8	23.333
Farmed	Sulphite	ADI= 0.7 mg/kg body weight	169.19	167.33	435	289.6	292.8	112.64
Wild			304.98	258	2327	160.7	189.9	21.06
Unknown			172.72	147.5	511	283.7	332.2	95.89

a, origin of shrimp not specified in RASFF data. Designation in table by inference.

b, where contaminants belong to same class and have the same RPAs/ADI, they have been considered together (eg all tetracyclins and all nitrofuran metabolites)

c, not all contaminants have ADIs, and Cd is not expressed as daily maximum intake. RPAs have been used to back-calculate maximum safe intakes based on 1.5kg food per day for a 70 kg adult. PTMI: provisional tolerable monthly intake

d, the mean, median and maximum RASFF alert levels in shrimps in mg/kg.

e, the maxiumum amount of shrimps a 70kg adult can eat before exceeding ADI or back-calculated equivalent, expressed in terms of the mean, median or maximum contaminant levels form RASFF

The main issue of public concern is whether levels of contaminant are of toxicological significance to consumers of shrimps. Based on the maximum levels of contaminants listed in the RASFF database there is a theoretical risk to the public from consuming farmed shrimps. For example, calculations indicate that 0.3g-0.5g per day of shrimp with the most serious chloramphenicol contamination would pose a health risk to an average adult. This is based on a back-calculation from the RPA for chloramphenicol. The situation for nitrofurans is similar to that of chloramphenicol. Less than 1g/day represent a health risk to adults if the shrimp are contaminated at the worst levels encountered. However, it is also possible to estimate risk by the Margin of Exposure (MOE) method when toxicological data exists for a particular compound and no MRL has been established. Thus MOE is calculated as the ratio of a defined adverse effect level, based largely on animal laboratory tests, to estimated human intake. Currently EFSA uses MOE for risk assessments of genotoxic compounds, to ensure that RPAs are sufficiently protective of the population as whole. For example for nitrofurans (based on the RPA of 1μg/kg in all foodstuffs) EFSA has calculated MOEs of 2.0×10^5 or greater for carcinogenicity and at 2.5×10^3 or greater for non-neoplastic effects (EFSA 2015). These MOEs were considered protective and "unlikely to be of concern" by the expert panel charged with undertaking the risk assessment (EFSA 2015). As an example, the dose of furazolidone (a nitrofuran for which toxicological data exists) at which 10% of tested animals show effects is 2.6mg $kg^{-1}bwday^{-1}$ and given a protective MOE recommended at 10000 (EFSA 2005), the safe limit for all foodstuffs would be 0.26μg$kg^{-1}bwday^{-1}$. The mean alert nitrofuran levels in shrimps on the RASFF database is 159μg/kg, indicating that, using this MOE approach, 112g of shrimps consumed per day by a 70kg adult would exceed safe levels. This compares with 0.136g per day back-calculated from the RPA for nitrofurans in the case of shrimps showing the highest level of contamination. Although this level of shrimp consumption indicated by the MOE approach could be considered high compared to the RPA position, it is not inconceivable. The same arguments can be made for chloramphenicol. That is, assuming a worst case that all shrimps are contaminated at maximum level, then the amounts of shrimp meat consumption required to present a risk could be exceeded easily from RPA and just possibly by MOE. The latter is less likely considering median contamination values for which consumption of at least 130g of shrimp per day are required to exceed the ADI for nitrofurans. Clearly these quantities will depend, not only on the calculation of safe daily intakes, but also on some estimate of the proportion of imported shrimps which are contaminated and which enter the human food chain. Whilst there are several publications reporting on contamination in shrimp available to consumers, only one of them (Tittlemier et al 2007) reported levels of contamination from antibiotics or other substances which breach maximum residue limits or reference points for action.

Data for shrimps of wild origin and imports that cannot be reliably classified from RASFF data as wild or farmed, are also included for comparison (Table 1). Contaminants belonging to the same group, that share the same ADIs or RPAs have been presented together, for example, all tetracyclins and all nitrofuran metabolites. Very little information, other than RASFF data, is available for contaminant levels in farmed shrimps. A few investigations have targeted antibiotic residues (see below), and although residues have been found, in only one of these publications were MRLs or RPAs exceeded. No data was found for pesticide or herbicide levels, and no alerts for these classes of compound are present on the RASFF database for shrimp. A review of MRLs for pesticides has been on-going since 2005 (WTO 2016).

Chloramphenicol levels exceed RPA more often in wild than farmed shrimps (77 versus 59 consignments). Eating just 0.5g of the most heavily contaminated shrimp notified by RASFF would be sufficient to exceed the hypothetical safe limit based on the RPA. When considering the median level of contamination registered in the RASFF database, eating 750g/day of contaminated farmed shrimp would be sufficient to exceed the hypothetical safe limit based on the RPA. In the case of nitrofurans the most frequently detected metabolite in farmed shrimps was semicarbazide (SEM) which was detected more than 3 times as frequently as 3-amino-2-oxazolidinone (AOZ). SEM and AOZ are taken to indicate contamination with the antibiotics furazolidone and nitrofurazone respectively. Eight samples were flagged for 3-amino-5-methylmorpholino-2-oxazolidinone (AMOZ), a metabolite of furaltadone. In comparison only about half the number of consignments of shrimps of wild or unclassifiable origin are represented in the database. Consuming as little as 0.14g of the most heavily contaminated shrimp notified by RASFF would be sufficient to exceed the hypothetical safe limit based on the RPA. At the median level of nitrofuran contamination registered in the RASFF database, eating 400g/day of contaminated shrimp would be sufficient to exceed the hypothetical safe limit based on the RPA. Tetracyclin levels exceeding MRLs were found almost exclusively in farmed shrimps (48 alerts) with no unequivocal alerts from consignments of wild shrimps, although there were 10 alerts in shrimps of unclassifiable origin. In order to exceed ADI for tetracycline it would be necessary to eat 1kg of shrimp with the highest level of contamination registered in the RASFF database, or 10 kg of shrimp contaminated at the median level.

Cadmium contamination was almost exclusively present in shrimps of Australian origin and was present at equally high levels in both farmed and wild shrimp, although very few consignments of farmed shrimp are flagged compared to wild (5 versus 21, with a further 31 of unknown origin). The ADI for shrimp with cadmium contamination was below 100g/day whether using maximum, mean or median values of contamination. Sulphite additives were also more often found at MRL exceedance levels in wild shrimp consignments (177) compared to farmed (124). Consuming just 20g of shrimp per day containing the highest level of sulphite registered by RASFF would be enough to exceed the ADI for sulphites. At the median level of sulphite contamination, consuming 2 kg of contaminated shrimp per day would exceed the ADI.

4.2 RASFF Contamination data

Results show clear trends in RASFF alerts (Figure 2.) that relate to changes in production and processing practices but also how contaminants are monitored both in Europe and the producer countries.

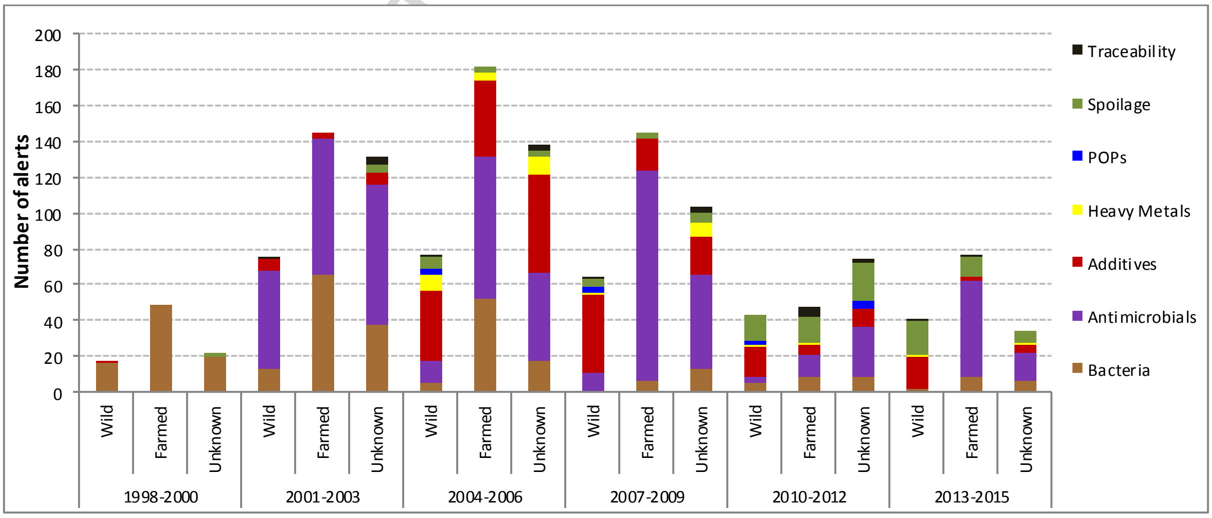

Figure 2. Frequency of RASFF alerts by contaminant type in EU imports of farmed and wild shrimp and prawns, 1998 - 2015

There were a total of 13 alerts from 1980, when the RASFF alerts begin, to 1997, all concerning presence of bacteria. Results are presented from 1998, following the implementation of EC directive 96/23/EC and where the bulk of the data lies. In the years up to the turn of the millennium, bacterial contaminants dominated alerts. Following this, from 2001 considerable number of alerts related to antimicrobials were flagged with peaks in 2002, 2006 and 2009. There was a large increase in antimicrobial alerts after 2002 coinciding with the development of analytical procedures for detecting nitrofuran metabolites within the FoodBRAND project. From 2004, many more alerts concerning additives were flagged, almost exclusively related to high or undeclared levels of sulphite, commonly used as a preservative. Alerts concerning additives decreased from 2010 but many more violations from spoilage were encountered. Overall, the number of alerts has decreased substantially since 2009, especially for antimicrobial, bacterial and additive contaminants despite an increase in imports. It is of note that large numbers of consignments considered to be from wild stocks were found to have residues of antimicrobials, especially in the period 2001 to 2003. Possible reasons for this are discussed below.

