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Hazards in Seafood Notified in the Rapid Alert System for Food and Feed (RASFF) in 1996–2020

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Abstract: Seafood covering fish, crustaceans, molluscs and cephalopods is broadly recognised for its nutritional value and popularity, but it can pose some hazards to health to the potential consumer. The aim of the study was to analyse Rapid Alert System for Food and Feed (RASFF) notifications for seafood over the period 1996–2020 by hazard, year, product, notifying country, country of origin, notification type, notification basis, distribution status and action taken. The research applied cluster analysis using the joining and two-way joining methods. The main reported hazards were micro-organisms (*Listeria*, *Salmonella*, *Escherichia coli*, *Vibrio*, norovirus, mesophiles, Enterobacteriaceae and histamine), heavy metals (mercury and cadmium), veterinary products (nitrofuran, chloramphenicol and leucomalachite green), controls (poor temperature control and hygienic state), parasites (*Anisakis*) and additives/allergens (sulphite). The reported seafood products originated mainly from European and Asian countries and were notified on the basis of official or border controls, respectively. In order to minimize or eliminate risks, it is important to have the right activity of control authorities, appropriate legislation at the European and national levels and awareness at the different stages of the food chain.

Keywords: cluster analysis; European Union; food safety; RASFF; seafood hazards

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1. Introduction

Seafood is broadly known worldwide for its high nutritional value and growing popularity among consumers. It is consumed in various forms, i.e., as fresh products, eaten raw or minimally processed, as well as salted, smoked, cured, canned and ready-to-eat [1]. Seafood can include fish, crustaceans, molluscs and cephalopods.

Due to the widespread consumption of seafood, its safety for consumers is of paramount important. Meanwhile, in the European Rapid Alert System for Food and Feed (RASFF), designed for the swift exchange of information on food posing a risk to public health, notifications relating to seafood products account for as much as about 17% of all notifications.

1.1. Characteristics of the RASFF

1.1.1. Basis for the Functioning of the System

The RASFF was established in 1979, but now operates under the Regulation (EC) No 178/2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety [2]. The system allows information to be shared (sent, received and responded to) between its members, namely the 27 countries of the European Union (EU), the European Commission, the European Food Safety Authority (EFSA), the European Free Trade Association Surveillance Authority (ESA), Norway, Iceland, Liechtenstein and Switzerland. Food or feed inspectors control the product on the market or at the border and, if necessary, also take samples and receive test results from the laboratory. If the product is non-compliant, it is reported to the national system. The surveillance authority then decides whether the issue falls under the RASFF and forwards it to the national RASFF contact point. The contact point in turn verifies the notification and transmits it to the European Commission using the appropriate form.

1.1.2. Types of Notifications

There are four types of notifications in the RASFF (alert, information, border rejection and news). Alert notifications are sent if food or feed poses a serious health risk on the market and rapid action is required. The system member who identifies the problem takes appropriate action (e.g., a withdrawal from the market) and triggers the alert. The purpose of this kind of notification is to provide all RASFF members with information so that they can check whether the product is on their market and initiate relevant measures. Information notifications are used if a risk has been identified in a food or feed placed on the market, but other RASFF members do not need to take rapid action. This is what is done for a product that has not reached their market, is no longer on their market or the nature of the risk does not require rapid action. Border rejections can refer to consignments that have been tested and rejected at the external borders of the EU (and more broadly the European Economic Area—EEA) after a health risk has been detected. Notifications are sent to all EEA border posts to reinforce controls and ensure that rejected products do not pass through another border post. Any other information relating to food or feed safety that may be of interest to the control authorities is reported under the heading "News" [3].

1.2. Product and Hazard Categories Related to the Seafood in the RASFF

Table 1 shows the number of notifications and their percentage for seafood groups and product categories reported in the RASFF in 1979–2020 (some of them are already obsolete). They are ordered from largest to smallest number of notifications in particular groups of products and within these groups. Due to rounding to the first decimal place, the percentages in the groups and the sum of the percentages in the categories may differ slightly.

Table 1. The number of notifications and their percentage for seafood groups and product categories reported in the RASFF in 1979–2020.

Group of Products	Number	Percentage	Product Category	Number	Percentage
Fish	7637	10.0%	Fish and fish products	7448	9.8%
			Wild caught fish and products thereof (other than crustaceans and molluscs) *	141	0.2%
			Farmed fish and products thereof (other than crustaceans and molluscs) *	48	0.1%
Crustaceans	2625	3.4%	Crustaceans and products thereof	2441	3.2%
			Farmed crustaceans and products thereof *	93	0.1%
			Wild caught crustaceans and products thereof *	91	0.1%
Molluscs	1986	2.6%	Bivalve molluscs and products thereof	1330	1.7%
			Molluscs and products thereof *	656	0.9%
Cephalopods	561	0.7%	Cephalopods and products thereof	561	0.7%
Seafood in total				12,809	16.8%
Other food in total				63,475	83.2%
Total				76,284	100.0%

Note: * Obsolete product category.

Figures 1 and 2 (cumulative stratified charts) present the number of notifications by groups of products and hazards (respectively) concerning seafood reported in the RASFF in 1979–2020. As notifications were made in 28 hazard categories, they were grouped together.

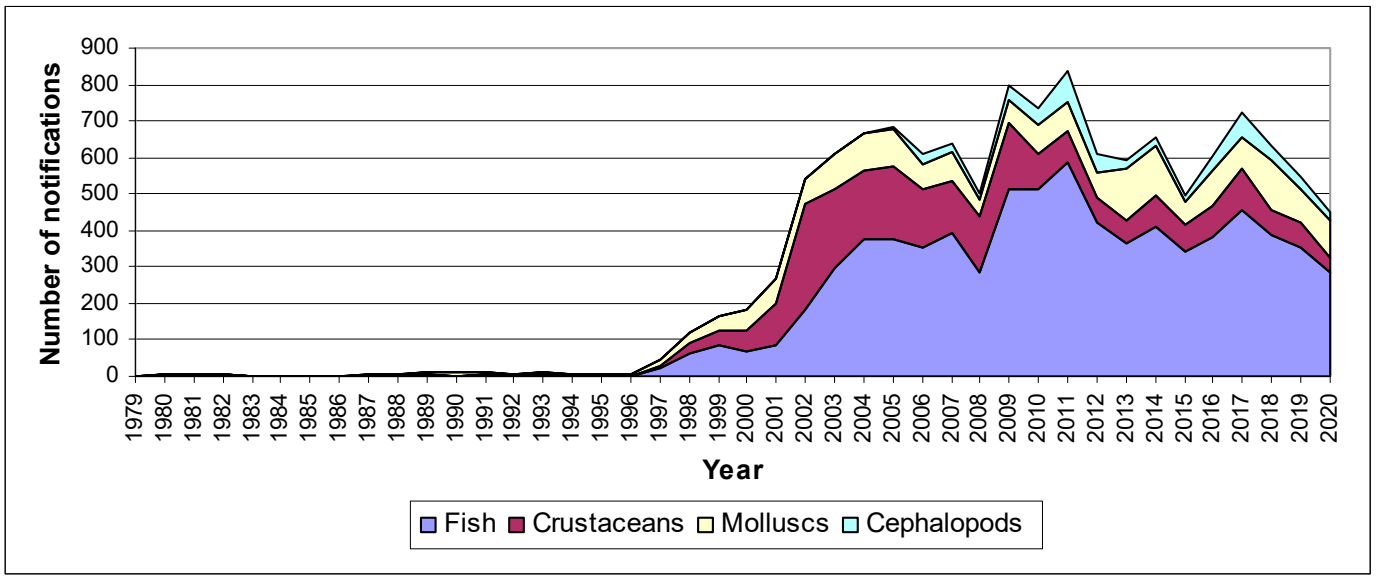

Figure 1. Number of notifications by groups of products concerning seafood reported in the RASFF in 1979–2020.

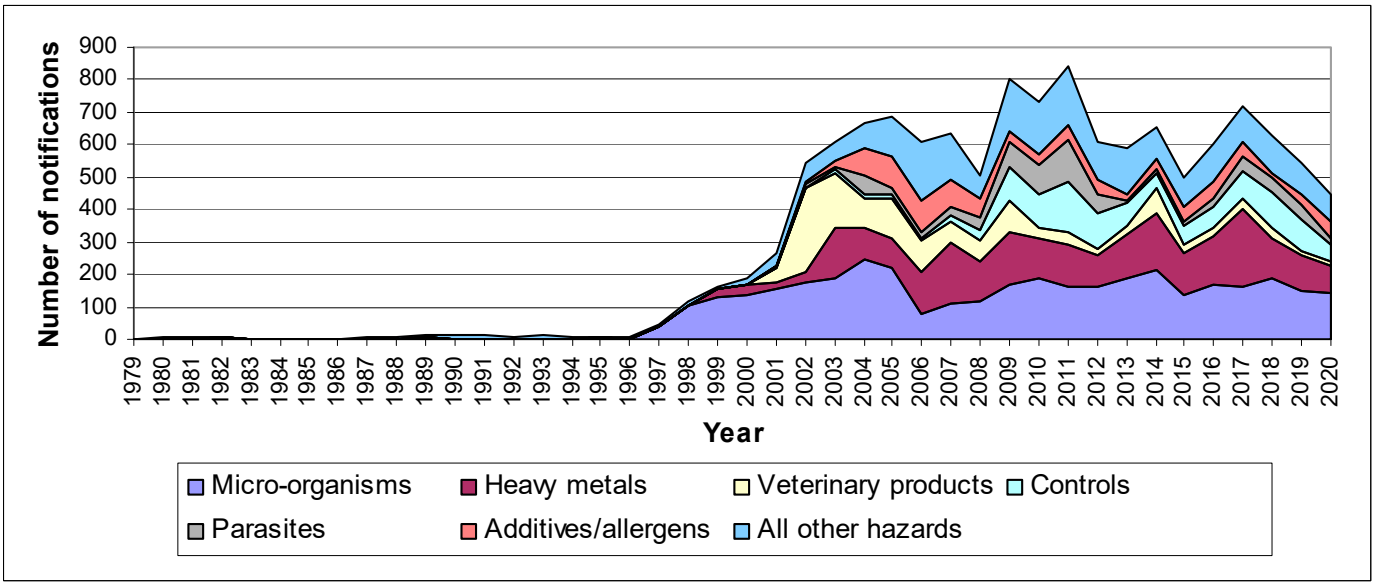

Figure 2. Number of notifications by groups of hazards concerning seafood reported in the RASFF in 1979–2020.

