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What is the true influence of the red tide on the production, price and marketing of the Galician mussel?

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ABSTRACT

In recent years, the Galician mussel industry has encountered an environmental factor capable of influencing its sea farming; the red tide. Its environmental and economic impact on mussel aquaculture is directly related to the duration of toxic processes. Therefore, in this work will be used the number of days of closure of production areas in order to analyze what is the true influence that red tides exert on the production, price and marketing of the mussel Galician.

TABLE OF CONTENTS

ACKNOWLEDGMENTS .... **III**

ABSTRACT .... **IV**

TABLE OF CONTENTS .... **V**

LIST OF TABLES .... **VII**

LIST OF FIGURES .... **VII**

LIST OF ABREVIATIONS .... **IX**

1. INTRODUCTION 1

1.1. The Mussel *(Mytilus galloprovincialis)* 1

1.2. What is the Red Tide? 3

1.3. Research Problem 4

1.4. Research Questions 5

1.5. Structure of the thesis 6

2. BACKGROUND INFORMATION 7

2.1. The World mussel production 7

2.2. The Spanish mussel production *(Galician production)* 11

2.2.1. The Galician Rías (zoning) 13

2.2.2. Phases and culture techniques 15

2.2.3. Marketing of the Galician mussel 17

3. METHODOLOGY 19

3.1. Case study 19

3.2. Data collection 21

4. RESULTS AND DISCUSSION........22

4.1. Influence of the red tide on Galician mussel production........25

4.2. Influence of the red tide on the prices of the Galician mussel........30

4.3. Influence of the red tide on the commercialization of the Galician mussel........35

5. CONCLUSION........39

6. REFERENCES........40

7. APPENDIX........42

LIST OF TABLES

Table 1. Distribution of Spanish mussel production by Autonomous Communities……..…12

Table 2. Distribution of polygons and bateas according to their rías.....................................14

Table 3. Export and import data for the Galician mussel industry (Third countries and European Union)…………………………………………..…………………………..17

Table 4. Export and import data for the Galician mussel industry (fresh, frozen and prepared)……………………………………………………………….…………………..18

Table 5. Calculation of the level of incidences of the red tide...22

Table 6. Correlation between mussel production and the incidence of biotoxins..................26

Table 7. Correlation between the incidence of biotoxins and industrial mussel production and fresh mussel production……………………………………………………………….29

Table 8. Correlation between mussel production and the Galician mussel price……………30

Table 9. Correlation between Galician mussel price and the incidence of biotoxins………..32

Table 10. Correlation between the incidence of biotoxins and industrial mussel price and fresh mussel price..33

Table 11. Correlation between mussel sales value and the incidence of biotoxins………….36

Table 12. Correlation between the incidence of biotoxins and industrial mussel sales value and fresh mussel sales value……………………………………………………...……….38

LIST OF FIGURES

Figure 1. Mussel...1

Figure 2. Red Tide..3

Figure 3. Top 5 of mussel producing countries in the world……………………………………7

Figure 4. Distribution of mussel species in the world…………………………………………8

Figure 5. Map of exports and imports of mussels worldwide (2015)…………………………9

Figure 6. The five largest Spanish aquaculture productions (2015)......................................11

Figure 7. Zoning of Galicia in Spain..……………………………………………………..…12

Figure 8. Zoning of the Galician rías…………………………………………………………..13

Figure 9. Spanish imports of mussel (Third countries and European Union)………………..17

Figure 10. World exports of Galician mussel (Third countries and European Union)………17

Figure 11. Spanish imports of mussel (fresh, frozen and prepared).……………………...….18

Figure 12. World exports of Galician mussel (fresh, frozen and prepared).…………………18

Figure 13. Level of incidence of Red Tides in Galicia mussel production (2006-2016).........23

Figure 14. Comparison between the production of obtained mussels and the expected production without the red tide (2006-2016).……………………………………………....23

Figure 15. Comparison between the value production of obtained mussels and the value expected production without the red tide (2006-2016)……………………………………24

Figure 16. Comparison of mussel production, production expectation and the incidence level of red tide (monthly)...25

Figure 17. Production according to destination: fresh mussel and industrial mussel.............27

Figure 18. Comparison between industrial mussel production and the incidence level of red tide (Annually)...28

Figure 19. Comparison between fresh mussel production and the incidence level of red tide (Annually)..29

Figure 20. Comparison between Galician mussel price and the incidence level of red tide (monthly)...31

Figure 21. Comparison between Price of mussel destined for industry and the incidence level of red tide (Annually)...32

Figure 22. Comparison between Price of mussel destined for fresh and the incidence level of red tide (Annually)...34

Figure 23. Comparison of mussel sales (euro), sales expectation and the incidence level of red tide (monthly)...35

Figure 24. Comparison between industrial mussel sales (euro) and the incidence level of red tide (Annually)...37

Figure 25. Comparison between fresh mussel sales (euro) and the incidence level of red tide (Annually)..37

LIST OF ABREVIATIONS

INTECMAR	Technological Institute for the Control of the Marine Environment of Galicia
AFTA	Association and Free Trade Agreement

1. INTRODUCTION

1.1. The Mussel *(Mytilus galloprovincialis)*.

Figure 1. Mussel. Source: Mexillon de Galicia, 2017

The Mediterranean Mussel, as is know to this invertebrate mollusk, it has a orange body that is protected by two elongated valves commonly called shells. The shells are mostly dark blue color and are joined by a natural hinge. This bivalve mollusk lives forming numerous communities and colonizing large areas of rocks to which they adhere through the filaments of the biso[1] that are in his foot. It lives shallow in the tidal zone, preferably in very beaten areas with lots of suspended organic matter.

It feeds on phytoplankton and zooplankton, and even on decaying organic particles found in sea water, by filtering it through its gills. The filtration capacity of the mussels is enormous, being able to pump up to 8 liters per hour.

Regarding the reproduction we must take into account that the mussel is dioic, has separated sexes, so that the male pours the spermatozoa in the water that are absorbed by the female at the moment of sucking or pumping the food, arriving at the paleal cavity where find the eggs to be fertilized. Its incubation time varies according to temperature: it is shortened with highs and lengthened with lows, but it lasts for one to two weeks. Subsequently, larva born that swims for 20 days and then begins to develop a shell, in its beginnings transparent and rudimentary but necessary to be fixed to the rocks or any other object that is submerged. In principle, these larvae are planktonic and can travel hundreds of km through the currents. Of these, 99.9% die, but they survive from 2000 to 5000 larvae per female, from which the juveniles developed("Mexillón de Galicia," 2017).