Figure 3 shows the alerts from selected countries along with their production and export data. Unfortunately, export commodities include various levels of processing so there is no standardisation. However, the results show that in many countries, where export-oriented production is increasing, corresponding alerts have reduced. In China, for example, after the period of 2000 to 2002, emphasis shifted from capture based industries to aquaculture and exports also increased. Subsequently alerts increased in aquaculture produce compared to wild but dropped overall, especially in the periods after 2008. Similarly in Thailand, whereas exports have increased steadily up to 2011, alerts have reduced considerably after 2002 and continued to fall subsequently. Following increased alerts in China and Thailand due to antimicrobials during 2001 to 2002, and restrictions imposed by the EU on imports from those countries (EC 2001, 2002c), better monitoring procedures were put in place in the producer countries. A mandatory China Entry-Exit Inspection and Quarantine (CIQ) registration system (AQSIQ 2017, Zhang et al 2017) was initiated in 2004, which was followed by reduced RASFF alerts. However, India and Bangladesh have faced greater challenges in reducing contamination as demonstrated by increasing alerts until the period 2009 to 2011. The number and type of alerts can be compared to how the RASFF system has evolved and corresponding EU legislation, as discussed below.

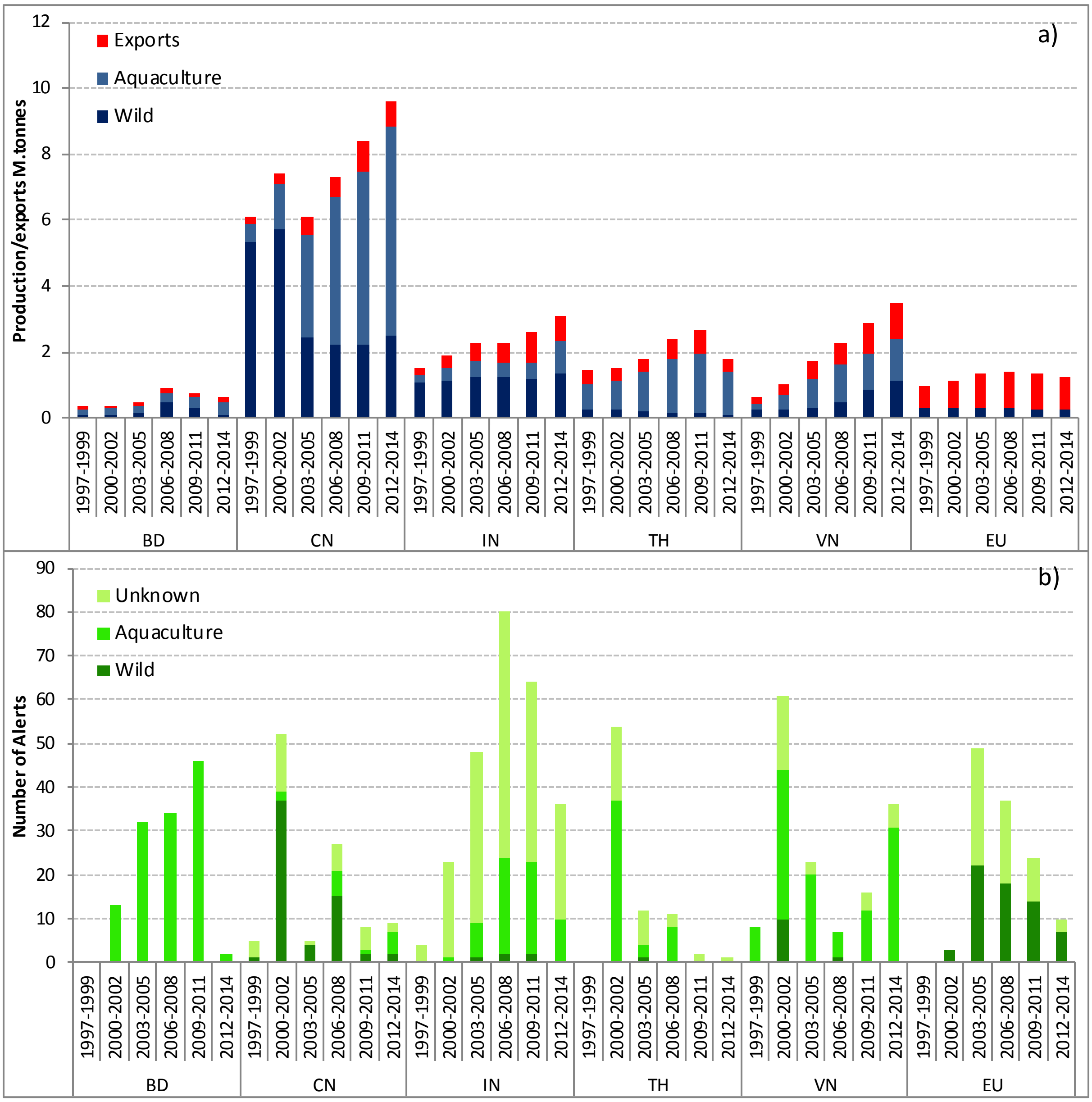

Figure 3. a) Production and total exports from aquaculture and fishery shrimp and prawns against b) number of alerts for selected countries/regions. Bangladesh (BD), China (CN), India (IN), Thailand (TH), Vietnam (VN), Europe (EU). Note: Europe refers to the geographical area and includes countries outside the trading block of the EU. Production and trade data from FAO FIshstat (2016).

Figure 4 shows the total number of alerts of different types, by country of origin. It is clear that Asian country alerts have been dominated by bacteria and antimicrobial alerts, whereas other countries or regions have had more diversity of violations. Europe, Africa and Brazil, particularly, have had proportionately more alerts for high or unauthorised additive content.

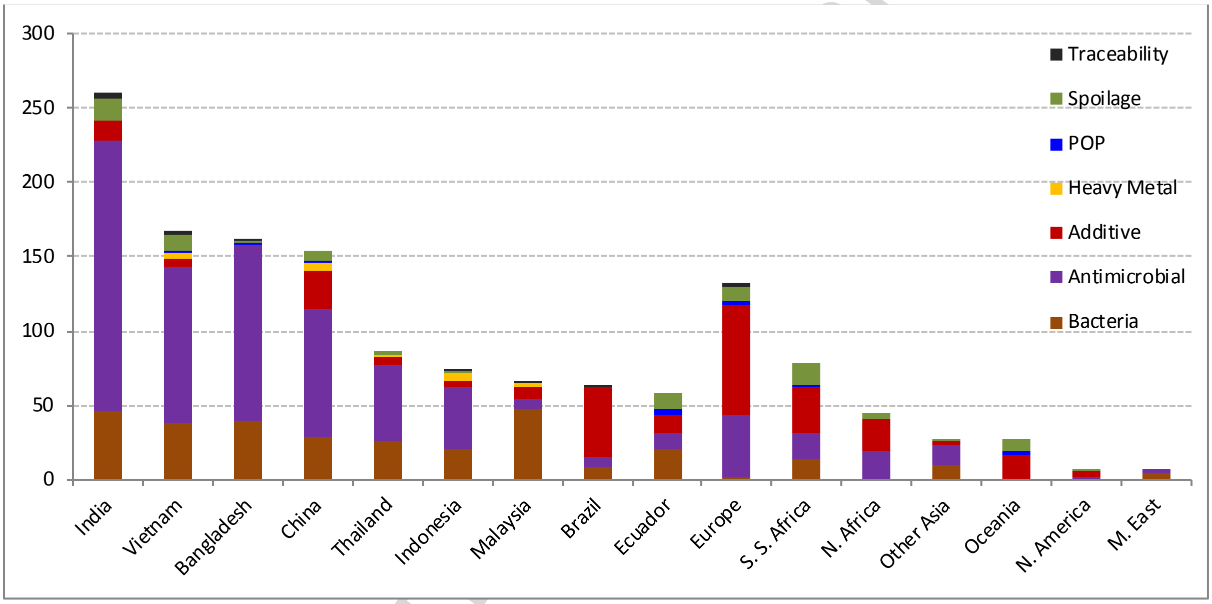

Figure 4. Total number of RASFF alerts from shrimp and prawn imports by country/region according to violation classification from 1997 to 2015.