Of particular attention is the significant number of notifications concerning fish (for groups of products) and micro-organisms (including also microbial and biological contaminants), and heavy metals (for groups of hazards). It should also be pointed out that notifications on seafood have only been noticeable since 1986, with the highest number reported between 2009 and 2011 (over 700), then declining significantly, with around 500 notifications in 2019–2020.

It is also worth noting some distinct increases in the number of notifications seen in Figures 1 and 2. They mainly related to the presence of veterinary products in: Fish from China in 2002 and from Taiwan in 2003, as well as in crustaceans from China, India, Thailand and Vietnam in 2002 and from Bangladesh in 2009. Heavy metals were reported in more in fish from Singapore in 2003 and in crustaceans from France in 2009. For molluscs, however, the increase was related to notifications for micro-organisms. In 2013, it concerned products from France, Spain, Turkey and Vietnam, and in 2018, products from France and

Spain. The increases in the number of notifications in the RASFF may also have been influenced by the introduction of border rejections since 2008, as well as the dividing of information notifications into two subtypes (information for attention and information for follow-up) since 2011 [4].

Seafood notifications are not discussed in detail in the annual RASFF reports. They only mention hazards reported against product categories involving seafood for the year covered by the annual report in question. More detailed analyses are included in the researchers' articles, but these refer only to several years or certain products. Therefore, the aim of the study was to analyse RASFF notifications for seafood over the period 1996–2020 by hazard, year, product, notifying country, country of origin, notification type, notification basis, distribution status and action taken.

2. Materials and Methods

2.1. Data

2.1.1. Data Pre-Processing

Data was sourced from the RASFF notifications pre-2021 public information database [4] and covered product categories including seafood, namely cephalopods, crustaceans, fish and molluscs (see Table 1). It should also be added that the RASFF database currently maintained by the European Commission does not contain historical data, but only data since 2000.

The detailed product names varied widely and therefore needed to be processed in the Microsoft Excel (Microsoft Corporation, Redmond, DC, USA) using the filtering and vertical look up:

- the method of preservation of the food was omitted (e.g., frozen, chilled, dried, smoked, salted, cooked, baked, cream, paste, sauce);
- type/part of product was omitted (e.g., claws, sticks, fillets);
- species was unified (e.g., tiger shrimps changed to shrimps, Atlantic cod to cod);
- if only a word "fish", "seafood", Latin name was given as the product, the name of the species was not clearly defined, the species was rare, product consisted of several species, it was changed to "(other product)".

2.1.2. Hazards Analysed

It was adopted that only notifications reported between 1996 and 2020 (the 25-year period) would be examined. Due to the small number of notifications, studying earlier years would not be meaningful (see Figures 1 and 2) and would not contribute much to the study, while their removal will facilitate the interpretation of the results. Due to the very diverse nature of the hazards (252 hazard types), only hazards with more than 100 notifications were selected for detailed study. These 25 hazards that covered a total of 10,551 (83%) notifications and also other hazards reported in 1996–2020 were presented in Table 2 (from largest to smallest number of notifications in particular groups of hazards and within these groups, with a few exceptions).

The data was processed in Microsoft Excel using filtering, pivot tables, sub-totals, transposition and data reorganisation with extracting the following variables: Hazard, hazard category, year, product, notifying country, country of origin, notification type, notification basis, distribution status and action taken. For the variable notification type, the values "information for attention" and "information for follow-up" have been changed to the value "information" to align the name throughout the period considered. In the case of variables, hazard category, hazard, notification basis, distribution status and action taken empty cells (no textual value) have been filled with the phrase "(not specified)" and if there was no notification the value "0" was entered. For the variables: product, country of origin, and action taken, the number of series of values was limited to the 30 with the highest sum (due to the low readability of results on charts with a larger number of values).

Table 2. Number of notifications on the 25 most frequently reported hazards and other hazards in seafood reported in the RASFF in 1996–2020.

Group of Hazards	Number	Percentage	Hazard	Number	Percentage	Hazard Category (Number)
Micro-organisms	3501	27.6%	*Listeria*	807	6.4%	Pathogenic micro-organisms (800), Microbial contaminants (other) (7)
			Salmonella	525	4.1%	Pathogenic micro-organisms
			Escherichia coli	494	3.9%	Microbial contaminants (other) (493), Pathogenic micro-organisms (1)
			Vibrio	459	3.6%	Pathogenic micro-organisms
			Norovirus	282	2.2%	Pathogenic micro-organisms
			Mesophiles	122	1.0%	Microbial contaminants (other)
			Enterobacteriaceae	103	0.8%	Microbial contaminants (other)
			Histamine	709	5.6%	Biological contaminants (other)
Heavy metals	2518	19.8%	Mercury	1763	13.9%	Metals
			Cadmium	755	5.9%	Metals
Veterinary products	1049	8.3%	Nitrofuran (metabolite)	681	5.4%	Residues of veterinary medicinal products
			Chloramphenicol	254	2.0%	Residues of veterinary medicinal products
			Leucomalachite green	114	0.9%	Residues of veterinary medicinal products
Controls	967	7.6%	Poor temperature control	806	6.3%	Poor or insufficient controls
			Poor hygienic state	161	1.3%	Poor or insufficient controls
Parasites	599	4.7%	*Anisakis*	599	4.7%	Parasitic infestation
Additives/allergens	535	4.2%	Sulphite	535	4.2%	Food additives and flavourings (441), Allergens (94)
Other hazards above 100 notifications	1382	10.9%	Carbon monoxide	283	2.2%	Composition
			Benzo(a)pyrene	202	1.6%	Environmental pollutants
			Diarrhoeic Shellfish Poisoning (DSP) toxins	187	1.5%	Natural toxins (other)
			Organoleptic characteristics	173	1.4%	Organoleptic aspects
			Spoilage	107	0.8%	Organoleptic aspects
			Health certificate(s)	168	1.3%	Adulteration/fraud
			Packaging	134	1.1%	Packaging defective/incorrect
			Foodborne outbreak	128	1.0%	Not determined/other
All the above 25 hazards in total				10,551	83.0%	
All other hazards in total				2156	17.0%	
Total				12,707	100.0%	

2.2. Methods

The overall research (covering all 12,707 notifications) was concerned with identifying the most frequent values for each variable, i.e., product, notifying country, country of origin,

notification type, notification basis, distribution status and action taken, and the results are shown in Table 3.

The data was then transferred to the source tables in Statistica 13.3 (TIBCO Software Inc., Palo Alto, CA, USA) and subjected to cluster analysis (one of the multivariate exploratory techniques). By using cluster analysis, data can be organised into meaningful structures whose elements are similar to each other.

Table 3. Number of notifications on seafood reported in the RASFF in 1996–2020 by variable.

Variable	Values (Notifications)
Product	Shrimps (1651), Tuna (1275), Swordfish (1216), Salmon (693), Mussels (591), (Other product) (580), Prawns (533), Clams (517), Squid (419), Mackerel (314), Oysters (301), Shark (301), Hake (280), Panga (252), Sardines (236), Crab (235), Octopus (228), Cuttlefish (219), Other (3446)
Notifying country	Italy (4346), Spain (2021), France (975), United Kingdom (953), Germany (940), Netherlands (463), Belgium (435), Norway (298), Denmark (281), Greece (281), Poland (225), Portugal (212), Other (1277)
Country of origin	Spain (1435), Vietnam (1096), France (735), India (688), China (604), Morocco (459), Thailand (455), Indonesia (433), Netherlands (374), Italy (322), Denmark (308), Poland (259), United Kingdom (250), Senegal (231), Bangladesh (222), Chile (220), Tunisia (220), Other (4396)
Notification type	Information (6233), Alert (3632), Border rejection (2842)
Notification basis	Official control on the market (4703) Border control-consignment detained (4095), (Not specified) (1332), Border control-consignment released (1142), Company's own check (748), Food poisoning (377), Consumer complaint (240), Other (70)
Distribution status	No distribution (2327), (Not specified) (2295), Distribution restricted to notifying country (1592), Distribution on the market (possible) (1478), Product not (yet) placed on the market (1312), Distribution to other member countries (1082), Product (presumably) no longer on the market (935), Other (1686)
Action taken	Re-dispatch (1932), Destruction (1750), Withdrawal from the market (1612), Import not authorised (1412), (Not specified) (1204), Official detention (762), Recall from consumers (546), Seizure (492), Product recall or withdrawal (479), No action taken (391), Informing authorities (382), Informing recipient(s) (279), No stock left (238), Re-dispatch or destruction (237), Return to consignor (233), Other (758)

2.2.1. Joining Cluster Analysis

In the preliminary research (using the joining cluster analysis) examined, the similarities in 12,707 notifications reported within particular variables, i.e.,: year, product, notifying country, country of origin, notification type, notification basis, distribution status and action taken–particular values in columns of source tables, combined in relation for hazards–in rows (an analysis of the similarity between hazards and hazard categories would not be justified). The joining cluster analysis (tree clustering) was applied using the following settings: Amalgamation (linkage) rule–Ward's method, distance measure–Euclidean distances and vertical icicle charts. The Ward's method uses an analysis of variance to evaluate the distances between clusters, attempting to minimize the sum of the squares of any two (hypothetical) clusters that can be created at each step. This method generates clusters of small size (cluster flattening), and it is considered to be very efficient. In turn, the Euclidean distance is the geometric distance in the multidimensional space [5]. Results of joining cluster analysis were presented in Supplementary Materials in Figure S1 in panels a–h (for particular variables), i.e., 8 charts, and summarized in Table 4.