The breeding season is very wide, being the most intense periods in spring and autumn, although in many of its zonifications in the world, reproduction can take place at any time of

[1] Biso: Secretion produced by some mollusks that hardens with water and takes the form of filaments with which they attach to rocks or other surfaces

the year, thanks to the ideal conditions for spawning along the same. Although it is true that for its cultivation depends among other reasons of its destination, and is that the mussel destined to transforming companies is generally harvested in summer and the one destined for fresh consumption is harvested preferably during autumn and winter.

Its habitat of cultivation in most countries of the world is characterized by zonifications "to shelter of the open sea" as is the case of fjords or rías that do not surpass 30 km in length, with an extension between 2 and 25 km of width and with 40 to 60 m of depth. The water temperature is in a range between 10-20 ° C, the ideal salinity is around 34 ‰ and the average amplitude of tides is between 4 and 6 m. These characteristics combined with a stream of cold water rich in nutrients, stimulate the abundance of phytoplankton, that as we emphasize above is its main source of food.

In addition to our species (Mytilus Galloprovincialis), it is estimated that there are 12-14 different mussel species in the world, such as the blue mussel, also called the Atlantic Mussel (Mytilus edulis), the Californian Mussel (Mytilus californianus), the Chilean Mussel or Chorito (Mytilus chilensis), the Green Mussel (Perna viridis), the New Zealand Mussel (Perna canaliculus), etc.

1.2. What is the Red Tide?

Figure 2. Red Tide. Source: Internet

The red tide is a natural process of excessive growth of microscopic algae known as dinoflagellates, which in large quantities give the water different colorations mainly reddish or brown (depending on the type of algae present). The problem is that it is usually accompanied by geners of algae producing toxins, causing short-term problems in the cultivation and extraction of the majority of molluscs that are grown in that area.

These mollusks, both farmed (mainly mussels) and others that live partially or totally buried (scallop, cockle, clams, etc.) are fed by taking these algae from the water through their filtration. Here the problem, that when that red tide produces toxins, the mollusc filters the toxins and the algae producing them, also storing the toxins in your body for long periods of time. These accumulated toxins do not pose a major problem for mollusc, but they can be a major risk to the consumer, which depending on the type of toxin may suffer different clinical conditions of diverse consideration.

Although the phenomens that determine the formation of red tides are not completely known, on the coast of Galicia its appearance is generally associated with periods of stability in the mass of water, abundance of nutrients and high temperatures. Specifically the most frequent time of occurrence of this type of tide takes place between the months of July and October, although as we will see later in some occasion they have advanced to the month of May and in several occasions prolong until the months of December and January.

1.3. Research Problem.

The economic impact of red tides on aquaculture is directly related to the duration of toxic processes and the type of organisms on which these processes are affected. In the case of Galicia, given the type of aquaculture that is carried out and its extraordinary development, the economic repercussions of toxic red tides are considerable and mainly affect the mussel industry.

Over the years, the unexpected presence of biotoxic algae increases the number of days in which this industry is forced to stop the extraction of the bivalve in question. In this way, the appearance of red tides prevents the mussel from reaching the different markets causing a negative effect on the economy.

The lack of a solution to this problem has led the Galician industry of the mussel to accept the situation, shelteryng solely in the knowledge about the evolution of these previous episodes and the availability of information as a warning provide to them by the Technological Institute for the Control of the Marine Environment of Galicia (INTECMAR). This institute informs and prhoibits mussel producers from bivalve extraction when the waters present high levels of toxicity.

The complexity of the situation also lies in the difficulty of estimating real losses. There are currently very few studies on these economic losses due to the large number of factors that may influence betwenn the closing days of the polygons and the final production or profit generated by the product. The final destination of the mussel (industrial or fresh), the time of the year in which the extraction takes place or even the introduction of a substitute product, are some of the many factors that make it difficult to obtain accurate data on the true losses that the red algae produces.

1.4. Research Questions.

The main objective of this work is to determine the true influence of red algae on the Galician mussel industry.

To do this, I will make use of the only reliable data available to me (the number of closing days of the production areas because of the red tides), focusing my efforts on estimating the level of influence suffered by this sector in basis to the reduction of the extractive activity of the mussel in these periods of toxic blooms.

Faced with the possible appearance of other factors that make it difficult to obtain accurate data, I will also focus my studies on obtaining the degrees of correlation between the periods of prohibition of extraction and the figures of production, marketing and price of the mussel Galician.

In this way I will be able to know if the times of red tide have a direct influence and what is the level of influence on the production, the price and the commercialization of this bivalve.

1.5. Structure of the thesis.

Chapter 1. Introduction

It offers an overview of the research topic, in addition is explain the problem that will be analyzed in this thesis and are pose the questions to be answered.

Chapter 2. Background Information

Its main objective is to provide basic information about the mussel industry. This second chapter shows production and marketing numbers as well as other data regarding the zoning, distribution and cultivation of the Galician mussel.

Chapter 3. Methodology

This chapter discussed how the case study will be carried out: by analyzing the data on the closing days of the cultivated areas in correlation with the production, price and marketing volumes of the mussel. In addition to explaining the origin of all the data needed to perform such analysis.

Chapter 4. Results and Discussion

Is based on showing and analyzing the data obtained on the influence of the red tide (closing days of the polygons) on the Galician mussel industry.

Chapter 5. Conclusion

In this last chapter will give a final conclusion on the analysis performed.

2. BACKGROUND INFORMATION

2.1. The World mussel production.

Aquaculture production has been around for hundreds of years, but in the last fifty years it has expanded to become a large industry of great economic and social importance. A growing demand of aquatic food products, combined with a levelling out in the capture fishery have led to an increased effort in aquaculture production (Apromar, 2016). Nowadays, this production is close to 100 million tons and has surpassed the capture production which is close to 95 million tons.

Mussel production which is the topic of this study, counted for more than two million tons of the aquaculture production in 2015, placing mussel farming as one of the main aquaculture products around the world. About 40 countries are involved in mussel production where the main producer is China which produced 845 thousand tons bivalves in 2015, more than 40% of the global production. Annual productions in Spain and Chile exceed the 200 thousand tons (13,5% and 10,4% respectively) while Thailand or New Zealand follow next with annual productions between 75 and 150 thousand tons (fig.2).