Clearly MRLs and RPAs are breached in some consignments of farmed shrimps as shown in the RASFF database. The generally low to insignificant levels of contaminant found in published studies are likely a result of small sample size compared to RASFF, as well as the likelihood that importation screening procedures have evolved sufficiently to identify and remove the vast majority of contaminated shrimps from the value chain. The bulk of published studies report antibiotic levels. There are no reports from any source that could be found which detail elevated pesticide /herbicide levels in farmed or wild shrimps.

4.3 Media analysis

The results of the Nexis media analysis are shown in Figure 5 along with the total number of RASFF alerts. 405 articles published between 1997 to 2015 were included in the analysis. The majority of alerts were concerned with economic issues, with large numbers of environmental and social issue-based articles and in later years. These had little to do with the RASFF system or public health but put into context the type of concerns that were at the forefront of the industry. In general, articles concerning public health and traceability broadly followed the number of RASFF alerts with a large peak in articles in 2002 corresponding to the highest number of alerts and subsequently tailing off up to 2014. Only in 2002 were public health articles more numerous than economic or environmental based articles (Figure 6) as subsequently the number of alerts has dropped markedly while imports have increased in the same time. Unfortunately, normalisation of alert rates is complicated by the aggregation of farmed and wild commodities in the FAO trade data, which make it impossible to separate alerts per unit import into the EU by farmed or wild origin. The large number of alerts concerning traceability issues in 2015 related to a few cases of mislabelling fraud in the German press. Traceability violations are also recorded in the RASFF system, with some consignments rejected because of incomplete paperwork. Some media articles have highlighting the mislabelling of farmed shrimp as wild, simultaneously implying that farmed shrimp were in some ways less safe than wild. However our own research puts this perception into question and points to safety and traceability concerns for both wild and farmed shrimp, further discussed below.

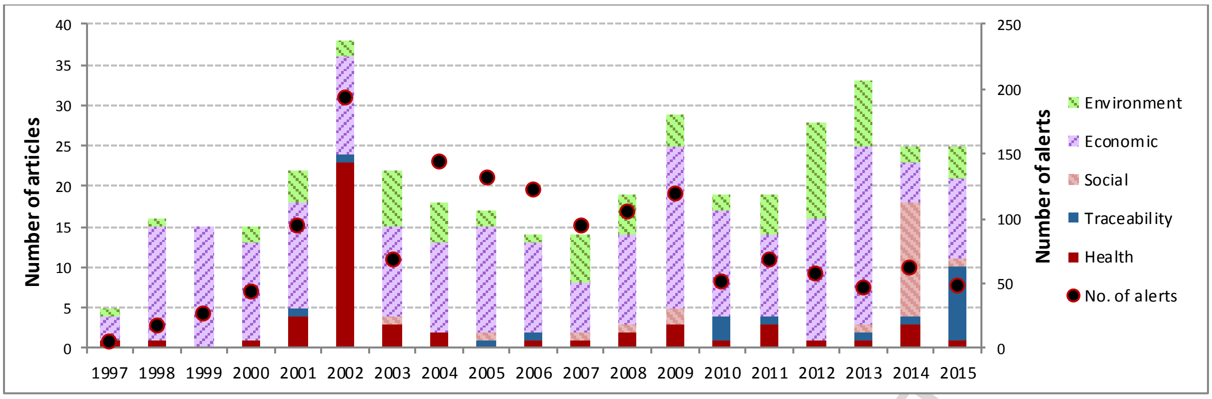

Figure 5. Total number of European media articles (English, French, Spanish and German) concerning "shrimp" and translations of by category, compared to total RASFF alerts from 1997 to 2015

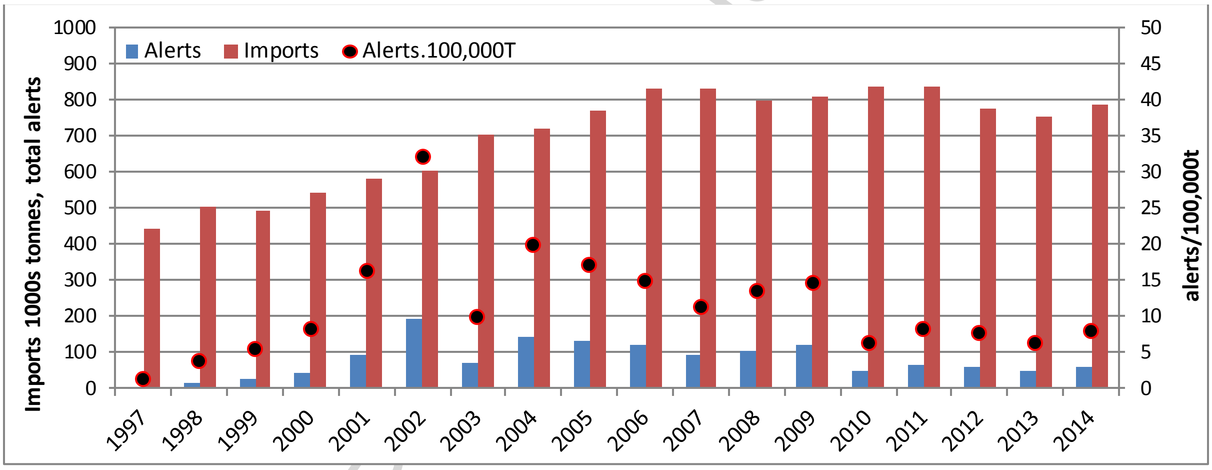

Figure 6. Number of RASFF alerts for shrimp and prawns compared to EU import volumes, 1997 - 2013

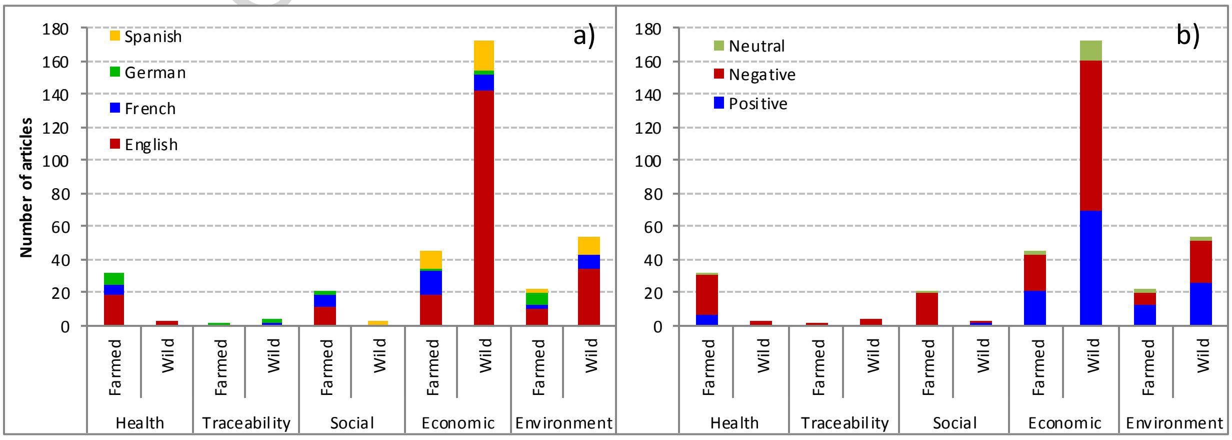

Figure 7 Number of European media articles concerning farmed and wild shrimp (and equivalents in 4 languages) for five different issues a) by different European languages and b) according to partiality. Articles which could not be designated to farmed or wild production were omitted (1997- 2015).

Figure 7a shows how the different issues presented by language and Figure 7b differentiates between wild and farmed produce for the different issues. The majority of economic-issue based articles were in English and concerned the quota allowances for Scottish fleets for Dublin Bay Prawn (*Nephrops* species). Economic issues were also important issues in French and Spanish language related to the sustainability of French and Spanish shrimp industries. Articles in German, tended to be concerned more with health and environment issues related to farmed shrimp. Traceability did not feature highly because in this case, articles were much more general focusing on how seafood was being mislabelled because of price, rather than safety. Few of those articles mentioned whether they concerned farmed or wild shrimp. The number of positive and negative articles related to economic issues and environment were fairly similar (Figure 7b). This contrasts with articles concerning health aspects of consuming farmed shrimp which were 78.1% negative (n= 32). 22 of the 25 negative health related articles in the media were concerned with antimicrobials with others mainly related to bacterial contamination. The majority of these referred to nitrofurans and their metabolites and expressed concerns that they were carcinogenic compounds. None of the articles gave information on contamination levels, other than stating that they were above acceptable national or EU levels, or how much shrimp would need to be consumed to exceed ADIs for given compounds. However, several articles specified how many samples had failed and more importantly the proportion of failed samples: four separate incidents were reported, all from 2002 to 2003 where 160/1200, 43/121, 1/7 and 16/77or 84[2] samples had detected antibiotic residues. 90.5% of articles related to social issues in the farmed shrimp industry were negative (n=21), dominated by a series of articles published in 2014 related to working conditions on Thai fishing boats.

[2] In four stories contamination was reported as being in 16/77 and in another four in 16/84 samples, related to an incident in Northern Ireland in 2002.