2.2.2. Two-Way Joining Cluster Analysis

More detailed research covering 10,551 notifications (i.e., relating to the 25 most frequently reported hazards identified in Table 2) was carried out using two-way joining cluster analysis. The following variables were taken into account: Product, notifying country, country of origin, notification type, notification basis, distribution status and

action taken (particular values in columns of source tables) and year (in rows). The two-way joining cluster analysis can be used when it can be expected that the values in the rows and columns can simultaneously reveal significant cluster patterns. Although the cluster structure in this method is not homogeneous by nature, it can be considered a powerful data analysis tool [5]. The similarities in the notifications were shown in the contour/discrete charts by colored squares: green, yellow, orange, red and brown, with the largest clusters expressed by the latter coolers. To increase the readability of the chart, the dark green color (occupying the largest part of the chart but expressing no or little clustering) has been changed to white. Results of two-way joining cluster analysis were presented in Supplementary Materials in Figures S2–S26 (25 hazards) in panels a–g (for particular variables), i.e., 175 charts, and summarized in Tables 5–11.

Table 4. Results of joining cluster analysis related to notifications on seafood in the RASFF in 1996–2020.

Variable (Figure)	Clusters and Subclusters
Year (Figure S1a)	First: 1996–1997, 1998–1999, 2000, 2001 Second: 2002–2003, 2004–2005, 2007–2008, 2006, 2009 Third: 2012–2019, 2010, 2011, 2018, 2020 Fourth: 2015–2016, 2013, 2014, 2017
Product (Figure S1b)	First: swordfish Second: salmon–tuna Third: clams–mussels Fourth: cuttlefish–octopus, crab, squid Fifth: hake–mackerel, oysters Other products
Notifying country (Figure S1c)	First: Italy Second: Belgium–Netherlands, Germany, United Kingdom Third: Austria–Poland, Denmark–Sweden, Greece–Portugal Other notifying countries
Country of origin (Figure S1d)	First: Spain Second: Bangladesh–Thailand, China–Morocco, Indonesia–Portugal, France, India, Italy, Vietnam Third: Denmark–Germany, Poland Fourth: Argentina–United States, Brazil–Ecuador, Chile–Senegal, Sri Lanka Other origin countries
Notification type (Figure S1e)	First: border rejection Second: alert–information
Notification basis (Figure S1f)	First: official control on the market–border control-consignment detained Second: company's own check–food poisoning, border control-consignment released, (not specified) Other notification basis
Distribution status (Figure S1g)	First: distribution on the market (possible)–distribution restricted to the notifying country, distribution to other member countries–product (presumably) no longer on the market, no distribution–product not (yet) placed on the market, (not specified) Second: no distribution from notifying country–information on distribution not (yet) available, product past use-by date Other distribution status
Action taken (Figure S1h)	First: destruction–re-dispatch, (not specified)–official detention, import not authorised, withdrawal from the market Other action taken

Table 5. Results of two-way joining cluster analysis related to notifications on micro-organisms in seafood in the RASFF in 1996–2020.

	Hazard/Variable	Value (Figure)
Listeria	Year	1999, 2001–2002, 2004–2005, 2009–2018, 2020
	Product	Salmon (1999, 2001–2002, 2004–2005, 2009–2018, 2020) (Figure S2a)
	Notifying country	Austria (1999), Italy (2002, 2004–2005, 2009, 2011, 2014) (Figure S2b)
	Country of origin	Denmark (2001, 2004–2005, 2011), Germany (1999, 2001, 2004), Netherlands (2005), Poland (2009–2011, 2014–2015, 2020), Vietnam (2005, 2009–2010) (Figure S2c)
	Notification type	Alert (2004–2005, 2014, 2018, 2020), information (2009–2010, 2014) (Figure S2d)
	Notification basis	(Not specified) (1999, 2001–2002), official control on the market (2004–2005, 2009–2011, 2014–2018, 2020) (Figure S2e)
	Distribution status	(Not specified) (1999, 2001–2002, 2004), distribution on the market (possible) (2005, 2009–2010), distribution to other member countries (2020), information on distribution not (yet) available (2011), no distribution (2009), no distribution from notifying country (2014), product past use-by date (2005) (Figure S2f)
	Action taken	(Not specified) (2001–2002), destruction (2004–2005), official detention (2005), product recall or withdrawal (2005), re-dispatch (2009), recall from consumers (2011–2012, 2016), seizure (1999, 2005), withdrawal from the market (2009–2011, 2013–2015, 2017–2018, 2020) (Figure S2g)
Salmonella	Year	1998, 2000–2001, 2003–2005, 2007, 2013, 2017–2019
	Product	(Other product) (2003), clams (2013), mussels (2004, 2007, 2017–2019), octopus (2005, 2018), perch (1998), shrimps (2000–2001) (Figure S3a)
	Notifying country	France (1998, 2000), Italy (1998, 2000–2001, 2003–2005, 2007, 2018–2019), Norway (2007), Portugal (2013) (Figure S3b)
	Country of origin	Indonesia (2012), Spain (2007), Vietnam (2009, 2013) (Figure S3c)
	Notification type	Alert (2007), border rejection (2013), information (1998, 2000–2001, 2003–2004, 2017–2019) (Figure S3d)
	Notification basis	(Not specified) (1998, 2000–2001), border control-consignment detained (2003–2005, 2013), official control on the market (2007, 2019) (Figure S3e)
	Distribution status	(Not specified) (1998, 2000–2001, 2003–2004), no distribution (2005), product (presumably) no longer on the market (2019) (Figure S3f)
	Action taken	Import not authorised (1998, 2000–2001), re-dispatch (2004–2005, 2012–2013) (Figure S3g)
Escherichia coli	Year	2004, 2007–2010, 2013–2014, 2016–2019
	Product	Clams (2007–2010, 2013–2014), mussels (2004, 2013–2014, 2016–2019) (Figure S4a)
	Notifying country	Italy (2004, 2007–2010, 2013–2014, 2016–2019) (Figure S4b)
	Country of origin	France (2016–2018), Italy (2008, 2010, 2013–2016, 2018–2019), Spain (2013, 2016, 2018), Turkey (2009–2010, 2013) (Figure S4c)
	Notification type	Alert (2010, 2013, 2016, 2018), Information (2004, 2009–2010, 2013–2014, 2016, 2018–2019) (Figure S9d)
	Notification basis	Official control on the market (2008–2010, 2013–2014, 2016–2019) (Figure S4e)
	Distribution status	(Not specified) (2004), distribution on the market (possible) (2010), distribution to other member countries (2013, 2017–2019), product (presumably) no longer on the market (2013–2014, 2016–2019), product not (yet) placed on the market (2013) (Figure S4f)
	Action taken	(Not specified) (2004), destruction (2013), no action taken (2014), physical/chemical treatment (2016), withdrawal from the market (2010, 2013–2014, 2016–2019) (Figure S4g)

Table 5. *Cont.*

Hazard/Variable		Value (Figure)
Vibrio	Year	1999–2005, 2008
	Product	Shrimps (1999–2005, 2008) (Figure S5a)
	Notifying country	France (1999), Italy (2000–2004), Norway (2000–2002, 2004–2005) (Figure S5b)
	Country of origin	Bangladesh (2001, 2005), China (1999), India (2001–2002, 2008), Indonesia (2000–2001, 2003), Malaysia (2001–2004), Thailand (1999–2001), Vietnam (2002, 2004) (Figure S5c)
	Notification type	Alert (2001–2002, 2004–2005), border rejection (2008), information (1999–2005) (Figure S5d)
	Notification basis	(Not specified) (1999–2002), Border control-consignment detained (2003–2004, 2008), official control on the market (2004–2005) (Figure S5e)
	Distribution status	(Not specified) (1999–2004) (Figure S5f)
	Action taken	Destruction (2004), import not authorised (1999–2002), prohibition to trade–sales ban (2005), re-dispatch (2003–2004) (Figure S5g)
Norovirus	Year	2013–2014, 2018, 2020
	Product	Clams (2014), oysters (2013, 2018, 2020) (Figure S6a)
	Notifying country	Italy (2013–2014, 2018, 2020), Spain (2014) (Figure S6b)
	Country of origin	France (2018, 2020), Vietnam (2014) (Figure S6c)
	Notification type	Alert (2013, 2018, 2020), border rejection (2014), information (2013, 2018, 2020) (Figure S6d)
	Notification basis	Border control-consignment detained (2014), food poisoning (2013, 2018, 2020), official control on the market (2018, 2020) (Figure S6e)
	Distribution status	Distribution to other member countries (2020), product (presumably) no longer on the market (2018, 2020), product not (yet) placed on the market (2014) (Figure S6f)
	Action taken	(Not specified) (2020), official detention (2018), re-dispatch (2014), withdrawal from the market (2013–2014, 2018) (Figure S6g)
Mesophiles	Year	2001–2003, 2005
	Product	Mussels (2003), octopus (2003), prawns (2003), shrimps (2001–2002), squid (2005) (Figure S7a)
	Notifying country	Spain (2001–2003) (Figure S7b)
	Country of origin	Chile (2003), Morocco (2003) (Figure S7c)
	Notification type	Information (2001–2003, 2005) (Figure S7d)
	Notification basis	(Not specified) (2001–2002), border control-consignment detained (2003) (Figure S7e)
	Distribution status	(Not specified) (2001–2003) (Figure S7f)
	Action taken	Import not authorised (2001–2002), re-dispatch (2003, 2005) (Figure S7g)
Enterobacteriaceae	Year	1999, 2005
	Product	Hake (1999), panga (2005) (Figure S8a)
	Notifying country	Spain (1999, 2005) (Figure S8b)
	Country of origin	Namibia (1999), Vietnam (2005) (Figure S8c)
	Notification type	Information (1999, 2005) (Figure S8d)
	Notification basis	(Not specified) (1999), border control–consignment detained (2005) (Figure S8e)
	Distribution status	(Not specified) (1999), no distribution (2005) (Figure S8f)
	Action taken	Import not authorised (1999), re-dispatch (2005) (Figure S8g)