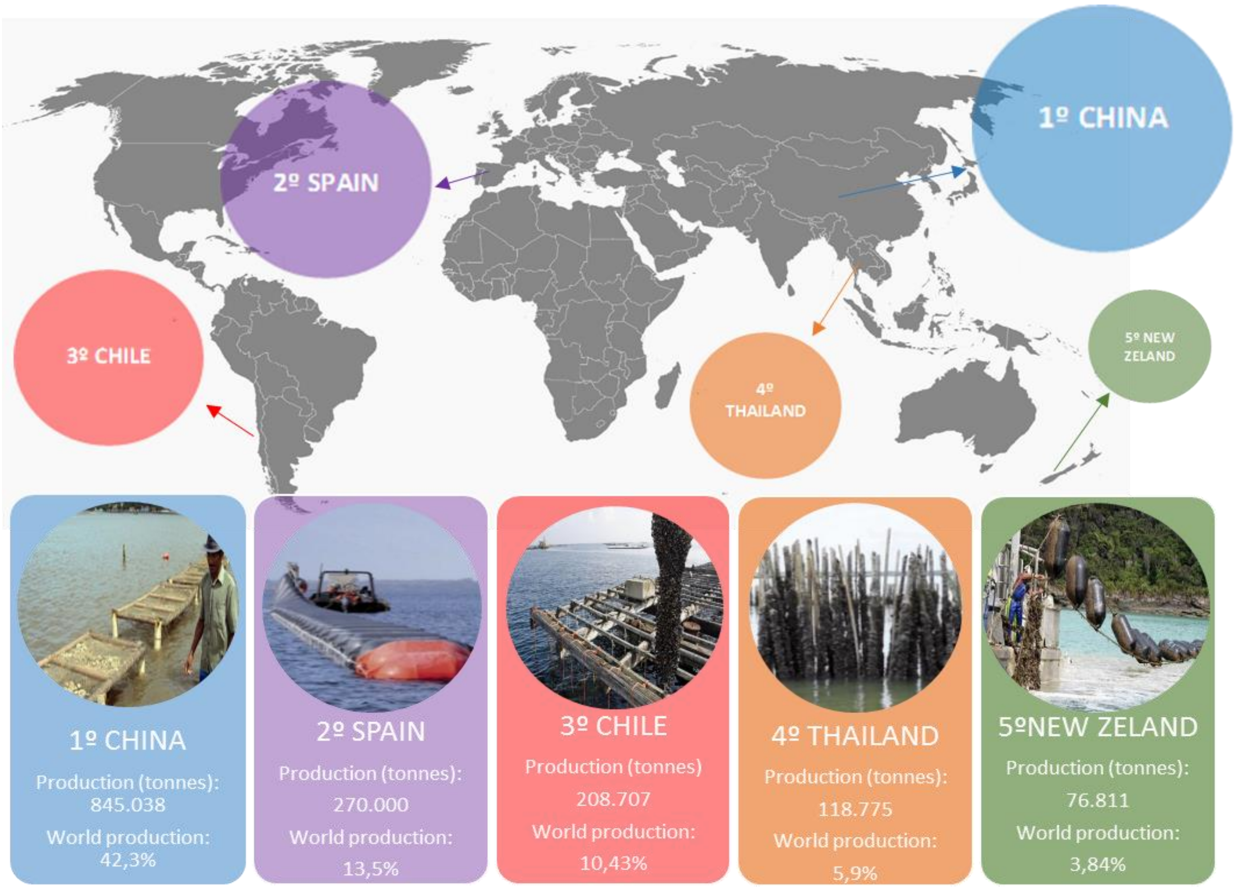

Figure 3. Top 5 of mussel producing countries in the world. Source: Own figure with FAO data, (Fishstat, 2016)

In the European context the mussel production peaked by the end of the 1990s reaching almost 750 thousand tons per year. Since then the production has declined to the current level of about 550 tons. Three countries are responsible for two-thirds of European mussel production. Spain is by far difference the largest producer followed by France (about 80 tons per year) and Italy (with about 65 tons per year). It is also noteworthy that in recent years several countries have become mussel producers, including other European countries such as Ireland and England.

The different mussel producing countries entail a remarkable diversity of cultivated and commercialized species, in this way the mussel is far from being a homogeneous and standardised product worldwide. The two main species produced in Europe are the Blue Mussel (Mytilus Edulis), typical of the Atlantic area and cultivated in countries such as France, Holland, Ireland and Great Britain, and the Mediterranean Mussel (Mytilus Galloprovincialis), grown in Spain and Italy. Other species of relevance are: Chorito (Mytilus chilensis) which is part of the Chilean production or Green Mussel (Perna viridis) that focuses on Thailand production, as well as some other Asian countries.

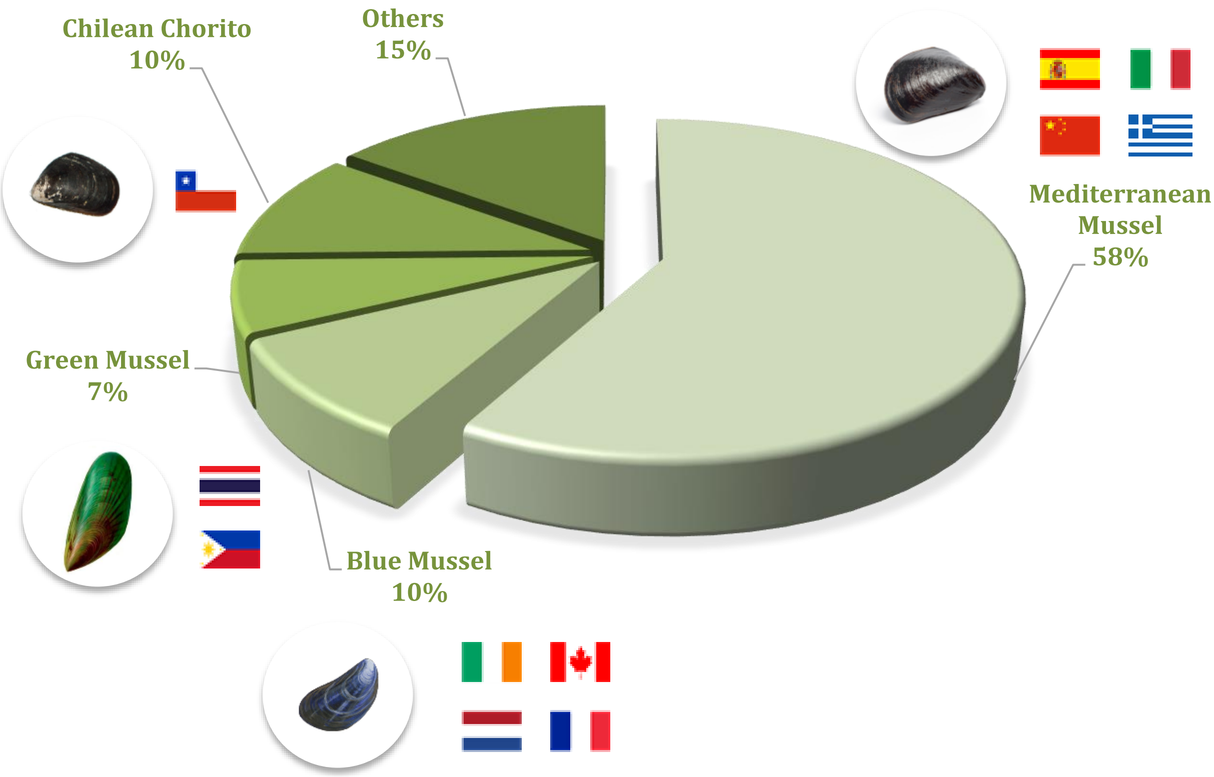

Figure 4. Distribution of mussel species in the world. Source: Own figure with FAO data, (Fishstat, 2016)