The results of the internet search on "farmed shrimp" are displayed in Figure 8. The top fifty sites portray a very different image of farmed shrimp to that portrayed in the mainstream media with very few positive representations. The few positive sites were those supporting certification schemes such as the Aquaculture Stewardship Council (ASC) and covered general aspects of production. All sites that focussed on human health and environmental aspects were negative. Businesses such as feed manufacturers were neutral about the different aspects of shrimp production. Internet sites did not tend to focus on any one aspect of shrimp production but were much more general, following an established negative discourse, covering health, environmental and social aspects, that has been repeated many times since concerns regarding tropical shrimp production were first declared.

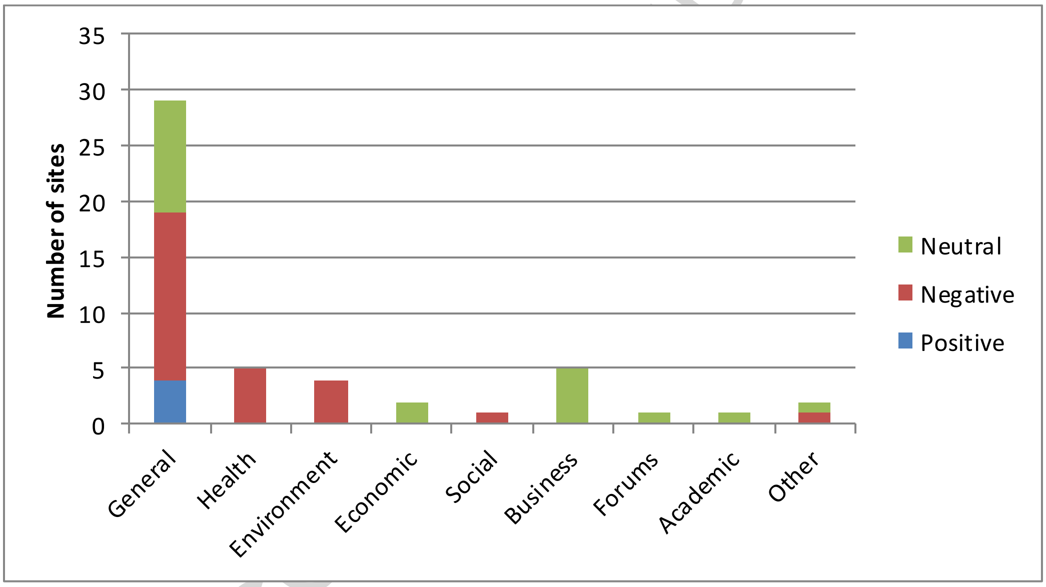

Figure 8. Internet assessment and categorisation of first 50 sites found after a search on "farmed shrimp"

Claims about negative human health impact had little scientific grounding and were often quite general in nature referring to issues such as polluted ponds, chemical and antibiotic use, unsanitary processing facilities and unhygienic practices throughout the value chain. However, several of the internet sites did refer to one web-based survey by Consumer Reports (http://www.consumerreports.org, accessed 21/7/16) in which 11 of 284 samples from US supermarkets tested positive for antibiotics and 60% for various bacterial contaminants. However, this article did not declare the quantity of contaminants in each sample and whether they were above allowable limits. No other internet site declared the number of samples or the amount of contaminant within any sample, unless referring directly to the Consumer Reports site.

5. Discussion

5.1 Risk associated with consuming shrimp and prawns

The RASFF data base shows that there is a clear reduction in the number of alerts especially with regards to antimicrobials, additives and heavy metals despite increases in imports. Generally detection of antimicrobials appears to be declining consistent with findings of Henriksson et al (2015) who found only around 3% of shrimp farmers in Vietnam were still using antimicrobials but practices vary regionally and temporally. Better awareness of food safety issues, especially among small scale producers combined with efforts to promote better management and use of probiotics are important. But stringent government residue testing, together with international certification that discourages the use of antimicrobial and chemical therapeutants, have driven this trend (Islam 2008, Tran et al 2013, Henriksson et al 2015, Zhang et al 2017).

Alerts dropped from a peak of 193 in 2002 to 43 in 2013, whereas trade almost doubled in value in the same time, and the accession of ten more countries to the EU in 2004 also meant that there were more countries reporting violations after this time (EC 2009). Based on the required 20% sampling rate of shrimp consignments being maintained, the risk to consumers of eating shrimp and crustacean products has fallen considerably since 2002. However, the consignment size and the number of samples taken are rarely consistent. Violations or changes in procedure have generally prompted more testing. The number of alerts has often reflected changing EU legislation (see 2.0).

The large peak in alerts in 2002 coincided with the introduction of analytical techniques and the establishment of the European food law (EC N° 178/2002), which not only prompted greater efforts in monitoring amongst member states but together with Regulation 96/23/EC laid down a framework for standardised monitoring protocols and sharing of data between member states. Better electronic communication at the turn of the Millennium also resulted in the ability for member states to communicate alerts more effectively and the introduction of a new mandatory notification system in 2004 gave advanced notice of possible violations to member states. Large numbers of chloramphenicol violations in 2001 from Chinese and Vietnamese exports and nitrofuran violations in 2002 in Thai exports led to specific EC decisions (2001/699/EC and 2002/251/EC respectively (EC 2001 and EC 2002c) that required 100% monitoring of shrimp consignments entering the EU from these countries until EU auditors were satisfied that offending countries had implemented a sufficient monitoring plan. These measures resulted in increased alerts in the short-term as more consignments were tested, but those countries quickly implemented better monitoring measures. Subsequently fewer alerts were notified for these countries, partially demonstrating the vigilance and effectiveness of the testing and alert system and, possibly improved practices on-farm including adoption of 3rd party certification programmes (e.g. Zhang et al 2017). However, Vietnam has since had large numbers of violations in both 2013 and 2014. Similarly, large numbers of violations due to antimicrobial presence were found in Bangladeshi and Indian consignments leading to similar measures (Decision 2008/630/EC;2009/727/EC) respectively. Bangladesh has struggled to implement monitoring plans more than other exporting countries to the point where it imposed a self-enforced six month ban on exports to the EU of freshwater prawn (*Macrobrachium rosenbergii*) in 2009 (Hassan et al 2013). During this time, the Bangladeshi government implemented various actions to improve monitoring and prevent banned antimicrobials in shrimp products.

However, the results reflect different national and regional capacities to detect and deal with contamination issues reflected by the structure of aquaculture value chains in these countries.

Thailand and China export industries are dominated by intensive farming systems and well developed testing procedures (Tran et al 2013, Zhang et al 2017). Conversely, the Bangladeshi and Indian industries are characterised by complex and more fragmented distribution networks and a heterogeneous mix of extensive, semi-intensive polycultures and intensive systems, including many small scale enterprises that collectively may contribute to individual export consignments and for many reasons, the industries are much harder to trace and regulate (e.g. Islam 2008). Non-Government Organisations encompass a wide range of actors that have had both positive and negative impacts. On the one hand their criticisms of aquaculture, often based on worst case scenarios, have fuelled disproportionately negative public perceptions (though arguably with limited effect on purchasing decisions). Others have strategically chosen to support improved environmental and social performance through industry collaboration e.g. with the World Wildlife Fund taking a leadership role in development of the 3rd party standards deployed by Aquaculture Stewardship Council (ASC 2014), operating alongside two other major industry lead Global Aquaculture Alliance, BAP (GAA 2017) and Global G.A.P. (2017) standards.

Clearly the RASFF database is not representative of the product choice that consumers have at the retail level. The evolution of RASFF and variability between testing procedures, temporally and geographically has demonstrated the complexities in extrapolating representativeness of RASFF to crustacean products available to consumers and providing an accurate risk assessment. A definitive risk assessment for consumers is not possible without knowledge of the proportion of total shrimp consignments imported to the EU that RASFF violations represent. Unfortunately, this data is not available in RASFF and the proportion of consignments tested has changed frequently in response to elevated violations, as indicated above. It is probable that the MRLs calculated even from median contamination levels shown in Table 1 are overstating the risk as they only include the failed consignments without any indication of what proportion of total consignments this represents. It should be stressed that these consumption risks, based on worst case contamination scenarios, are extreme cases. As indicated previously, the highest recorded contaminant levels in the RASSF database are outliers and can be an order of magnitude higher than the median exceeded levels. There is the possibility that they represent analytical or data recording errors, in which case median contamination levels may be considered as most relevant.

Contaminant levels reported in the scientific literature generally give no further indication to the risk, as they are based on a snap shot which cannot be related to the RASFF database for any given time. McCracken et al (2013) declared that no *M. rosenbergii* meat samples taken from Bangladeshi farms or processors exceeded the 1.0µg/kg for SEM residues, and Tittlemier (2007) showed that out of 30 samples, only AOZ (furazolidone metabolite) occurred above the 1.0µg/kg limit (4 samples at 0.5 – 2.0 µg/kg). Swapna et al (2012) also showed Indian samples of *M. rosenbergii* and *Penaeid* shrimp to have chloramphenicol residue levels below the MRLs. The specific analytical protocols are also known to impact on results. McCracken (2013) found that SEM (nitrofuran metabolite) residues were much higher in samples of freshwater prawn with the shell left on than removed. This has consequences for differing testing procedures between member states, particularly Belgium which was highlighted by McCracken et al (2013) as testing shell-on samples as standard. 21.95% of all RASFF alerts related to antimicrobial residues were raised by Belgium. Standardisation of testing procedures plus information on the consignment size are necessary steps to allow RASFF data to be used for risk assessment purposes. Inconsistent and potentially poor EU laboratory processes may have resulted in some of the outlier data in RASFF.