Table 5. *Cont.*

	Hazard/Variable	Value (Figure)
Histamine	Year	2004–2017, 2019
	Product	Sardines (2011), tuna (2004–2017, 2019) (Figure S9a)
	Notifying country	Italy (2004–2005, 2007–2010, 2012–2013, 2015–2017) (Figure S9b)
	Country of origin	Indonesia (2004), Malaysia (2007), Morocco (2011–2012), Spain (2013, 2015–2017), Sri Lanka (2008), Vietnam (2019) (Figure S9c)
	Notification type	Alert (2004, 2015, 2017), border rejection (2011), information (2004–2010, 2012–2017) (Figure S9d)
	Notification basis	Food poisoning (2015, 2017), border control-consignment detained (2007, 2009), official control on the market (2004, 2013, 2017) (Figure S9e)
	Distribution status	(Not specified) (2004), distribution restricted to the notifying country (2009, 2012–2013), no distribution (2007–2009, 2011), product (presumably) no longer on the market (2011, 2015, 2017), distribution to other member countries (2015) (Figure S9f)
	Action taken	(Not specified) (2015, 2018), destruction (2004, 2008, 2011), informing authorities (2013), product recall or withdrawal (2004), recall from consumers (2012, 2017), re-dispatch (2006–2007, 2009), withdrawal from the market (2008–2013, 2015) (Figure S9g)

Table 6. Results of two-way joining cluster analysis related to notifications on heavy metals in seafood in the RASFF in 1996–2020.

	Hazard/Variable	Value (Figure)
Mercury	Year	2006–2020
	Product	Swordfish (2006–2020) (Figure S10a)
	Notifying country	Italy (2007, 2009–2019) (Figure S10b)
	Country of origin	Spain (2007–2008, 2010, 2012–2019) (Figure S10c)
	Notification type	Alert (2007, 2010, 2013–2018), information (2006–2007, 2014, 2017) (Figure S10d)
	Notification basis	Official control on the market (2007–2008, 2010–2019) (Figure S10e)
	Distribution status	Distribution on the market (possible) (2006–2010), distribution restricted to notifying country (2009), distribution to other member countries (2014, 2016–2017), information on distribution not (yet) available (2011), no distribution (2006–2007), no distribution from notifying country (2014), product past use-by date (2007), product (presumably) no longer on the market (2013–2019) (Figure S10f)
	Action taken	(Not specified) (2017–2018), destruction (2015–2017), informing authorities (2014), official detention (2015–2017), re-dispatch (2006–2007), seizure (2007), withdrawal from the market (2008–2018) (Figure S10g)
Cadmium	Year	2003, 2009
	Product	Crab (2009), swordfish (2003) (Figure S11a)
	Notifying country	Italy (2003, 2009), Spain (2003) (Figure S11b)
	Country of origin	France (2009), Singapore (2003), Thailand (2003) (Figure S11c)
	Notification type	Information (2003, 2009) (Figure S11d)
	Notification basis	Border control-consignment detained (2003), official control on the market (2009) (Figure S11e)
	Distribution status	(Not specified) (2003) (Figure S11f)
	Action taken	Re-dispatch (2003) (Figure S11g)

Table 7. Results of two-way joining cluster analysis related to notifications on veterinary products in seafood in the RASFF in 1996–2020.

	Hazard/Variable	Value (Figure)
Nitrofuran (metabolite)	Year	2002–2003, 2006, 2008–2009
	Product	Prawns (2002–2003), shrimps (2002–2003, 2006, 2008–2009) (Figure S12a)
	Notifying country	Belgium (2008–2009), United Kingdom (2003, 2006) (Figure S12b)
	Country of origin	Bangladesh (2006, 2009), India (2008–2009), Taiwan (2003), Thailand (2002–2003) (Figure S12c)
	Notification type	Alert (2002), border rejection (2009), information (2002–2003, 2009) (Figure S12d)
	Notification basis	(Not specified) (2002), border control-consignment detained (2003, 2009) (Figure S12e)
	Distribution status	(Not specified) (2002–2003), no distribution (2009) (Figure S12f)
	Action taken	(Not specified) (2002), destruction (2002–2003), import not authorised (2002), product recall or withdrawal (2002), re-dispatch (2009) (Figure S12g)
Chloramphenicol	Year	2001–2002
	Product	Shrimps (2001–2002) (Figure S13a)
	Notifying country	Germany (2001–2002), Netherlands (2002), Spain (2002), United Kingdom (2002) (Figure S13b)
	Country of origin	China (2001–2002), Vietnam (2001–2002) (Figure S13c)
	Notification type	Information (2002) (Figure S13d)
	Notification basis	(Not specified) (2001–2002) (Figure S13e)
	Distribution status	(Not specified) (2001–2002) (Figure S13f)
	Action taken	Import not authorised (2002) (Figure S13g)
Leucomalachite green	Year	2004–2006
	Product	Catfish (2005), eel (2006), panga (2005–2006), tilapia (2004) (Figure S14a)
	Notifying country	Belgium (2005), Poland (2006), Spain (2005), United Kingdom (2004–2005) (Figure S14b)
	Country of origin	Vietnam (2005) (Figure S14c)
	Notification type	Information (2004–2006) (Figure S14d)
	Notification basis	Border control-consignment detained (2005–2006), Border control-consignment released (2004), official control on the market (2005) (Figure S14e)
	Distribution status	Distribution on the market (possible) (2005), distribution restricted to the notifying country (2005), no distribution (2005–2006) (Figure S14f)
	Action taken	Official detention (2006), product recall or withdrawal (2005), re-dispatch (2005) (Figure S14g)

Table 8. Results of two-way joining cluster analysis related to notifications on controls in seafood in the RASFF in 1996–2020.

	Hazard/Variable	Value (Figure)
Poor temperature control	Year	2010–2013, 2015–2020
	Product	(Other product) (2011–2012), cuttlefish (2010), hake (2011, 2018), squid (2011), shrimps (2011–2013, 2018–2020), tuna (2010–2013, 2015–2020) (Figure S15a)
	Notifying country	Spain (2010–2013, 2017–2020) (Figure S15b)
	Country of origin	Indonesia (2012), Vietnam (2013) (Figure S15c)
	Notification type	Border rejection (2010–2013, 2015–2020) (Figure S15d)
	Notification basis	Border control-consignment detained (2010–2013, 2015, 2017–2019) (Figure S15e)
	Distribution status	No distribution (2010–2012), product not (yet) placed on the market (2013, 2015, 2017–2019) (Figure S15f)
	Action taken	Destruction (2018), import not authorised (2012–2013, 2015–2019), re-dispatch (2010–2012), re-dispatch or destruction (2011) (Figure S15g)

Table 8. *Cont.*

Hazard/Variable		Value (Figure)
Poor hygienic state	Year	2009–2011
	Product	(Other product) (2009–2011), squid (2009), tuna (2009) (Figure S16a)
	Notifying country	Spain (2009–2011) (Figure S16b)
	Country of origin	Argentina (2009), Chile (2009), Malta (2009–2010), Mauritania (2009–2010), Morocco (2009–2010), Senegal (2009), Sri Lanka (2009) (Figure S16c)
	Notification type	Border rejection (2009–2011) (Figure S16d)
	Notification basis	Border control-consignment detained (2009–2011) (Figure S16e)
	Distribution status	No distribution (2009–2011) (Figure S16f)
	Action taken	Destruction (2009–2010) (Figure S16g)

Table 9. Results of two-way joining cluster analysis related to notifications on parasites (*Anisakis*) in seafood in the RASFF in 1996–2020.

Variable	Value (Figure)
Year	2004, 2007–2012, 2017, 2019
Product	Anchovies (2011), anglerfish (2010), hake (2009–2011, 2017), mackerel (2004, 2011-2012, 2019), squid (2011) (Figure S17a)
Notifying country	Greece (2011), Italy (2004, 2009–2012, 2017, 2019), Spain (2011) (Figure S17b)
Country of origin	Croatia (2008), Denmark (2004), France (2009, 2011, 2019), Morocco (2011), New Zealand (2011), Norway (2004), Spain (2007, 2010–2011, 2017), United Kingdom (2004) (Figure S17c)
Notification type	Alert (2004, 2010–2011), border rejection (2009–2011), information (2004, 2010–2012, 2017, 2019) (Figure S17d)
Notification basis	Border control–consignment detained (2009, 2011), official control on the market (2004, 2010–2012, 2017, 2019) (Figure S17e)
Distribution status	Distribution on the market (possible) (2004, 2010), information on distribution not (yet) available (2011), no distribution (2009–2011) (Figure S17f)
Action taken	Destruction (2004, 2009–2011), re-dispatch (2011), withdrawal from the market (2011) (Figure S17g)

Table 10. Results of two-way joining cluster analysis related to notifications on additives/allergens (sulphite) in seafood in the RASFF in 1996–2020.