Regarding the global commercialization of the mussel, we must point out that although there have produced around two million tons in the last year, the participation of this bivalve in international trade has been relatively small, since most of the cultivated mussels is consumed in The country of production. In 2016, world mussel exports reached between 250,000 and 300,000 tons, with a market value of between 500-550 million dollars. 78.62% of the total was exported live, fresh or refrigerated, corresponding to this figure 62.05% of the value of the product. The second largest presentation was frozen mussel meat with a 15.08% of the volume, reaching 25.9% of the value marketed, being the fastest growing type of product in recent years. At this point we must emphasize that we are not making a homogeneous comparison, since while the fresh or frozen mussel includes the whole shell or half shell, the frozen mussel meat bases its weight only and exclusively on the weight of the food.

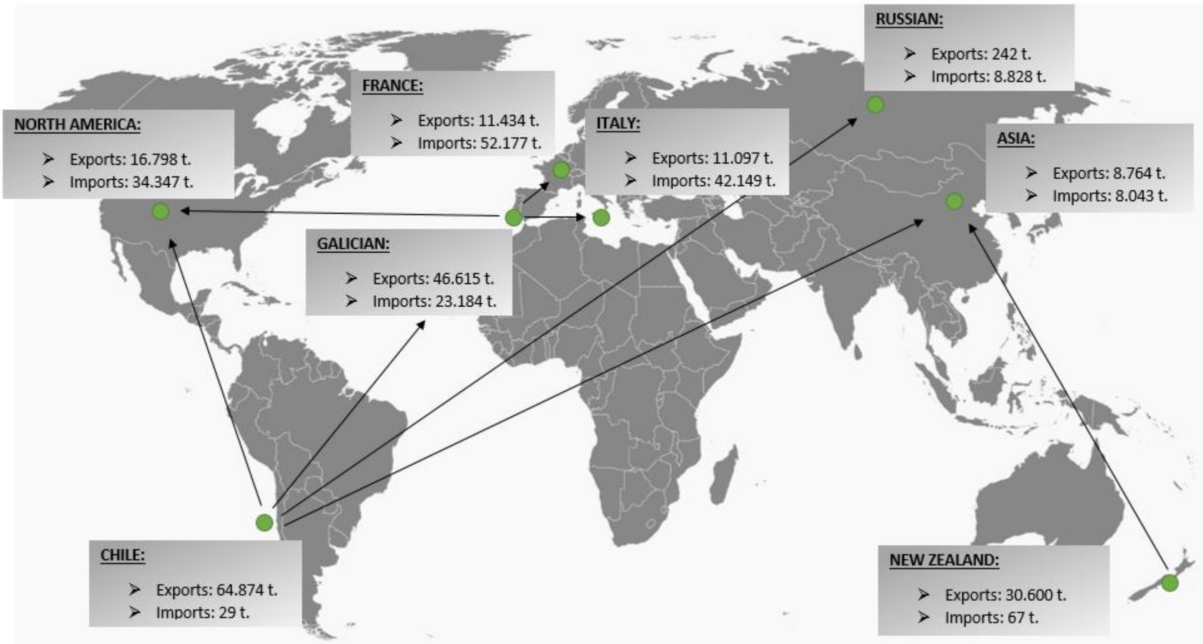

Figure 5. Map of exports and imports of mussels worldwide (2015). Source: Own figure with FAO data, (Fishstat, 2015)

As we can see in Figure 5, the diversity of mussel producing countries make up a world market that is certainly expanded to most continents. In order to give a small vision of this market I have decided to divide it according to its terms of export and import.

- **Exports:**

According to data from the year 2015, Chile is currently still the largest exporter of mussels worldwide. The volume of these exports in the last year represented 70,000 tons, reducing their volume by 12% over the previous year due to serious problems with the red tide. The 60% of these exports go to France, Spain or Italy among other countries of the European Union, however the Chilean industry has concentrated its efforts in diversifying its markets, in order to reduce the exposure to European countries. So the efforts of South American industry are now focused on increasing shipments to destinations such as China, Russia or the United States.

Within the European Union, the largest exporter of mussels is the Netherlands, currently has export figures close to 45,000 tonnes, with a total production of 65,000 tonnes of mussels. It is also important to highlight the increase in exports by countries such as Denmark (3,800 tonnes), New Zealand (30,600 tonnes) and Canada (16,525 tonnes).

- **Imports:**

Although in recent years have been reduced in terms close to 3-4%, imports of mussels in the European Union are around 100,000 tonnes of bivalve annually. The largest importers in the EU have for years been France and Italy, which consolidate their position by hoarding between the two the 58% of the total imports of mussels from the EU. In much smaller import figures are countries as Germany, Belgium and the Netherlands.

Outside the European Union highlight imports from the United States and Russia, which due to their high populations have imported 33,420 tonnes and 8,828 tonnes respectively in the last year.

2.2. The Spanish mussel production *(Galician production)*.

Spanish aquaculture began in the 60's, in these years expectations indicated it as an activity capable of compensating for the decline suffered by fishing, but the true is that never have been able to counteract the decrease in catches (Apromar, 2016). However aquaculture production was increasing, cutting differences annually with respect to fishing. This development of aquaculture is largely the fault of the mussel, which in 2015 produced 270,000 tonnes in Spain, being the main aquatic resource alive in terms of weight. In total, Spanish aquaculture production in the last year produced 334,022 tonnes, of which 80.8% correspond to the mussel, generating a sales value of 120.1 million euros. In addition to the mussel, the Spanish aquaculture sector has production of seabass (21,830 t), gilthead (16,902 t), rainbow trout (10,162 t) and turbot (7,860 t).