For contaminants with ADIs the situation is much clearer. For example, some imported shrimps contained high levels of cadmium. Notably these are almost entirely of Australian origin and are likely mostly wild, and only relate to shrimp imported between 2004 and 2007. Nevertheless there is good evidence that Cd levels in some shrimps can exceed safe limits and consumption of only 20-30g of shrimp per day (i.e. about 1 shrimp tail per day) presents a clear risk under a worst-case scenario. However, given the low market volumes, and somewhat puzzling geographical restriction of shrimps with high Cd, such a worst case is highly improbable.

For tetracyclins, again the case is clear. Over 1kg of shrimps would have to be consumed per day in a worst contamination case scenario to present a significant risk to the consumer.

Sulphites are commonly used to prevent browning in both raw and cooked shrimps and are only a risk to a sub-population who are susceptible to sulphite-related sensitivities. However sulphites are by far the most frequently exceeded additive recorded for shrimps on RASFF. Given the increasing frequency of high sulphite levels since 2003, it seems that consumption of shrimps could significantly add to overall sulphite intake and present a risk to a section of the population. However, sulphites are allergenic and have a low ADI of 0.7 mg/kg body weight (EU 2005) and therefore there is a requirement to declare their presence (2003/89/EC). Large numbers of violations were thought to have originated from a mismatch between the levels allowed in raw (150mg/kg) compared to cooked product (50mg/kg) (Directive 92/2/EC). Although raw shrimp may have contained allowable concentrations, the levels could then be exceeded during the cooking process at another operator. Proposals were subsequently tabled and adopted to align the limit for cooked with raw shrimp (2006/52/EC). In the years following the alignment of allowable limits in different products, fewer violations were recorded overall for sulphite and most of them were based on non-declaration (2003/89/EC) rather than exceeding the limits (EU 2010). The large number of European sulphite violations recorded over the study period reflects the higher level of secondary processing in Europe.

One of the most standout results shown in Figure 1, is the number of alerts attributed to antimicrobials in wild product (as characterised by the authors), particularly in the period 2001-2003, as antimicrobials would only be expected to appear in products from farmed sources. The majority of the alerts of known antimicrobials attributed to wild product are from *Solenocera spp* originating from China with chloramphenicol residues. The explanations for the occurrence in wild shrimp are not easily explained, but all have importance for farmed shrimp production. There are three possible explanations for these positives in wild crustacea: that the antimicrobials are naturally occurring, that the wild shrimp were contaminated from shrimp farm effluents where antibiotic use was widespread or that the shrimp were farmed but have been mislabelled. If the source of antimicrobial contamination is demonstrated to be of natural origin, it then becomes much harder to manage levels within food either of wild or farmed origin. Of the 857 reported antimicrobial violations between 2000 and 2015, 103 (12.0%) were from sources characterised as wild and of these, 89.3% were due to chloramphenicol, with the rest coming from nitrofurans. No tetracycline residues were reported in wild shrimp. Saari and Peltonen (2004) showed that the nitrofuran metabolite, semicarbazide (SEM) could be found in crayfish that had never been treated with nitrofurans and a statement from Stadler et al (2004) revealed that SEM could be formed from the heat treatment of certain packaging materials. More recently it has been found that semicarbazides occur naturally in shrimp exoskeletons are a potential source of contaminated tail meat (McCracken et al 2013). There is also some evidence that chloramphenicol can occur naturally in foodstuffs, having been concentrated in the food chain. Concern over destruction of shrimp consignments, containing low-level chloramphenicol contamination, led to debate about the possibility of natural occurrence or cross- contamination. Berendsen et al (2010) showed that chloramphenicol can be synthesised naturally in soils by the bacteria *Streptomyces venezuelae*, and that this could then be taken up by plants, which may subsequently be taken up by livestock through contaminated feeds (Berendsen *et al* 2013, McEvoy 2002). Wang et al (2017) also found many fishmeal and other animal protein sources were contaminated to the point that they contained antimicrobial resistant genes. However, adulteration of marine ingredients and fraud is also a well-known occurrence in China (e.g. Yang et al 2008). However, this is unlikely to explain the presence of chloramphenicol in truly wild shrimp as they will not have been exposed to contaminated feed apart from those close to farm effluents. There is some evidence that antibiotics may occur in the marine environment, either synthesised by organisms (Ng et al 2015) or discharged from land sources. Within the marine environment, the *Streptomyces* genus of bacteria and other *actinomycetes*, that are known to be responsible for synthesising naturally occurring antibiotic compounds in the terrestrial environment, are also present, but which have yet to be fully characterised (Jensen et al 2005, Fiedler et al 2005).

However, the rapid drop in alerts in all products, including wild, from 2003, suggests that it is not due to natural occurrence. Another more likely cause of low level contamination with chloramphenicol in Chinese wild product is its use by processing workers to treat their hands (Li et al 2002) and may account for 60% of the cases of antimicrobial contamination in wild shrimp. However, this has not been widely documented.

The mislabelling of food items is widespread, evidence of which was directly reported in the media analysis part of this study. In many cases, this may be in an effort to avoid import tariffs (Johnson 2014), although other complex reasons may exist. Although intentional price fraud does undoubtedly exist, it is hypothesised that in some cases where there has been a disease problem, farmers may resort to an emergency harvest (Sahoo et al 2005) to save the rest of the crop and prevent disease spreading, perhaps after medical interventions such as the use of antibiotics having failed. The surviving crop may then enter trading networks and spot markets where it is either mistakenly or intentionally mislabelled as being from wild origin, being smaller than would normally be expected for farmed shrimp, before going to processors and export. In countries where consignments of processed shrimp may consist of produce from several small scale producers, perhaps sold through extensive trading networks and auction markets before reaching the processor, this is not inconceivable. These mixed consignments may thus contain antimicrobial residues but continue to be sold throughout the value chain as “wild” shrimp after the original mislabelling/selling has occurred.

2.1 Media Analysis

The media reports are dominated by stories around the status of wild shrimp in the North Sea (*Nephrops spp*.) and the Mediterranean (*Aristeus antennatus*) in English and Spanish language respectively. English articles are very much concerned with ever changing fishing quotas, whereas Spanish reports are often worried about the future of traditional industries. Concerns over the sustainability of local wild fisheries may result in protectionist efforts to promote them over cheaper farmed competitors (Little et al 2012), leading to distorted media coverage that, highlights health risks and environmental impacts. Despite this research demonstrating that wild shrimp had similar health concerns compared to farmed, 91.4% of media articles (N=35) were related to the health aspects of consuming farmed products and of these 75% were negative. Two of the three articles concerning consumption of wild shrimp were negative but the results show that the media are disproportionately concerned with farmed compared to wild product.

As shown in Figure 2, 43.3% of alerts were related to farmed product compared to 21.2% from wild. However, the timings of the articles closely match the time line of RASFF alerts, showing that in this respect, conventional mainstream media is quite balanced on reporting health concerns. The stories of 2002 reported the growing number of antibiotic residues found in imported shrimp and between 2009 and 2014 the number of stories had reduced to a small number, picking up on a few important cases and far fewer in proportion to violations than in 2002. The vast majority of these articles concerned the presence of residues of nitrofurans and its metabolites and a few mentioned the presence of chloramphenicol, although none of them reported contamination levels. Acute exposure is currently considered more of a risk than chronic considering the zero tolerance on presence of chloramphenicol and nitrofurans. On the basis that consumers may occasionally be exposed to chloramphenicol or nitrofuran contaminated shrimp, there could be genuine cause for concern that there will be some contaminated consignments that slip through the net and it is fair for the media to report that there is a definite risk attached. In summary, the total number of consignments is increasing while the number contaminated is decreasing. So, although the risk of consuming contaminated shrimp may be considered the same, the probability of encountering a contaminated product is reduced. However, EU standards are strict. If median levels of nitrofuran and chloramphenicol contamination reported in RASFF are considered over the eighteen years covered, an ADI of 130g would still be acceptable, which may be considered a generous portion size.

The risk to consumers depends on whether chronic or acute exposure is considered more critical. Although there were on average, less than 12 antimicrobial alerts per year for the last five years in farmed shrimp across the whole of the EU, it is not possible to calculate from the database, the proportion of tested consignments that this represents, and by extrapolation, what proportion that may be available to consumers and therefore the risk. It is, in our view, an important omission, that while the RASFF portal is transparent on the number and nature of alerts, without more knowledge of the sampling regime and the representativeness of the consignments that are tested, it is of little use for determining current risk or risk trends to consumers. The representativeness of the RASFF database could be determined by including data on the size of violating consignments that could be matched against total imports. Considering the inability to provide a definitive risk assessment from the RASFF data, the lack of any contamination level data in the media articles and that most are concerned with substances for which there is no established MRL, the best basis for comparing risk versus media claims is by comparing numbers of alerts and health related articles. However, in any case the data and mainstream media reports do not necessarily reflect the perceptions of consumers that are increasingly informed by the internet and social media (McTavish et al 2011).