Variable	Value (Figure)
Year	2004–2008, 2016–2017
Product	Prawns (2004–2006, 2008), Shrimps (2004–2007, 2016–2017) (Figure S18a)
Notifying country	Italy (2004–2007) (Figure S18b)
Country of origin	Brazil (2004–2006), France (2004–2006), Spain (2005), Tunisia (2008) (Figure S18c)
Notification type	Alert (2004–2006), information (2004–2009, 2016–2017) (Figure S18d)
Notification basis	Border control-consignment detained (2007), border control-consignment released (2008), official control on the market (2004–2008, 2016–2017) (Figure S18e)
Distribution status	(Not specified) (2004–2005), distribution on the market (possible) (2005–2006), distribution restricted to the notifying country (2008), no distribution (2005–2007), product (presumably) no longer on the market (2016), product not (yet) placed on the market (2017), product past use-by date (2005–2006) (Figure S18f)
Action taken	(Not specified) (2006–2007), destruction (2004–2006), no action taken (2005), official detention (2005–2006), product recall or withdrawal (2005), recall from consumers (2008), re-dispatch (2004–2007), seizure (2005–2007) (Figure S18g)

Table 11. Results of two-way joining cluster analysis related to other hazards above 100 notifications in seafood in the RASFF in 1996–2020.

Hazard/Variable		Value (Figure)
Carbon monoxide	Year	2005–2006, 2013
	Product	Tuna (2005–2006, 2013) (Figure S19a)
	Notifying country	Italy (2005, 2013) (Figure S19b)
	Country of origin	Indonesia (2005), Netherlands (2005–2006), Spain (2013) (Figure S19c)
	Notification type	Alert (2005–2006), information (2006, 2013) (Figure S19d)
	Notification basis	Official control on the market (2005–2006) (Figure S19e)
	Distribution status	Distribution on the market (possible) (2005–2006) (Figure S19f)
	Action taken	Product recall or withdrawal (2006), official detention (2005), seizure (2005), withdrawal from the market (2013) (Figure S19g)
Benzo(a)pyrene	Year	2003, 2006–2007, 2011
	Product	Sprats (2003, 2006–2007, 2011) (Figure S20a)
	Notifying country	France (2007), Germany (2003, 2006), Hungary (2014), Slovakia (2006), United Kingdom (2006) (Figure S20b)
	Country of origin	Estonia (2003), Ghana (2006), Ivory Coast (2007), Latvia (2003, 2006–2007, 2014) (Figure S20c)
	Notification type	Alert (2003, 2006–2007, 2017), information (2006–2007) (Figure S20d)
	Notification basis	Border control-consignment detained (2006), official control on the market (2003, 2006–2007, 2014) (Figure S20e)
	Distribution status	(Not specified) (2003), Distribution on the market (possible) (2006–2007), no distribution (2006) (Figure S20f)
	Action taken	Destruction (2006), product recall or withdrawal (2006), withdrawal from the market (2007, 2011) (Figure S20g)
Diarrhoeic Shell-fish Poisoning (DSP) toxins	Year	2000–2001, 2004, 2006–2007, 2009–2011, 2013–2016
	Product	Clams (2007), mussels (2000–2001, 2004, 2006, 2009–2011, 2013–2016), molluscs (2001) (Figure S21a)
	Notifying country	Italy (2001, 2004, 2010, 2013), Spain (2007) (Figure S21b)
	Country of origin	Greece (2000–2001), France (2011), Italy (2010), Spain (2013–2014) (Figure S21c)
	Notification type	Alert (2000–2001, 2006–2007, 2009–2011, 2013–2016), information (2001, 2006–2007, 2010, 2015) (Figure S21d)
	Notification basis	(Not specified) (2000–2001), official control on the market (2006–2007, 2010–2011, 2013–2015) (Figure S21e)
	Distribution status	(Not specified) (2000–2001), distribution on the market (possible) (2006, 2010), distribution to other member countries (2011, 2016), no distribution (2007) (Figure S21f)
	Action taken	Product recall or withdrawal (2000), re-dispatch (2007), withdrawal from the market (2010–2011, 2013–2014) (Figure S21g)
Organoleptic characteristics	Year	2009–2011
	Product	(Other product) (2009–2011), clams (2011), sardines (2009), shrimps (2011) (Figure S22a)
	Notifying country	Spain (2009–2011) (Figure S22b)
	Country of origin	Chile (2011), Mauritania (2010), Mozambique (2011) Morocco (2009), Senegal (2010–2011), United States (2011) (Figure S22c)
	Notification type	Border rejection (2009–2011) (Figure S22d)
	Notification basis	Border control-consignment detained (2009–2011) (Figure S22e)
	Distribution status	No distribution (2009–2011) (Figure S22f)
	Action taken	Destruction (2009–2011), official detention (2011), re-dispatch (2009, 2011), re-dispatch or destruction (2010) (Figure S22g)

Table 11. *Cont.*

Hazard/Variable		Value (Figure)
Spoilage	Year	2003–2004, 2009–2011, 2016–2017
	Product	(Other product) (2009–2011), clams (2016), shrimps (2003–2004, 2011), tuna (2017) (Figure S23a)
	Notifying country	Germany (2003), Spain (2010–2011) (Figure S23b)
	Country of origin	India (2003–2004), Malta (2010) (Figure S23c)
	Notification type	Border rejection (2009–2011, 2017), information (2004) (Figure S23d)
	Notification basis	Border control-consignment detained (2003–2004, 2009–2011, 2016–2017) (Figure S23e)
	Distribution status	(Not specified) (2004), no distribution (2009–2011), product not (yet) placed on the market (2016–2017) (Figure S23f)
	Action taken	Destruction (2009–2011, 2016–2017), re-dispatch (2003, 2011) (Figure S23g)
Health certificate(s)	Year	2006, 2008–2011, 2018
	Product	(Other product) (2008), clams (2006, 2009), mussels (2009), pollock (2010), shark (2018), shrimps (2010), tilapia (2011), tuna (2018) (Figure S24a)
	Notifying country	Cyprus (2008), Germany (2010), Italy (2010–2011), Netherlands (2009), Poland (2011), Portugal (2018) (Figure S24b)
	Country of origin	China (2008, 2010–2011), Ecuador (2010), Namibia (2018), Republic of Korea (2006), Senegal (2009), Vietnam (2009) (Figure S24c)
	Notification type	Border rejection (2008–2011, 2018) (Figure S24d)
	Notification basis	Border control-consignment detained (2008–2011, 2018) (Figure S24e)
	Distribution status	No distribution (2008–2011), product not (yet) placed on the market (2018) (Figure S24f)
	Action taken	Destruction (2008–2010, 2018), re-dispatch (2011, 2018) (Figure S24g)
Packaging	Year	2004, 2009–2010, 2012, 2016–2018
	Product	Anchovies (2010), cod (2004), mackerel (2009), tuna (2010, 2012, 2016–2018) (Figure S25a)
	Notifying country	Spain (2010), United Kingdom (2017) (Figure S25b)
	Country of origin	Morocco (2009–2010), Peru (2010), Republic of Korea (2009), Russian Federation (2004), Seychelles (2016, 2018) (Figure S25c)
	Notification type	Border rejection (2009–2010, 2012, 2016–2017) (Figure S25d)
	Notification basis	Border control-consignment detained (2009–2010, 2012, 2016–2017) (Figure S25e)
	Distribution status	No distribution (2009–2010, 2012), product not (yet) placed on the market (2016–2017) (Figure S25f)
	Action taken	Destruction (2017), re-dispatch (2009–2010, 2017) (Figure S25g)
Foodborne outbreak	Year	2017–2018, 2020
	Product	Oysters (2018, 2020), tuna (2017) (Figure S26a)
	Notifying country	France (2017), Italy (2017), Sweden (2020) (Figure S26b)
	Country of origin	France (2018, 2020), Spain (2017) (Figure S26c)
	Notification type	Alert (2017–2018, 2020), information (2017–2018, 2020) (Figure S26d)
	Notification basis	Food poisoning (2017–2018, 2020) (Figure S26e)
	Distribution status	Distribution restricted to notifying country (2017), distribution to other member countries (2017, 2020), product (presumably) no longer on the market (2017–2018, 2020) (Figure S26f)
	Action taken	Withdrawal from recipient(s) (2017), withdrawal from the market (2017) (Figure S26g)

3. Results

3.1. Overall Results. Number of Notifications by Variable

Table 3 presents a number of notifications on seafood reported in the RASFF in 1996–2020 by particular variables and values (from largest to smallest number of notifications

within particular variables). Only values with the number of notifications above 200 have been shown, and the others have been summed up as "Other".

The most frequently notified were shrimps (13.0%), tuna (10.0%), swordfish (9.6%), salmon (5.5%), mussels (4.7%), and also prawns, calms, squid, mackerel, oysters, shark, hake and panga. It should be noted that some of the species reported live in freshwater (panga and also tilapia and catfish), but notifications to them would be a distinct minority, however their removal from the study would alter the structure of the population examined. Other species mentioned can live both in fresh or brackish water (perch and prawns) or in fresh and salt water (salmon).

Notifications were reported by Italy (34.2%), Spain (15.9%), as well as France (7.7%), the United Kingdom (7.5%) and Germany (7.4%). The notified products originated mainly from European countries, i.e., Spain (11.3%), France (5.8%), the Netherlands and Italy and Asian countries, i.e., Vietnam (8.6%), India (5.4%), China (4.8%), Thailand, Indonesia and Morocco.

The largest number of information notifications was reported (49.1%), followed by alerts (28.6%) and border rejections (22.4%). Notifications were based to a similar extent on official controls on the market (37.0%) and border controls (32.2%), after which the consignment was detained. Mostly the reported product was not distributed (18.3%), although the distribution status was also often left not specified (18.1%). Notified products were re-dispatched (15.2%), destroyed (13.8%), withdrawn from the market (12.7%) or import was not authorized (11.1%).

3.2. Results of Joining Cluster Analysis

In Table 4 presented results of joining cluster analysis (Figure S1 in Supplementary Materials) related to notifications on seafood in the RASFF in 1996–2020. Clusters and subclusters were listed starting with the most outstanding. The most similar values (directly related to each other in the charts) were mentioned first in the respective cluster or subcluster and linked by a long hyphen.