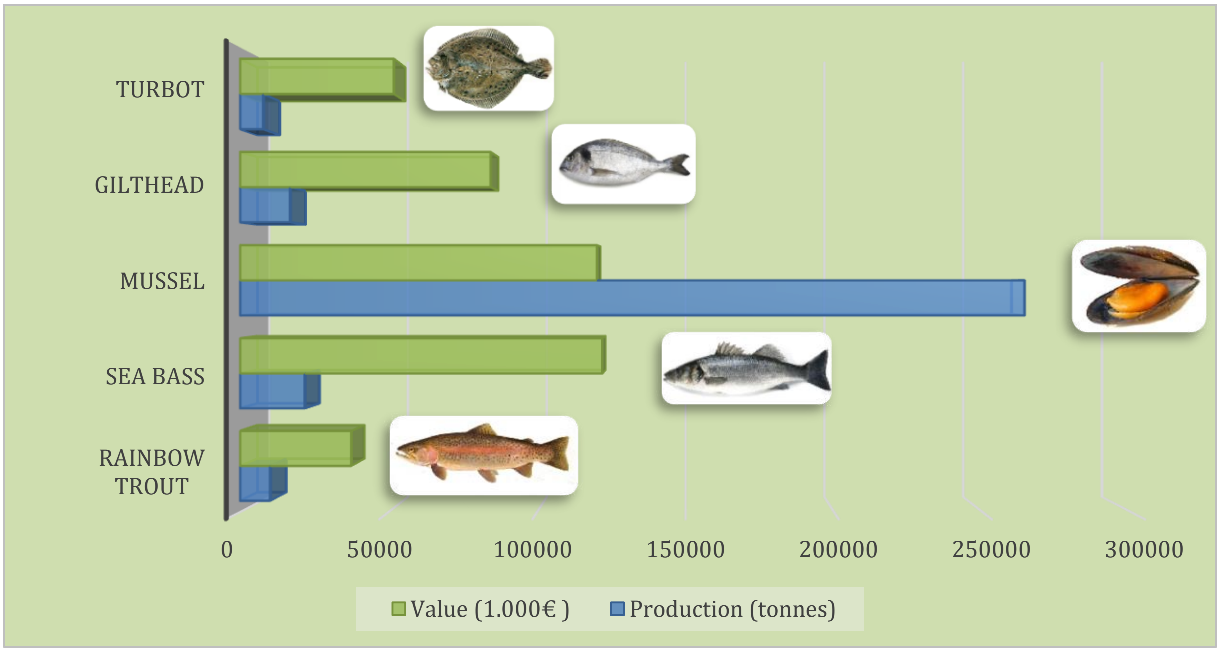

Figure 6. The five largest Spanish aquaculture productions (2015). Source: Own elaboration from Jacumar, 2015.

Globally, it was at the beginning of this century that Spain consolidated as the second mussel-producing country in the world, only surpassed by China. Since then its production has remained in a scale of between 170,000 and 300,000 tons in the last decades.

Five are the Spanish autonomous communities in which mussel is cultivated, but its main production is based in Galicia (figure.6). The traditional cultivation carried out in the bateas of the 5 Galician rías represent 97% of the total national mussel, leaving only the remaining 3% in the hands of four other autonomous communities. This fact makes it possible for the production of mussels to mean for Galicia an engine of social and economic development of its coastal zones that are closely linked to the maritime, fishing and aquaculture sectors.

Figure 7. Zoning of Galicia in Spain.
Source: Internet

In addition to being the dominant autonomous community, Galicia increased its fresh mussel production by more than 12% in 2015, from 235,462 tonnes in 2014 to 264,119 tonnes in 2015 (Table 1). In this way, Galicia raised more than 112 million thanks to its "black gold" of its nurseries, that is to say, 93% of the value of this species in Spain and 78% of all the income generated by cultivated molluscs. Meanwhile, the mussel last year generated revenues of just over one million euros in Andalucia, just over four million in Cataluña and two million in the Valencian Community (Jacumar, 2016).

Table 1. Distribution of Spanish mussel production by Autonomous Communities, 2012-2015 (tonnes).

	2011	2012	2013	2014	2015
Galicia	222.946,90	227.232,720	183.169,490	235.462,055	264.119,480
Cataluña	3.609,59	2.843,620	3.436,280	4.314,220	3.756,370
Andalucía	502,36	1.115,980	1.601,940	802,940	1.704,940
C. Valenciana	356,02	384,100	607,430	787,420	937,200
Baleares	174,98	177,870	129,800	112,100	116,930
TOTAL SPAIN	227.589,85	231.754,290	188.944,940	241.478,735	270.634,920
% Galicia	97.92 %	98.04 %	96.94 %	97.50 %	97.59 %

Source: Own table with Jacumar data, 2017

2.2.1. The Galician Rías (zoning).

The term "rías" is known in Spain as those incursions of the sea in the coast in which flooded valleys by the descent of the terrestrial level (and relative rise of the level of the sea). These rias have a major role along the 1,200 km of coast that have the Galician autonomous community (Mexillón de Galicia, 2017). The Galician Rías are traditionally divided into Rías Higher and Rías Lower, according to their position with respect to Finisterre as the westernmost point of Galicia.

Like the fjords, the Galician Rías possess great nutritional value for the multitude of species that can inhabit in them. In this case the phytoplankton that is generated on the Galician coast is the star food around which the entire marine system revolves. The warm temperatures of the water and the high primary production, make of them an excellent place for the development of the seafood.