The internet portrayal of farmed shrimp is very different than that present in the mainstream press (Figure 8). Sites are generally much vaguer about the risk that they are claiming and talk to a broader consumer audience, without declaring any contamination levels and rarely demonstrating any evidence at all for their claims. They may refer to ‘cocktails of chemicals’, antibiotics and pollution that have potential to cause cancer or be otherwise harmful to human health, if consumed. Often the internet behaves as an echo-chamber for the same, usually negative, views and compounds them. For example, one report aimed at US citizens (Consumer Reports 2014) entitled, “How Safe Is Your Shrimp?” was referred to several times in other web sites and blogs. Many of these blogs are highly unscientific and factually wrong, as spurious factoids are mingled with opinion. In an age where larger numbers of the lay-public increasingly feel a responsibility for their health and are turning to easily available internet-based knowledge platforms, there is a danger that more reliable institutional bases are replaced with unaccountable web-based information (McTavish et al 2011).

A lack of accountability and self-positioning of contributors as experts within a field, without any evidence of qualification is common. Sites are often linked to other internet sources, also with little epistemic merit. Frost-Arnold (2014) argued that a lack of accountability was undermining epistemic practices to the point that the internet became a poor medium for the dissemination of knowledge and Holderied-Milis (2010) went further by saying that online chat-rooms provide an environment that encourages lying. A tendency for people making internet searches to look at the first hits in a list rather than having a critical eye (McTavish et al 2011), may serve to compound the repetition of publicly accepted factoids rather than provide balanced evidence based advice. Thus, rather than empowering the public to make informed decisions, the internet repeats a narrative and narrows the scope of the discourse around a given subject. Some of the reasoning behind the repetition of misleading and out-dated information is that authors may not have access to the most recent scientific information, where information is limited or where it is available, may be beyond the skills of the lay-person to interpret such as complex issues establishing risk from some genotoxic compounds where no ADI has been set.

Generally, the aquaculture industry is poor at promoting the positive aspects of the industry, in terms of sustainability or quality of the product, with many companies adopting a defensive stance providing information on how their product is safe and that they are improving their responsible practices. In some cases retailers do not promote farmed seafood in the same way as wild product is promoted as being traditional and healthy food option. Some products may have little reference to it having been farmed but is referred to as being “responsibly sourced”. However, the evidence is that farmed product is at least as safe and healthy as wild product.

3. Conclusions

According to the number of alerts flagged within the RASFF database, the risk of encountering non-compliant shrimp is reducing. However, it is not possible to calculate the absolute risk or an ADI for shrimp based on product available to consumers because the proportion of shrimp imports that the RASFF violations represent is not available, and consequently it is concluded that the RASFF database alone is not suitable for assessing the risk associated with consuming shrimp. According to risk assessments based on the RASFF violations, consuming shrimp that is heavily contaminated i.e. above the median levels of contaminants reported in the RASFF database, is a concern to health. With the shrimp most heavily contaminated with nitrofurans this may be as little as 0.136g of shrimp per day for a 70kg adult, based on the highest level of nitrofuran metabolite residues. The highest levels of nitrofuran and chloramphenicol recorded in the RASFF database were several orders of magnitude above the median, leading us to believe this may be a recording error. However, limited peer reviewed and grey literature showed that very few shrimp samples contained contaminants which were in excess of the EU MRLs or TTCs.

The highest number of articles in main stream media related to antimicrobial contamination were in 2002, corresponding with the highest number of violations and subsequently dropping in line with violations. Subsequently, we conclude that the mainstream media has demonstrated greater accuracy in portraying health risks relative to online media. However, no article has ever reported the absolute risk in terms of the level of contamination and consequently how much shrimp can safely be consumed. Internet sites tend to repeat an established narrative of negativity around farmed shrimp. They often have no evidence or references to support their claims and do not refer to any particular contaminants or the quantities which have been observed. They are therefore unrepresentative of the risk that is related to consuming shrimp. It is also concluded that the shrimp and aquaculture industry as a whole is poor in communicating the benefits of their products and usually adopt a damage limitation exercise in response to the negative narrative that pervades the internet.

4. Acknowledgements

This study was funded entirely by the Seafood Importers' and Producers' Alliance (SIPA).

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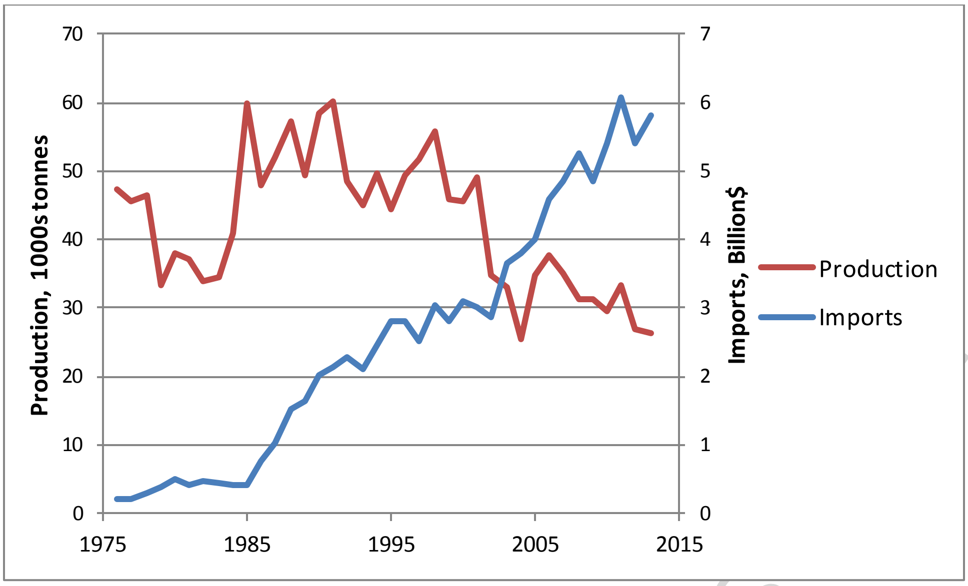
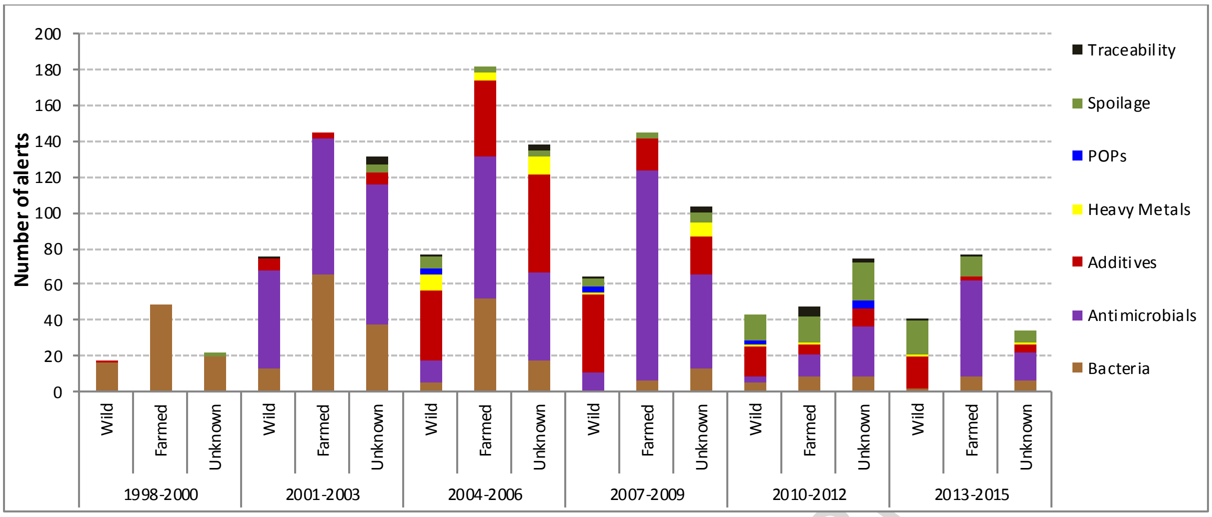
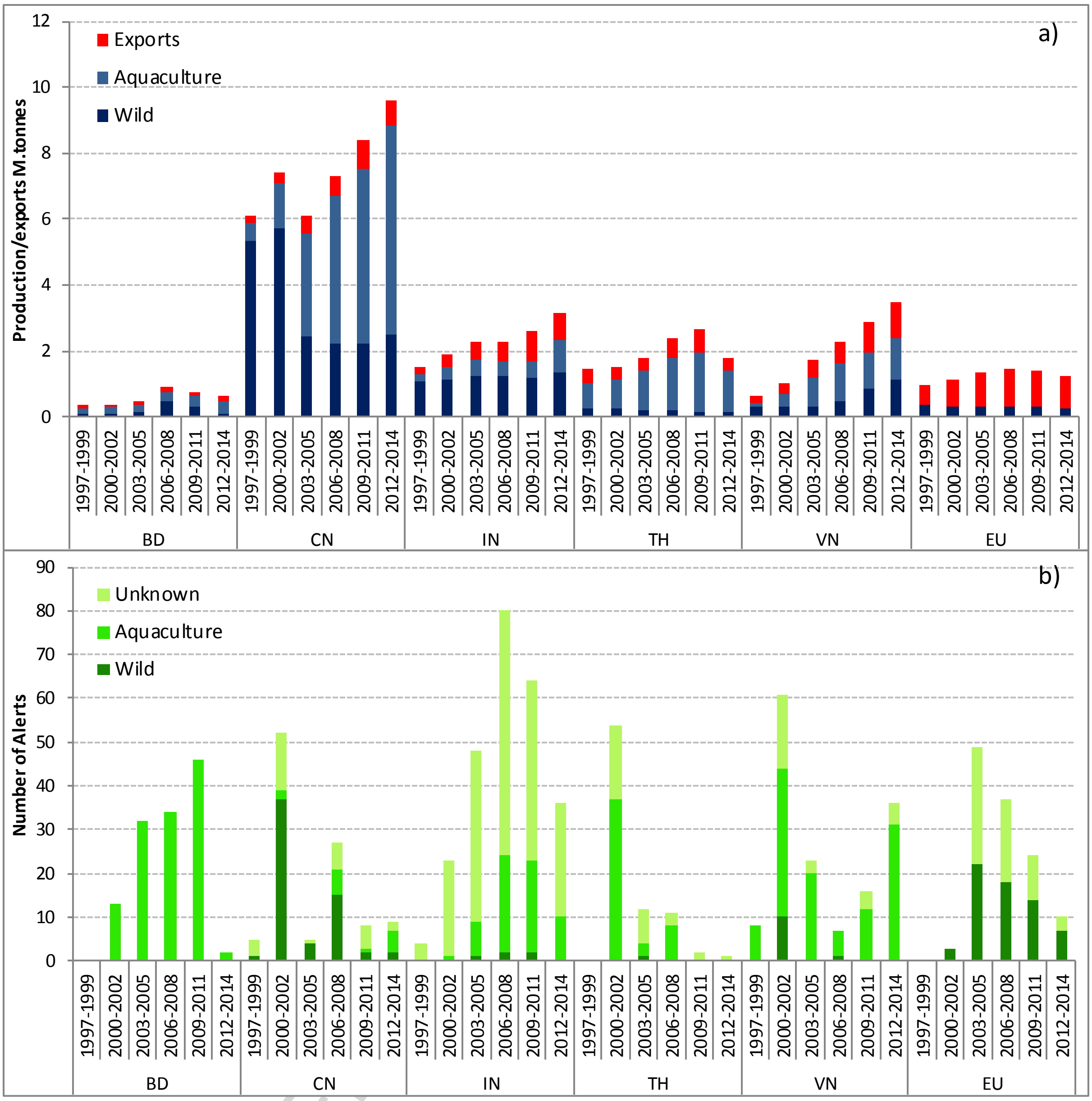