For the first variable analyzed (year), the similarities in notifications in the following two years (i.e., 1996–1997, 1998–1999, 2002–2003, 2004–2005 and 2012–2016) are noteworthy. Problems with notified hazards therefore often either lasted for two years or only at the turn of the years mentioned. In terms of products, notifications against swordfish occurred in such large numbers that a one-element cluster was formed. Notifications for salmon and tuna, clams and mussels, cuttlefish and octopus, hake and mackerel were similar, meaning that these species were affected by the same hazards (due to similar environment, area of occurrence or mode of functioning of the organism). In the case of the notifying country, the large number of notifications made by Italy resulted in a separate one-element cluster being created here as well. It is worth noting, however, that notifications were reported in a similar way by geographically close countries, that is, Belgium and the Netherlands, Denmark and Sweden, Austria and Poland, and Greece and Portugal. The pairs of countries share similar climatic conditions, and in the case of the first two pairs, close trade relations can also be said to exist.

Regarding the next variable (country of origin), for some country pairs it can also be seen that similar hazards were present in geographically close countries (Bangladesh and Thailand, Denmark and Germany, Brazil and Ecuador). However, here too, a one-element cluster emerged (Spain), indicating a high number of notifications against products originating from this country.

In the case of the variable notification type, a separate one-element cluster was created by border rejections, which involved products being stopped at the external border of the European Union. In turn, alert and information notifications sent against products already in the common market were similar. However, a similarity can be noted for another variable (notification basis) resulting from market and border controls carried out by the authorities of individual European countries. It is noteworthy that there were also similarities in notifications based on companies' own checks, as well as food poisoning, which may have been the result of increased producers awareness following food safety rules due to market

observation. Notifications relating to distribution status, in turn, varied widely, but the similarities were notable in terms of possible distribution on the market and distribution restricted to the notifying country, as well as no distribution and a situation where the product was not (yet) placed on the market. In the case of the last variable analyzed (action taken), notifications regarding destruction and re-dispatch of products were similar.

3.3. Results of Two-Way Joining Cluster Analysis

Tables 5–11 present the results of two-way joining cluster analysis (Figures S2–S26 in Supplementary Materials) related to notifications on seafood in the RASFF in 1996–2020. The following subsections present the results of the two-way joining cluster analysis, by groups and hazards most frequently reported (according to Figure 2 and Table 2). The range of years (variable "year") was based on the variable "product" (colors: Light green, yellow, orange, red and brown). However, if some years are missing with a given other variable, it does not mean that there were no notifications at all, but that they occurred in smaller numbers (different shades of green or white).

3.3.1. Micro-Organisms

Notifications on pathogenic micro-organisms, microbial and biological contaminants related to *Listeria*, *Salmonella*, *Escherichia coli*, *Vibrio*, norovirus, and also mesophiles, Enterobacteriaceae and histamine were presented in Table 5 (they covered 27.6% of all seafood notifications).

Listeria (6.4% of notifications) was reported primarily in salmon over a wide range of time (1999, 2000–2001, 2004–2005, 2009–2018 and 2020). This product was notified by Italy and originated mostly from Poland, but also from Denmark, Germany and Vietnam. In turn, *Salmonella* (4.1%) was notified in the similar years (1998, 2000–2001, 2003–2005, 2007, 2013, 2017–2019), however, reported products were much more varied. They were mostly mussels, but also clams, octopus, perch and shrimps. Notifications were made mainly by Italy for products originating from Asia (Indonesia and Vietnam), but also Spain. Notifications related to *Escherichia coli* (3.9%) were reported in 2004, 2007–2010, 2013–2014 and 2016–2019. They also involved mussels and clams. The products were notified by Italy and came mainly from that country, but also from France, Spain and Turkey. In turn, *Vibrio* (3.6%) was notified in shrimps in 1999–2005 and 2008 mainly by Italy and Norway, but also France. Reported products originated from Asian countries (Bangladesh, China, India, Indonesia, Malaysia, Thailand and Vietnam). Norovirus (2.2%) was found in oysters and clams in 2013–2014, 2018 and 2020. They were notified by Italy and Spain and originated from France and Vietnam.

Information notifications were most commonly used against reported products, followed by alerts and border rejections, however, closer analysis of the data showed that the notification type varied depending on the micro-organisms. In the case of *Listeria* (reported as a pathogenic micro-organism as indicated in Table 2), almost all notifications concerned *Listeria monocytogenes* and half of these were alerts, implying a serious risk to consumer health and requiring a rapid response from RASFF members. Notifications relating to *Salmonella* (reported as pathogenic micro-organism) mainly concerned *Salmonella* spp. and in 17.9% these were alerts and in 45.3% information notifications not requiring a rapid action.

In turn, in the case of *Escherichia coli* (reported as microbial contaminants), the notifications were due to too high count of this bacterium and were alerts in one third and information notifications in half. Notifications regarding *Vibrio* (reported as pathogenic micro-organism) referred in half to the presence of *Vibrio parahaemolyticus* and in 10.5% were reported as alerts and in 40.3% as information notifications. Also reported were *Vibrio cholerae*, including NON O:1 and NON O:1/NON O:139, and in much smaller numbers *Vibrio vulnificus* and *Vibrio alginolyticus*. In turn, for norovirus, (reported also as pathogenic micro-organism) 40.8% were alerts and 46.5% information notifications.

Seafood concerning micro-organisms was notified mainly on the basis of official controls in the market, controls at the border, after which the consignment was detained or released, the company's own checks and food poisoning, but in many cases the notifica-

tion basis was not specified. The distribution status was often not specified, but it was also indicated that the product was no longer on the market, could be found in other member countries or that distribution was restricted to the notifying country. Products were withdrawn from the market or imports were not authorized, and they could also be re-dispatched, destroyed or recalled from consumers, but in many cases the action taken against them was not specified.

Mesophiles (1.0%) were notified in shrimps, prawns, mussels, octopus and squid in 2001–2003 and 2005. They were reported by Spain in products from Chile and Morocco. In turn, Enterobacteriaceae (0.8%) was found in hake and panga in 1999 and 2005. For both mesophiles (three quarters of the notifications related to aerobic mesophiles) and Enterobacteriaceae, the problem was too high to count. However, due to the type of notifications (information notifications were by far the predominant type), there was no need for rapid action by RASFF members. These bacteria were also notified by Spain, and products from Namibia and Vietnam were affected. These were mainly information notifications, but the notification basis was most often not specified or it was a border control, after which the shipment was detained. The distribution status was also usually not specified. Imports of notified products were not authorized or products were re-dispatched.

Histamine was reported in 5.6% of notifications in 2004–2017 and 2019 mainly in tuna, but also in sardines. The notifications were transmitted mostly by Italy and concerned products from Spain, Morocco, and also from Asia (Indonesia, Malaysia, Sri Lanka and Vietnam). These were generally information notifications, but also alerts and border rejections. The basis for the notifications was usually an official control on the market, but also food poisoning and a control at the border, after which the consignment was detained. The distribution status varied and the products were not distributed or were no longer on the market, distribution could be restricted to the notifying country, but could also be distribution to other member countries. The product was withdrawn from the market and it was also recalled from consumers or destroyed.

3.3.2. Heavy Metals (Mercury and Cadmium)

Notifications on heavy metals (Table 6) covered 19.8% of all seafood notifications.

Mercury (13.9% of notifications) was reported mainly by Italy in swordfish originated from Spain in the long term (2006–2020). The notification type was alert or information and notification basis was the official control on the market. Recently, most often the product was no longer on the market, although in earlier years it was possible. The actions taken with regard to the product consisted mainly in its destruction, official detention or withdrawal from the market.

In turn, cadmium (reported in crab and swordfish) covering 5.9% of notifications, is no longer such a hazard, having been notified mainly in 2003 and 2009. The notifying countries were Italy and France, and the countries of origin were France, Singapore and Thailand. These were information notifications on the basis of which, after border controls, the consignment was detained and re-dispatched or official controls on the market.

3.3.3. Veterinary Products (Nitrofuran, Chloramphenicol and Leucomalachite Green)

Notifications relating to residues of veterinary products (Table 7) covered 8.5% of all notifications referring to seafood.

Nitrofuran (metabolite) (5.4%) was found in shrimps and prawns in 2002–2003, 2006 and 2008–2009. It was reported by Belgium and the United Kingdom in products from Asian countries (Bangladesh, India, Taiwan and Thailand). Chloramphenicol (2.2%) was notified in 2001–2002 in shrimps also from Asian countries (China and Vietnam) and notifying countries were Germany, the Netherlands, Spain and the United Kingdom. Leucomalachite green (0.9%) was reported in catfish, eel, panga and tilapia in 2004–2006. They were notified by Belgium, Poland, Spain and the United Kingdom and originated from Vietnam.

Products were reported mainly as information notifications, to a lesser extent as alerts or border rejections. Notifications were based on border control, after which the

consignment was detained or released, official control on the market, but in many cases this was also not specified. The distribution status was also often not specified or indicated as no distribution or distribution restricted to the notifying country. Products were most often destroyed, re-dispatched or imports were not authorized.

3.3.4. Controls (Poor Temperature Control and Hygienic State)

Notifications regarding poor or insufficient controls (Table 8) accounted for 7.6% of all notifications relating to seafood.

3.3.5. Parasites (Anisakis)

Notifications on *Anisakis* (4.7%) was found mainly in mackerel and hake, but also in anchovies, anglerfish and squid in 2004, 2007–2012, 2017 and 2019 (Table 9).

It was reported by Italy, Greece and Spain in products originated from European countries (Croatia, Denmark, France, Norway, Spain, the United Kingdom) and also from New Zealand.

Information notifications were mainly reported, but also alerts and rejections at the border. Notifications were based on official control on the market and controls at the border, after which the consignment was detained. Products were not distributed, but distribution could also be possible. They were mostly destroyed, but also re-dispatched or withdrawn from the market.

3.3.6. Additives/Allergens (Sulphite)

Sulphite (4.2% of notifications) was reported in shrimps and prawns in 2004–2008 and 2016–2017 by Italy in products originated from Brazil, France, Spain and Tunisia (Table 10).