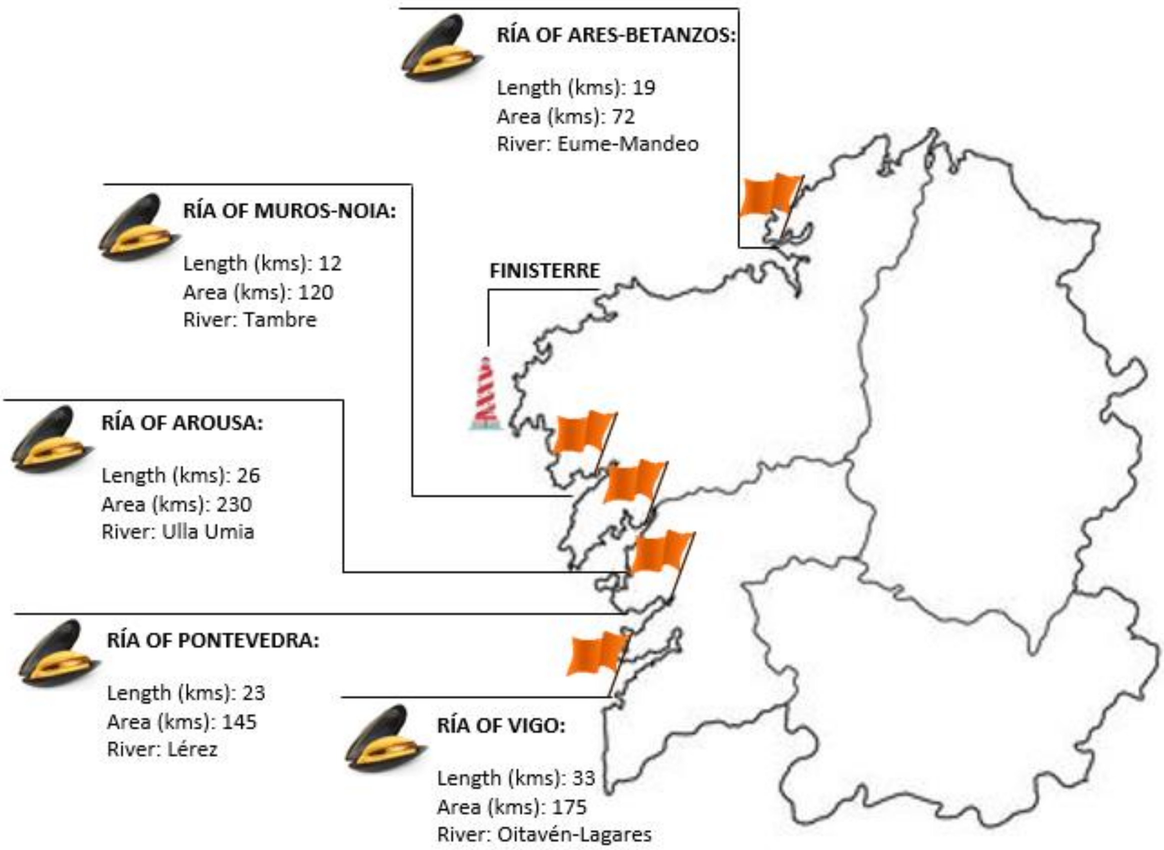

Figure 8. Zoning of the Galician rias. Source: Own figure.

The mussel production in Galicia is developed in the inside of these rias and in particular in the Rias Baixas (fig. 8). The distribution of the bateas[2] in the rias follows a structure of polygons which has recently been rearranged. In the years 70-80, had a total of 5,500 anchorage points (bateas) that were distributed in 78 polygons. However, because they had poor bottoms or were in very exposed areas, some 2,000 anchorage points were not used for production. Subsequently, in search of an improvement in production and an administrative clarification of the concessions, a new framework was established with 52 polygons that currently exist, including 3,337 bateas in 2016 (Xunta de Galicia, 2017).

Table 2. Distribution of polygons and bateas according to their rías.

Ría	Mussel Polygons	Number of Bateas	% Bateas
Ares-Betanzos	2	103	2,09 %
Arousa	27	2.292	68,68 %
Pontevedra	8	346	10,37 %
Muros-Noia	3	118	3,54 %
Vigo	12	478	14,32%
Total	52	3.337	100 %

Source: Own table, with Conselleria do mar data, (Xunta de Galicia, 2017)

As can seen in table 4, these bateas are grouped into 52 polygons, being the Ría de Arousa the that concentrating almost 69% of the bateas, with a total of 2,292 installations. Outside of Galicia, or what is the same in the rest of Spain, only represent 5% of the total of the bateas, which supposes a small number of 210 bateas distributed between Cataluña, Baleares, Comunidad Valenciana and Andalucia.

One of the main secrets of this good pairing between the zoning and the Galician mussel lies in reaching a commercial size (70-95 mm) in about 17 months, compared to what happens in other producing countries, where the growing period is much more dilated. A clear example we can observe in the rest of Europe, where the mussel needs 2 to 6 times more time to reach the same size.

[2] Batea: Is a floating structure of rectangular shape (100 to 500 m) destined to the breeding of the mussel.

2.2.2. Phases and culture techniques.

1º SEED:

The process of obtaining the seed has its starting point in the thousands of bateas that populate the Rías Gallegas. Here naturally millions of males and females of cultivated mussel cast the gametes into the sea, where fertilization occurs, giving rise to larvae that will later be fixed to the rocks.

Subsequently the mussel growers themselves go to these rocks which are hit hard by the coast and collect the seed.

2º ENCORDADO:

The seed collected from the rocks is taken to the batea or to the boat and the are made mussel strings. The mussel is wrapped around the rope with the aid of a thin biodegradable rayon netting, giving the mussel long enough for it to be drawn onto the rope. This operation is done either manually or by machines specially designed for that purpose.

3º UNFOLDING:

After 4 to 6 months at sea, when the mussel reaches 4.5 or 5.5 cm, due to the considerable increase in weight of the mussel, it becomes necessary the unfolding of the ropes, that is, the making of new ropes of lower density. With this unfolding it facilitates the growth of the mussel, in addition to avoiding its detachment of the cords. For each rope of mussel are obtained between two or three strings of unfolding that are thrown to the sea until its commercialization.

4º EXTRACTION:

After about a year, the mussel reaches commercial size. The ropes are removed from the water with the help of the crane and the boats for later selection and commercialization.
The cultivation is a totally natural process in where the mussel efficiently uses that wealth of nutrients that nature give to the Galician rías.

- **BATEA:**

The Bateas consist of a rectangular wooden framework of 100 to 500 square meters supported by steel floats coated with glass fiber, polyester or filled with expanded polyester. This construction is secured to the bottom by one or two steel chains and weighing about twenty tons. Nylon ropes of three centimeters thick and ten to twelve meters long are hung from the wooden framework, where the mussel is fattened.

2.2.3. Marketing of the Galician mussel

Thanks to the Galician production, the commercial exchanges of mussel at European and international level have increased in the last years. In these years Spain was adopting a position as an exporting country while maintaining a positive trend in its participation in the international market (Ministerio de Agricultura, 2015). In the year 2015, a total of 264,109 tonnes of mussels were produced in Galician rías. Curiously, 19% (49,630 t.) Of this production is destined for markets outside Spain. This destination, as we can see below (Table 3) is mainly the European Union, where they go for 99% of the tons of Galician bivalve. However when we talk about the importation of mussels in Spain, we see that 66% of these purchases come from third countries such as Chile.

Table 3. Export and import data for the Galician mussel industry (Third countries and European Union).

Galician Mussel Trade	Imports (tonnes)			Exports (tonnes)		
	2013	**2014**	**2015**	**2013**	**2014**	**2015**
Third Countries	13.145	16.137	13.254	947	881	719
European Union	4.959	7.101	6.679	46.835	46.645	48.911
TOTAL	**18.104**	**23.238**	**19.933**	**47.810**	**47.527**	**49.630**

Source: Own table with FAO data (2016)

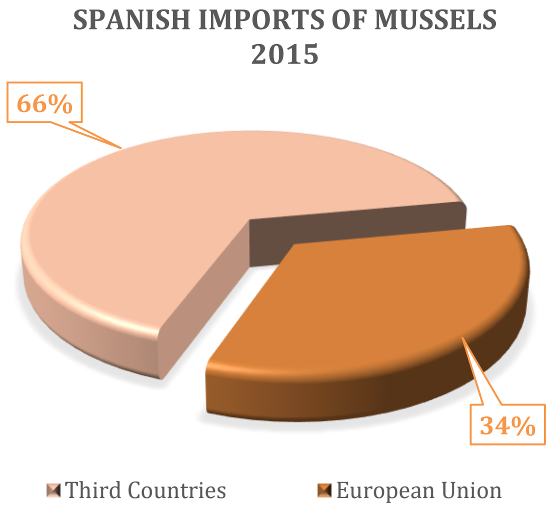

Figure 9. Spanish imports of mussel (Third Countries and European Union).
Source: Own table with FAO data (2016)