70
60
50
40
30
20
10
0
7
6
5
4
3
2
1
0
1975
1985
1995
2005
2015
Production, 1000s tonnes
Imports, Billion$
Production
Imports

Fig1



200
180
160
140
120
100
80
60
40
20
0
Number of alerts
Wild
Farmed
Unknown
1998-2000
2001-2003
2004-2006
2007-2009
2010-2012
2013-2015
Traceability
Spoilage
POPs
Heavy Metals
Additives
Antimicrobials
Bacteria

Fig 2.



a)
Exports
Aquaculture
Wild
Production/exports M.tonnes
12
10
8
6
4
2
0
1997-1999
2000-2002
2003-2005
2006-2008
2009-2011
2012-2014
BD
CN
IN
TH
VN
EU
b)
Unknown
Aquaculture
Wild
Number of Alerts
90
80
70
60
50
40
30
20
10
0

Fig3

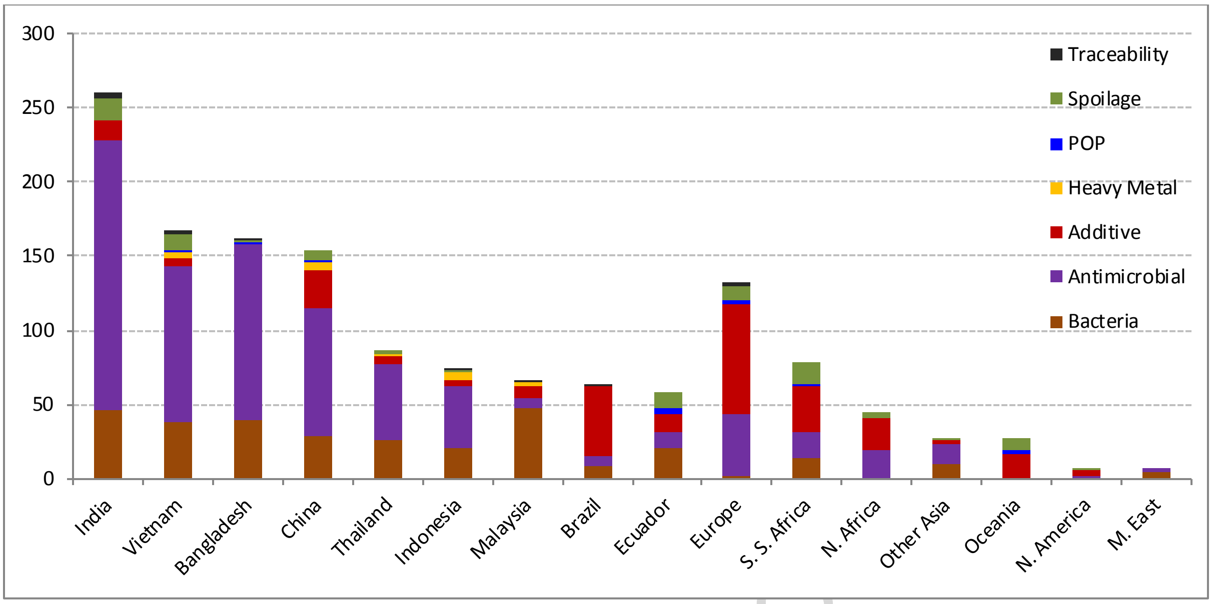
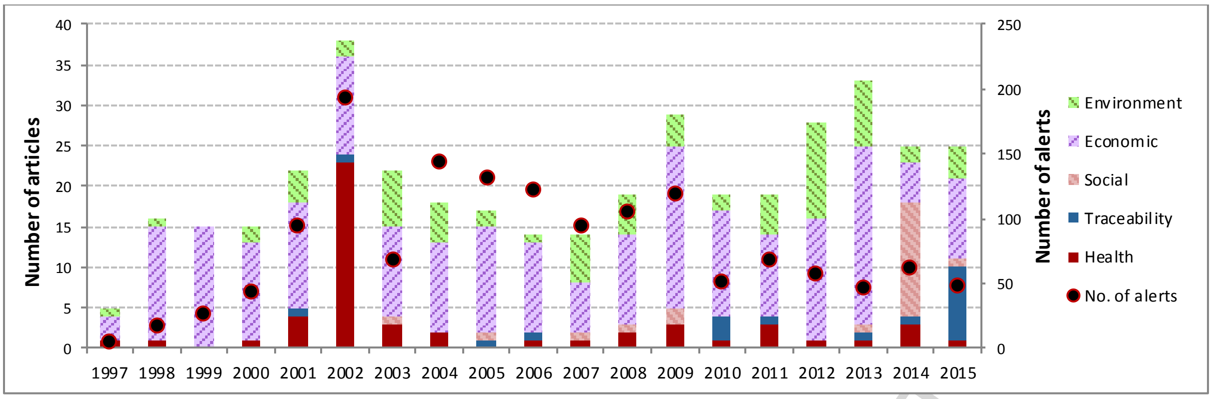

300
250
200
150
100
50
0
Traceability
Spoilage
POP
Heavy Metal
Additive
Antimicrobial
Bacteria
India
Vietnam
Bangladesh
China
Thailand
Indonesia
Malaysia
Brazil
Ecuador
Europe
S.S. Africa
N. Africa
Other Asia
Oceania
N. America
M. East

Fig4



Number of articles
Number of alerts
40
35
30
25
20
15
10
5
0
250
200
150
100
50
0
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Environment
Economic
Social
Traceability
Health
No. of alerts