These were mainly information notifications, and to a lesser extent alerts, and these were based on official controls on the market and border controls, after which the consignment was detained or released. The status of the distribution and the action taken varied greatly, depending on the year of notification.

3.3.7. Other Hazards above 100 Notifications

Other hazards above 1000 notifications accounted for 10.9% of the notifications studied were usually made in earlier years (Table 11). They were related to carbon monoxide in tuna, benzo(a)pyren in sprats, Diarrhoeic Shell-fish Poisoning (DSP) toxins in mussels, organoleptic aspects (organoleptic characteristics and spoilage) in clams and shrimps, but also concerned health certificate(s), packaging and foodborne outbreaks.

4. Discussion

4.1. Seafood Import and Supply in the European Union

Seafood is the main type of food subjected to international trade and is often transported over very long distances [1]. The Standard International Trade Classification (SITC) managed by Eurostat contains data on the European Union's imports (million kg) of seafood (fish–not marine mammals, crustaceans, molluscs and aquatic invertebrates, and preparations thereof) [6]. Over the period 1999–2020 a clear upward trend can be observed in the import of seafood to the EU market (an increase of 55.5%). The vast majority of imported seafood came from other European countries (65.9% in 1999 and 69.5% in 2020), so it was mostly intra-EU imports (only in second place can one notice products from Asia with 9.2% in 1999 and 11.2% in 2020). It should be added that only countries from which seafood reported in the RASFF originated were taken into account, so a marked increase in imports of these foods may expose European consumers to additional hazards. It should be borne in mind that individual EU countries manufactured the products only for their own markets, which, however, should also be reported in the RASFF when a hazard is detected.

Faostat publishes data on the average supply of fish and seafood across the population, measured in kilograms per person per year [7]. Food supply can be defined as food available for human consumption, however, it does not include consumption waste, so the amount of

food consumed may be overestimated [8]. The average supply of fish and seafood in the EU in the period 2010–2019 remained stable at around 22 kg. The largest changes in this supply were recorded in countries such as Latvia (−13.2%), Slovakia (+10.6%) and Luxembourg (+12.3%). However, it is worth noting that it varied greatly from country to country, with the lowest in Hungary (6 kg), Bulgaria and Romania (7 kg), and with the highest in Portugal (56 kg), Spain (43 kg), France (34 kg), and also other Mediterranean and Scandinavian countries. Therefore, in these countries, seafood should receive special attention from official surveillance authorities, taking into account notifications in the RASFF.

4.2. RASFF Notifications on Seafood in EU Reports and by Various Authors

4.2.1. RASFF Annual Reports

Since 2010, the RASFF annual reports have included information on the 10 most frequently reported hazards for the year in question. For the period 2010–2020, seafood has appeared in every such report (Table 12).

Table 12. Frequently reported hazards on seafood in the RASFF by annual reports for 2010–2020.

Year	Hazard	Product Category	Notifying Country	Country of Origin *	Reference
2010	*Anisakis*	Fish and fish products	Italy	NDA	[9]
	Mercury	Fish and fish products	Italy	Spain	
2011	*Anisakis*	Fish and fish products	Italy	NDA	[10]
	Mercury	Fish and fish products	Italy	NDA	
	Poor temperature control	Fish and fish products	Spain	NDA	
2012	Mercury	Fish and fish products	Italy	NDA	[11]
	Poor temperature control	Fish and fish products	Spain	NDA	
2013	Carbon monoxide	Fish and fish products	Italy	Spain	[12]
	Mercury	Fish and fish products	Italy	Spain	
2014	*Escherichia coli*	Bivalve molluscs and products thereof	Italy	NDA	[13]
	Listeria monocytogenes	Fish and fish products	NDA	Poland	
	Mercury	Fish and fish products	Italy	Spain	
	Norovirus	Bivalve molluscs and products thereof	NDA	Vietnam	
2015	Mercury	Fish and fish products	Italy	Spain	[14]
2016	*Escherichia coli*	Bivalve molluscs and products thereof	Italy	NDA	[15]
	Mercury	Fish and fish products	Italy	Spain	
2017	Mercury	Fish and fish products	Italy	Spain	[16]
2018	*Anisakis*	Fish and fish products	Italy	NDA	[17]
	Mercury	Fish and fish products	Italy	Spain	
	Norovirus	Bivalve molluscs and products thereof	NDA	France	
2019	Mercury	Fish and fish products	Italy	Spain	[18]
2020	Norovirus	Bivalve molluscs and products thereof	NDA	France	[19]

Note: * NDA—No Data Available.

The most common problem among the 10 most frequently reported hazards was mercury in fish from Spain, notified by Italy. Other apparent problems were also pathogenic micro-organisms (*Escherichia coli* and norovirus in bivalve molluscs, *Listeria monocytogenes* in fish) and *Anisakis* also in fish. It should also be noted that Italy was the most active country in terms of these most common notifications.

4.2.2. EFSA Reports and Opinions

Table 13 shows hazards on seafood notified in the RASFF by EFSA reports and opinions for 1999–2017. The notifying country and the country of origin were not indicated in these documents.

Table 13. Hazards on seafood notified in the RASFF by EFSA reports and opinions for 1999–2017.

Year/Years	Hazard	Product/Product Category	Reference
1999–2013	Hepatitis A	Shellfish	[20]
2000–2010	Norovirus	Shellfish	[21]
2002–2013	Chloramphenicol	Fish and products thereof, crustaceans and products thereof	[22]
2002–2014	Nitrofuran (metabolite)	Fish and products thereof, crustaceans and products thereof	[23]
2002–2014	Malachite green, leucomalachite green	Fish and products thereof, crustaceans and products thereof	[24]
2005–2010	Histamine	Tuna	[25]
2006–2015	Norovirus, *Salmonella*	Shellfish	[26]
2008–2016	*Listeria monocytogenes*	Fish and products thereof, crustaceans and products thereof	[27]
2017	Histamine	Tuna	[28]

EFSA's reports and opinions therefore mainly highlight residues of veterinary medicinal products (nitrofuran, chloramphenicol, malachite and leucomalachite green) in fish and pathogenic micro-organisms (*Listeria monocytogenes* in fish, and also norovirus and *Salmonella* in shellfish), as well as the biological contaminant histamine.

4.2.3. Various Authors

Table 14 presents hazards on seafood in the RASFF reported by various authors for 1979–2020. The name of the hazard/hazard category, product/product category is given as provided by the individual authors. Sources that referred to the RASFF notifications in relation to seafood but did not state that the hazards were omitted.

An analysis of the papers on notifications in the RASFF shows that they highlight four main hazards (similar to EU reports), i.e., pathogenic micro-organisms, heavy metals, residues of veterinary medicinal products and parasitic infestation in seafood originated from Europe and Asia.

Some authors also supplemented the information on RASFF notifications with additional comments. Amagliani et al. (2012) pointed out that the presence of *Salmonella* in seafood can be due to natural causes as well as during processing. In doing so, they added that *Salmonella* is resistant and multi-resistant to antibiotics [1]. Crossley and Baines (2014) outlined that mercury is released into the environment from both natural and anthropogenic sources and can occur as methylmercury or organic mercury. They indicated that fish and seafood is the main source of methylmercury in most populations, with the highest concentrations in predatory and long-lived fish such as marlin, swordfish and shark [29]. In turn, Golden at al. (2022), referring to Portugal as the country with one of the highest levels of fish consumption in the world (see Section 4.1), highlighted that anisakiosis (associated with the consumption of raw or undercooked fish) poses some risk to consumers there, but it seems quite small. However, it is necessary to communicate the risk and implement consumer education campaigns on this issue [30].

Table 14. Hazards on seafood notified in the RASFF by various authors for 1979–2020.

Year/ Years	Hazard/Hazard Category	Product/Product Category	Notifying Country/ Country of Origin *	Reference
1979–2020	Residues of veterinary medicinal products	Crustaceans and products thereof	NDA	[31]
	Microbial contaminants (other), metals	Fish and fish products		
1980–2015	Antibiotic residues	Shrimps (farmed and wild)	NDA	[32]
1980–2016	Heavy metals	Fish and fish products	NDA	[33]
1980–2020	Histamine	Fish (canned)	NDA	[34]
1987–2017	Absence of health certificate(s)	Swordfish (chilled)	Country of origin–Morocco	[35]
	False certificate	Hake	Country of origin–Ecuador	
	Absence of health certificate(s)	Cuttlefish, squid (frozen)	Country of origin–Morocco	
1997–2005	*Anisakis*	Fish products	NDA	[36]
1998–2011	Pathogenic micro-organisms, antibiotics	Pangasius	Country of origin–Vietnam	[37]
	Antibiotics	Shrimps		
	Heavy metals, food additives	Swordfish, tuna		
2001–2008	Chloramphenicol	Shrimps	NDA	[38]
2001–2011	Benzo[a]pyren	Sprats (smoked canned)	Country of origin–Latvia, Poland	[39]
2001–2011	Heavy metals	Fish products	NDA	[40]
2001–2021	Veterinary drugs	Pangasius, tilapia, trout, eel, catfish, salmon	Country of origin–Vietnam, China	[41]
2002–2010	Nitrofuran, chloramphenicol	Aquaculture	Country of origin–Asian countries	[42]
2002–2010	Histamine	Fish products	NDA	[43]
2002–2014	Drug residues	Fish and seafood products	Country of origin–Asian countries	[44]
2002–2014	Pesticides, preservatives, antibiotics	Pangasius	Country of origin–Vietnam	[45]
2002–2015	Residues of veterinary medicinal products, pesticide residues, heavy metals	Pangasius	Country of origin–Vietnam	[46]
2003	Malachite green	Salmon	Country of origin–Chile	[47]
2003–2007	*Anisakis*	Fish products	NDA	[48]
2003–2007	Drug residues, cadmium, mercury, *Escherichia coli*, *Vibrio*, norovirus, *Anisakis*, problems with temperature control, organoleptic characteristics, spoilage	Seafood	NDA	[49]
2004–2006	Nitrofuran (metabolite)	Aquaculture products	Country of origin–Asian countries	[50]
2005–2007	Carbon monoxide	Fishery products	Country of origin–Germany	[51]
2006	Residues of chloramphenicol, nitrofurans and malachite green	Aquaculture products	Country of origin–China	[52]
2006–2010	Norovirus	Oysters	NDA	[53]
2007	Mercury, cadmium, lead	Seafood	NDA	[54]