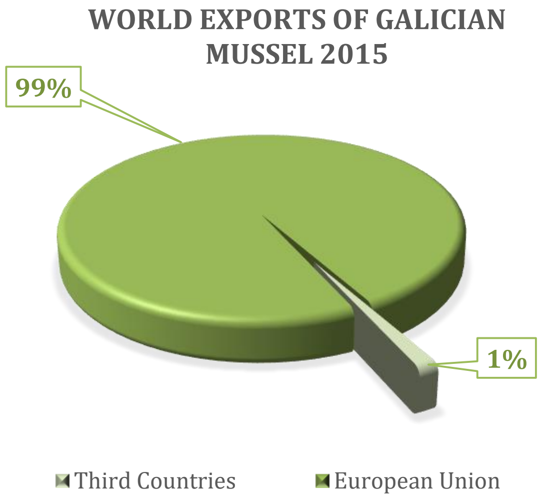

Figure 10. World exports of Galician mussel (Third Countries and European Union).
Source: Own table with FAO data (2016)

In a more detailed analysis we observed that 61% of Spanish mussel imports are prepared and preserved, 30% being fresh or refrigerated, and the remaining 9% being frozen (Table 5). It is difficult to understand that a country like Spain that has a high production of mussels needs to import this product while also exporting large tonnage abroad. The answer to this contrast is the low price of the Chilean mussel, a product that has characteristics very similar to those of the Galician mussel and that at the moment begins to represent a great problem for the Spanish industry.

On the other hand, and returning to terms of export of our mussel, we can see in table 5 that 74% of the mussel exported by Spain is fresh or refrigerated, 19% being frozen, and the remaining 7% prepared and preserved.

Table 4. Export and import data for the Galician mussel industry (fresh, frozen and prepared). Source:

Galician Mussel Trade	Imports (tonnes)			Exports (tonnes)		
	2013	**2014**	**2015**	**2013**	**2014**	**2015**
Fresh and Chilled	3.991	6.460	6.043	35.573	36.144	36.557
Frozen	2.557	1.625	1.861	9.518	8.985	9.732
Prepared and Preserved	11.556	15.154	12.029	2.719	2.398	3.341
TOTAL	**18.104**	**23.238**	**19.933**	**47.810**	**47.527**	**49.630**

Source: Own table with FAO data (2016)

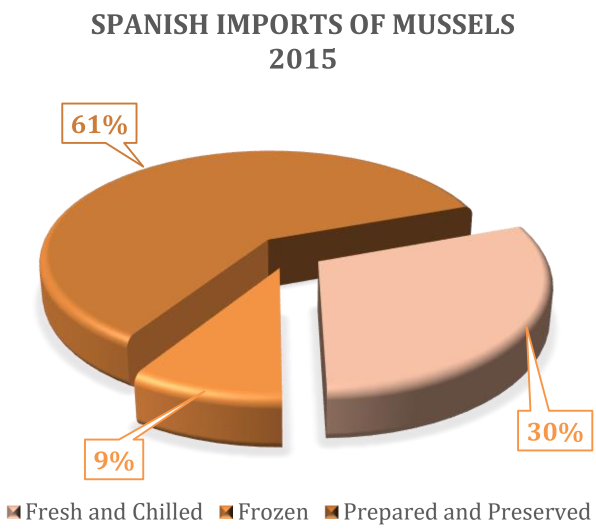

Figure 11. Spanish imports of mussel (fresh, frozen and prepared).
Source: Own table with FAO data (2016)

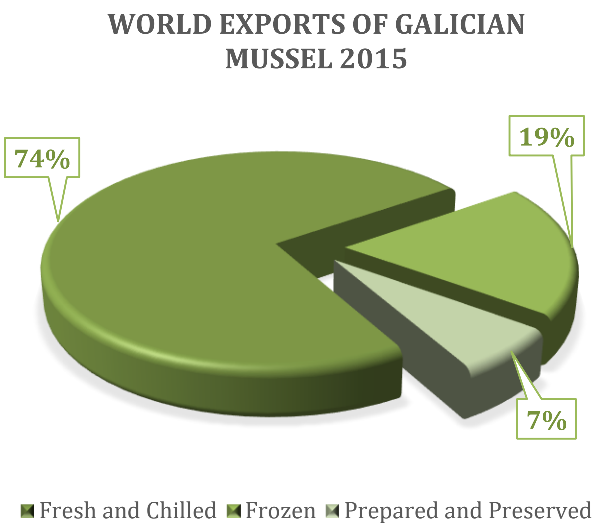

Figure 12. World exports of Galician mussel (fresh, frozen and prepared).
Source: Own table with FAO data (2016)

3. METHODOLOGY

This thesis is an empirical research based on secondary sources of data on Galician mussel production. The main focus of this work is the quantitative analysis of the data on the closing days of the cultivated areas in correlation with the volumes of production, price and commercialization of the mussel.

3.1. Case study. *(What level of influence does have the red tide on the mussel industry?)*

During the last 20 years, has been blamed to the proliferation of red tides of incalculable losses on the Galician mussel industry, but the reality is that there are no concrete results in this regard. So in order to clarify these figures, I will proceed to study the impact of the red tides as a whole on the mussel industry. To make this estimate, I will first use the information related to the closing days of the polygons. These data correspond to the period of the last 10 years (2006-2016), providing for each annual date of:

- **Number of polygons:** which we will call A.
- **Days of closure of the polygon per year:** which we will call B.
- **Maximum number of possible closing days:** 365 or 366 respectively and we will call it C.

Through these and by means of the following formula I will be able to calculate the level of incidence of the red tide in percentage for each year (Rodríguez et al., 2011).

$$\textbf{Level of Incidence} = \sum \frac{B}{A * C} * 100$$

We must bear in mind that the maximum incidence would occur if all the polygons remained closed throughout the year, which would mean that all mussel bateas did not produce during this period.

Once the percentage of annual incidence has been obtained during the years chosen for the study, will be calculate the new estimated value of sales (euros), as well as the new

production numbers (tons) of the mussel. In this way we will be able to near to the losses caused by the red tide on the industry of the mussel.
However, must take into account that the closure of a polygon during a certain period does not necessarily imply a loss of production or economic, since there may not be a product removable or marketable at the time of closure or the product could have been extracted before or after the closing period.
In this way, in order to verify more precisely the level of influence that the red tides exert on the mussel industry, I will subdivide this analysis into three sections: Production, Price and Marketing Value.