Fig 5

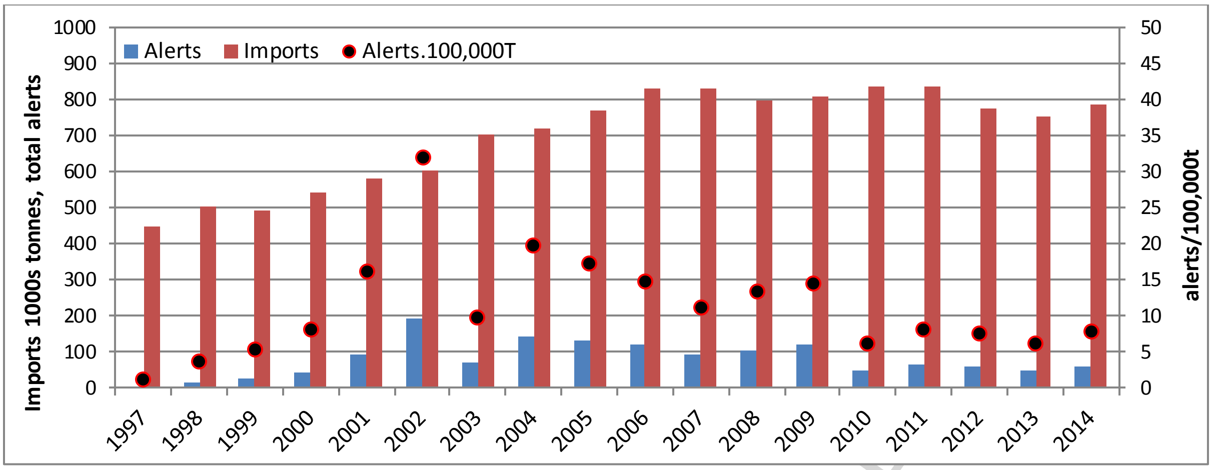
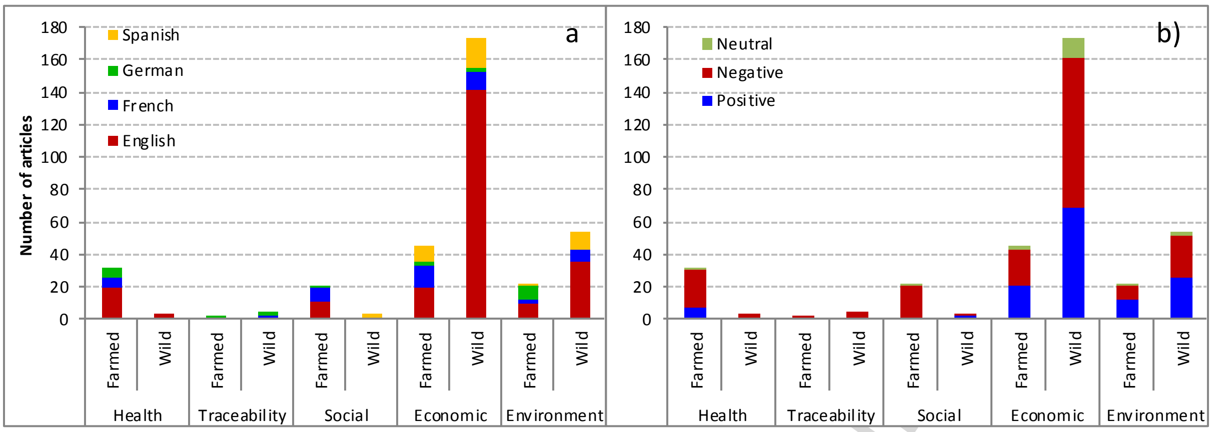
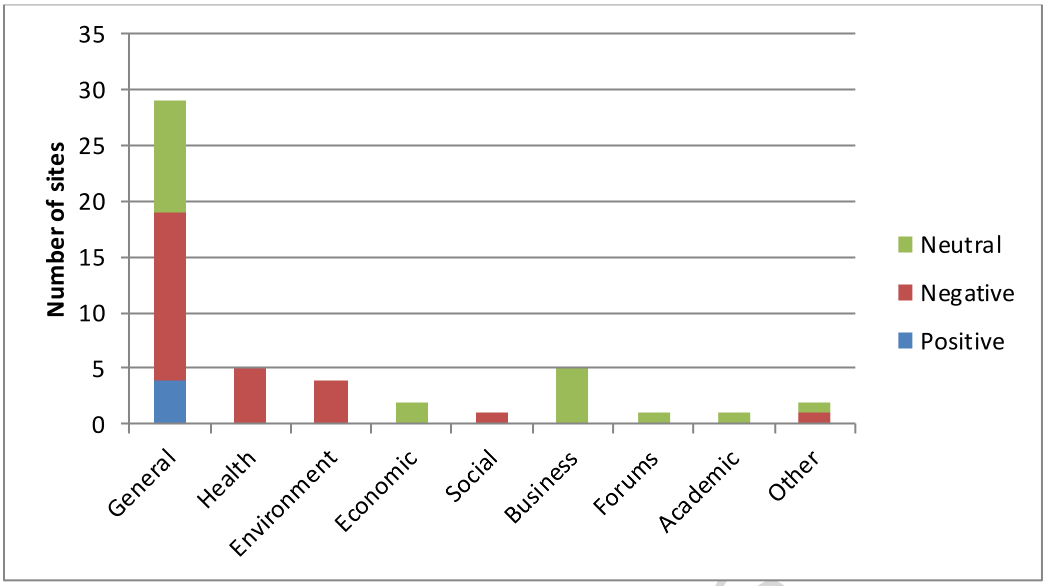

Alerts
Imports
Alerts.100,000T
Imports 1000s tonnes, total alerts
alerts/100,000t
1000
900
800
700
600
500
400
300
200
100
0
50
45
40
35
30
25
20
15
10
5
0
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014

Fig 6



a
Spanish
German
French
English
Number of articles
180
160
140
120
100
80
60
40
20
0
Farmed
Wild
Health
Traceability
Social
Economic
Environment
b)
Neutral
Negative
Positive

Fig 7



35
30
25
20
15
10
5
0
Number of sites
General
Health
Environment
Economic
Social
Business
Forums
Academic
Other
Neutral
Negative
Positive

Fig 8

Highlights

- The reduction in number of RASFF alerts compared to increased supply suggests the overall risk of consuming shrimp in the EU has reduced over the lifetime of the alerts system.
- The coverage in the mainstream media has generally reflected the level of risk of consuming farmed shrimp
- Social media and internet sources repeat established negative narratives which perpetuate a bad image surrounding imported farmed aquatic produce
- The RASFF alerts system is not representative of products available to consumers and therefore not adequate to establish ADIs of those products.

Shrimp Origin[a]	Contaminant[b]	ADI[c]	Mean RASSF[d]	Median RASSF[d]	Max RASSF[d]	Max intake (g) Mean[e]	Max intake (g) Median[e]	Max intake (g) Max[e]
Farmed	Chloramphenicol	RPA=0.3 µg/kg	0.0182	0.0006	0.91	24.8	750.0	0.495
Wild			0.0534	0.0024	1.4	8.4	187.5	0.321
Unknown			0.0761	0.0006	1.2	5.9	750.0	0.375
Farmed	Nitrofurans	RPA=1 µg/kg	0.1587	0.0045	11	9.5	333.3	0.136
Wild			0.1343	0.0115	1	11.2	130.4	1.500
Unknown			0.0194	0.0038	1.2	77.1	394.7	1.250
Farmed	Tetracyclins	ADI=0.03 mg/kg body weight	0.2139	0.158	2.065	9819.3	13291.1	1016.95
Wild			N/A		N/A	N/A	N/A	N/A
Unknown			0.2107	0.21	0.382	9966.8	10000.0	5497.38
Farmed	Cadmium	PTMI=25 µg/kg body weight	1.1400	0.86	1.8	51.2	67.8	32.407
Wild			1.3054	0.96	2.5	44.7	60.8	23.333
Unknown			1.0752	0.9	2.5	54.3	64.8	23.333
Farmed	Sulphite	ADI= 0.7 mg/kg body weight	169.19	167.33	435	289.6	292.8	112.64
Wild			304.98	258	2327	160.7	189.9	21.06
Unknown			172.72	147.5	511	283.7	332.2	95.89

Table 1

Figure 1 Trends in EU28 shrimp fishery production volume and value of imported shrimp trade within and to the EU (data from FAO fishstat 2016).

Figure 2 Frequency of RASFF alerts by contaminant type in EU imports of farmed and wild shrimp and prawns, 1998 - 2015

Figure 3 a) Production and total exports from aquaculture and fishery shrimp and prawns against b) number of alerts for selected countries/regions. Bangladesh (BD), China (CN), India (IN), Thailand (TH), Vietnam (VN), Europe (EU). Note: Europe refers to the geographical area and includes countries outside the trading block of the EU. Production and trade data from FAO FIshstat (2016).

Figure 4. Total number of RASFF alerts from shrimp and prawn imports by country/region according to violation classification from 1997 to 2015.

Figure 5. Total number of European media articles (English, French, Spanish and German) concerning "shrimp" and translations of by category, compared to total RASFF alerts from 1997 to 2015

Figure 6. Number of RASFF alerts for shrimp and prawns compared to EU import volumes, 1997 - 2013

Figure 7 Number of European media articles concerning farmed and wild shrimp (and equivalents in 4 languages) for five different issues a) by different European languages and b) according to partiality. Articles which could not be designated to farmed or wild production were omitted (1997 - 2015).

Figure 8 Internet assessment and categorisation of first 50 sites found after a search on "farmed shrimp"