Table 14. *Cont.*

Year/ Years	Hazard/Hazard Category	Product/Product Category	Notifying Country/ Country of Origin *	Reference
2007	Mercury	Swordfish, shark	Notifying country–Italy, Spain, Country of origin–Spain, France, Indonesia	[55]
2007–2009	Cadmium	Crabs	Notifying country–Italy, Country of origin–France, Ireland, United Kingdom	[56]
2007–2015	*Escherichia coli*	Bivalves (live/fresh)	NDA	[57]
	Norovirus	Oysters (live/fresh)		
	Listeria monocytogenes	Fish (smoked)		
	Histamine	Seafood (canned)		
2008	Chloramphenicol, nitrofuran	Crustaceans	NDA	[58]
	Malachite green	Fish		
2008	Bacteria, viruses, histamine, allergens	Shellfish (precooked frozen)	Country of origin–Ireland	[59]
2008–2009	Heavy metals	Fish	Country of origin–Sri Lanka	[60]
2008–2012	Histamine	Tuna	NDA	[61]
2009	Biocontaminants, biotoxins, heavy metals, industrial contaminants, pesticide residues, residues of veterinary medicinal products	Fish, crustaceans and molluscs	Country of origin–Asian and European countries	[62]
2009–2010	Nitrofuran (metabolite)	Shrimps	NDA	[63]
2009–2010	Nitrofuran (semicarbazide)	Shrimps, fish	NDA	[64]
2009–2011	*Escherichia coli*, biotoxins, norovirus, *Salmonella*, labelling and organoleptic causes	Bivalve molluscs	NDA	[65]
2009–2013	*Anisakis*	Fish and seafood	Notifying country–Italy, Spain	[66]
2009–2013	*Anisakis*	Fish	Notifying country–Italy, Spain	[67]
2010	*Anisakis*	Anchovies	NDA	[68]
2010	*Escherichia coli*	Bivalve molluscs (live)	NDA	[69]
2010–2013	Histamine, heavy metals	Tuna	Country of origin–Sri Lanka	[70]
2010–2016	*Anisakis*	Fishery products	NDA	[71]
2011	*Listeria monocytogenes*	Catfish (striped fillets)	NDA	[72]
2011–2014	Allergens	Seafood	NDA	[73]
2011–2015	Mercury	Fish and fish products	Country of origin–Spain	[74]
2011–2015	Heavy metals	Fish, cephalopods	Country of origin–Italy, Spain, Vietnam, Morocco	[75]
2011–2015	Heavy metals	Fish, cephalopods	Notifying country–Italy, Spain	[76]
	Pathogenic micro-organisms	Bivalve molluscs	Country of origin–Italy, Spain, Vietnam, Morocco	
	Poor temperature control, unsuitable transport conditions, fraudulent/absence of health certificate	Seafood		

Table 14. *Cont.*

Year/ Years	Hazard/Hazard Category	Product/Product Category	Notifying Country/ Country of Origin *	Reference
2011–2019	*Anisakis*	Mackerel, hake, anglerfish	Notifying country–Italy	[77]
2012	*Listeria monocytogenes*	Crustaceans and product thereof, fish and products thereof	NDA	[78]
2012–2013	Chemical residues, undeclared substances, mercury, fraudulent health certificates	Fish and fish products	Country of origin–Vietnam	[79]
2013	Environmental contaminants	Fish and fish products	NDA	[80]
2013	Heavy metals, residues of veterinary drugs, prohibited substances	Fishery products	Country of origin–China	[81]
2014	Mercury	Seafood products	NDA	[82]
2014–2018	Fraud	Fish and seafood	NDA	[83]
2015	*Listeria monocytogenes*, *Staphylococcus epidermidis*	Fishery products	Country of origin–Thailand	[84]
2015–2020	Poor temperature control	Tuna, salmon, shrimps, squid, octopus	Notifying country–Spain, United Kingdom Country of origin–China, Morocco, United States	[85]
2016	*Listeria monocytogenes*	Salmon (smoked)	NDA	[86]

Note: * NDA—No Data Available.

4.3. Limitations in Using RASFF Data

Interpretation of the results was hampered by: lack of some data for the variables: hazard category, hazard, notification basis, distribution status and action taken, especially in the earlier years of the RASFF functioning, giving product names in a non-uniform manner and the large variation in notifications for some hazards, which required a wide range of colors to be adopted in the two-way joining cluster analysis.

D'Amico et al., (2014), referring to seafood from China, noted problems with the scientific name and approximate label names reported in the RASFF. In this regard, they recalled the need, suggested earlier, for comprehensive tracking of trade flows through global standardization of procedures and conventions and even relying on molecular testing of fish [87,88]. D'Amico et al. (2018) also noted the increasing number of notifications in the RASFF against products originating from the EU, but emphasized that the raw materials used in their production come from third countries [76]. It is therefore important to point out that the declared country of origin of a product is not necessarily the same as the country of origin of the hazard.

In turn, Lawrence et al., (2022), referring to the adulteration of seafood, and relying on research by other authors, found that most RASFF reports come from border inspections, after which the food is rejected, so some adulteration may not even be detected. They add that incidents of food adulteration, especially of food exported to many EU countries, may be repeatedly reported. Some authors also noted that the high number of notifications from several countries (they pointed to the United Kingdom, Spain, Germany, Italy and Belgium) may be due to conditions related to their laws, as well as purposeful inspections [76,89,90]. It has been noted, for example, that the increase in controls on shipments from Spain has put this country in first place in terms of the notification of mercury in fish [74,76].

5. Conclusions

The most common hazards reported in the Rapid Alert System for Food and Feed (RASFF) in seafood between 1996 and 2020 were: micro-organisms, heavy metals veterinary products, controls parasites and additives/allergens.

Particularly worrying is the fact that in recent years notifications have largely concerned products originating from European Union countries, where free movement of goods is allowed within the common market, which, together with the growth of intra-EU seafood trade, further increases the possibility of the spread of hazards. Particularly important is the activity of the control authorities within traceability (based on their knowledge, training and experience) in southern European and Scandinavian countries, where seafood consumption is highest, as well as the relevant legislation at EU and national level.

However, a high awareness and training for marine species farmers in the use of veterinary medical products (authorized, in specific concentrations) to reduce or eliminate diseases and parasites in marine organisms, as well as the observance of withdrawal periods for these products, is already important. In turn, in order to reduce the occurrence of pathogenic micro-organisms, it is essential to maintain the right temperature, humidity, cleanliness of premises, means of transport, composition and quality of packaging using traceability at the production and distribution stages, as well as additives during processing.

Unfortunately, a large part of the notification was also heavy metals (particularly dangerous due to bioaccumulation), whose presence results from specific human activities (e.g., emissions and mineral extraction) and whose elimination from the environment is difficult or even impossible. In this, it is particularly important to pay attention to land-based emissions in semi-enclosed seas such as the Baltic Sea [91]. Other causes of hazards to seafood, also indirectly due to anthropopressure, are changes in salinity, sea level and temperature, as well as winds, currents and tides.

Further research could look for a correlation between the volume of seafood produced or imported (according to Eurostat or Faostat databases) and the number of RASFF notifications.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/w15030548/s1, Figure S1: Results of joining cluster analysis; (a) year; (b) product; (c) notifying country; (d) country of origin; (e) notification type; (f) notification basis; (g) distribution status; (h) action taken; Figure S2: Results of two-way joining cluster analysis related to *Listeria*; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S3: Results of two-way joining cluster analysis related to *Salmonella*; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S4: Results of two-way joining cluster analysis related to *Escherichia coli*; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S5: Results of two-way joining cluster analysis related to *Vibrio*; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S6: Results of two-way joining cluster analysis related to norovirus; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S7: Results of two-way joining cluster analysis related to mesophiles; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S8: Results of two-way joining cluster analysis related to Enterobacteriaceae; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S9: Results of two-way joining cluster analysis related to histamine; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S10 Results of two-way joining cluster analysis related to mercury; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S11: Results of two-way joining cluster analysis related to cadmium; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S12: Results of two-way joining cluster analysis related to nitrofuran (metabolite); (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S13: Results of two-way joining cluster analysis related to chloramphenicol;

(a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S14: Results of two-way joining cluster analysis related to leucomalachite green; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S15: Results of two-way joining cluster analysis related to poor temperature control; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S16: Results of two-way joining cluster analysis related to poor hygienic state; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S17: Results of two-way joining cluster analysis related to *Anisakis*; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S18: Results of two-way joining cluster analysis related to sulphite; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S19: Results of two-way joining cluster analysis related to carbon monoxide; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S20: Results of two-way joining cluster analysis related to benzo(a)pyrene; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S21: Results of two-way joining cluster analysis related to Diarrhoeic Shell-fish Poisoning (DSP) toxins; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S22: Results of two-way joining cluster analysis related to organoleptic characteristics; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S23: Results of two-way joining cluster analysis related to spoilage; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S24: Results of two-way joining cluster analysis related to health certificate(s); (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S25: Results of two-way joining cluster analysis related to packaging; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken; Figure S26: Results of two-way joining cluster analysis related to foodborne outbreak; (a) product; (b) notifying country; (c) country of origin; (d) notification type; (e) notification basis; (f) distribution status; (g) action taken.

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