- **Production:** In the first place I will make an evolutionary comparison between January 2010 and December 2016. It compares the monthly data of 3 variables: the production data of each month, the expected production of each month (calculated through of a monthly average in previous years) and the closing rate of the polygons (incidence level of each month previously calculated) caused by the appearance of episodes of biotoxins. In it can see with greater precision if the fluctuations exerted by high or low levels of biotoxins have an abrupt influence on production figures.
  Once the comparative is visualized, will analyze the degree of correlation between the monthly production data and the levels of influence of the biotoxins used in the previous comparison.

- **Price:** When analyzing the possible influence of the red tide on the price of the mussel, we must always keep in mind the importance of supply and demand, since this is the first factor by which the price of any product must be guided. In this way, the analysis of the degree of correlation between the price of the mussel and the production will be carried out first.
  Subsequently, as in the previous section we will make an evolutionary comparison between the price of the Galician mussel and the incidence level of the red tide for all the months from 2010 to 2016.
  Finally, in order to verify the real influence of the red tide on the price, the degree of correlation between the two variables will be calculated.

- **Marketing:** I must point out that in this section are always talking about the value of sale the mussel. In this case the purpose of this analysis is to estimate what are the economic losses that the red tide produces in this industry.
  As in the analysis of the production, in the evolutionary comparison the monthly data of 3 variables will be used: the sales value of each month, the expected sales value of each month (it is calculated through a monthly average in the Years) and the rate of closure of the polygons (incidence level of each month previously calculated) caused by the occurrence of episodes of biotoxins.
  Also, as in the previous sections, the calculation of the degree of correlation between the sales value of the mussel and the incidence level of the toxic algae will help us to verify the relationship between both variables.

In addition, with the idea of giving a still deeper view on the level of influence, data will be analyzed separately according to fresh or industrial mussel destination for each of our three variables: production, price and marketing.

3.2. Data collection.

One of the main difficulties when analyzing a sector such as that of the Galician miticulture is to find the appropriate data, since the sources are generally scarce and incomplete. In this way has had to complement and calculate several of them to be able to carry out the relevant analysis, as well as to answer the objective of my work.
It is important to point that the effect of red tides on mussel culture depends not only on the number of days the red tide can be detected but also on the extent of the affected area. So thanks to the Technological Institute for the Control of the Marine Environment of Galicia (INTECMAR) have been able to know which days of the year and in which specific areas the red tide made its appearance. Through to online contacts and in person, I have been able to understand the difficulty of carrying out an analysis of these dimensions, where in addition to the main factor, in this case red tide, there are many others that hinder and cloud the understanding of it.
On the other hand, all data related to the production, marketing value or price of the Galician mussel have been extracted from the Consellería del Mar de la Xunta de Galicia, the main regulating body of aquaculture that is developed in Galician waters.

4. RESULTS AND DISCUSSION

Once the thesis procedure has been explained, I will first start by applying the incidence equation, in order to obtain the annual percentage corresponding to the impact of the red tide on mussel production.

As we can see in table 5, during the last ten years, the level of affectation on the production of mussels was increasing, and is that as the years pass, the number of days of closing of production is greater . It is in 2013 when the maximum incidence level is presented with 47.25%, or what is the same, an annual closing of 8,624 days out of the 18,250 possible a year. On the other hand, its lowest peak was found in 2008 where the cultivated areas were closed for a total of 1,801 days out of the 17,934 possible, assuming these figures a production incidence rate of 10.04%.

Table 5. Calculation of the level of incidences of the red tide.

Year	Number of polygons (A)	Closure days (B)	Days of the year (C)	Maximum possible incidence of red tides (A × C) = D	Incidence level (B/D) × 100 = %
2006	49	4010	365	17885	22.42 %
2007	49	2316	365	17885	12.95 %
2008	49	1801	366	17934	10.04 %
2009	49	4301	365	17885	24.04 %
2010	49	4015	365	17885	22.44 %
2011	50	4988	365	18250	27.33 %
2012	50	4646	366	18300	25.38 %
2013	50	8624	365	18250	47.25 %
2014	50	7784	365	18250	42.65 %
2015	52	6976	365	18980	36.75 %
2016	52	7589	366	19032	39.87 %

Source: Own elaboration based on Intecmar data (2016).

If these percentages of incidence are plotted in an evolutionary chart (figure 13) we can see with greater clarity the upward trend that produces the red tide in recent years. As can be seen in the regression curve, the influence begins to be worrisome with the passage of time, since in only 10 years it has been placed in a percentage close to half of the production. In other words we could be talking about that about half of the Galician mussel production that could be extracted from the troughs, is lost due to the parónes by the closing of the polygons.

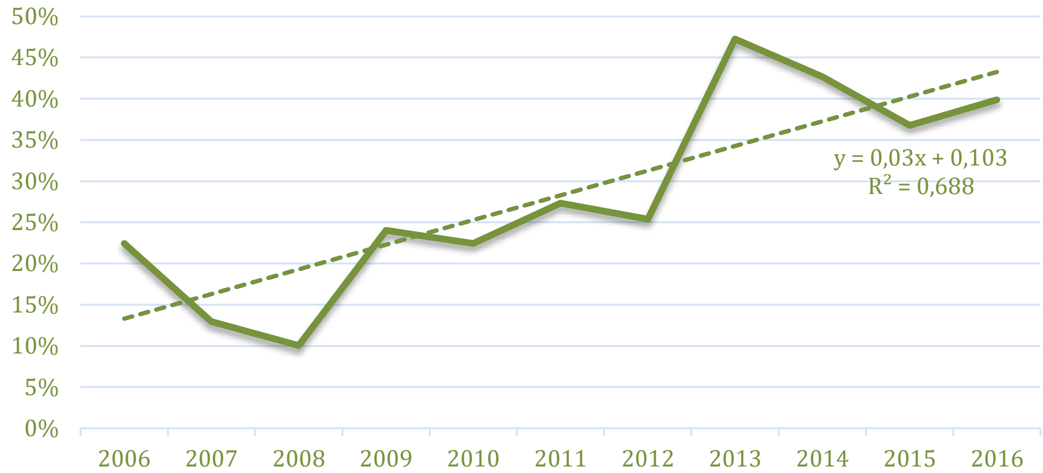

Figure 13. Level of incidence of Red Tides in Galicia mussel production (2006-2016). Source: Own elaboration.

Thus, if we apply these percentages of incidence on the numbers of mussel extracted (tons), we can approximate the amount of mussel that could not be extracted because of the red tide. In the figure 14 shows the numbers for the last years, where an influence of close to 40% in 2014, 2015 or 2016, would mean an estimated decrease of 100,000 tons of mussels per year.

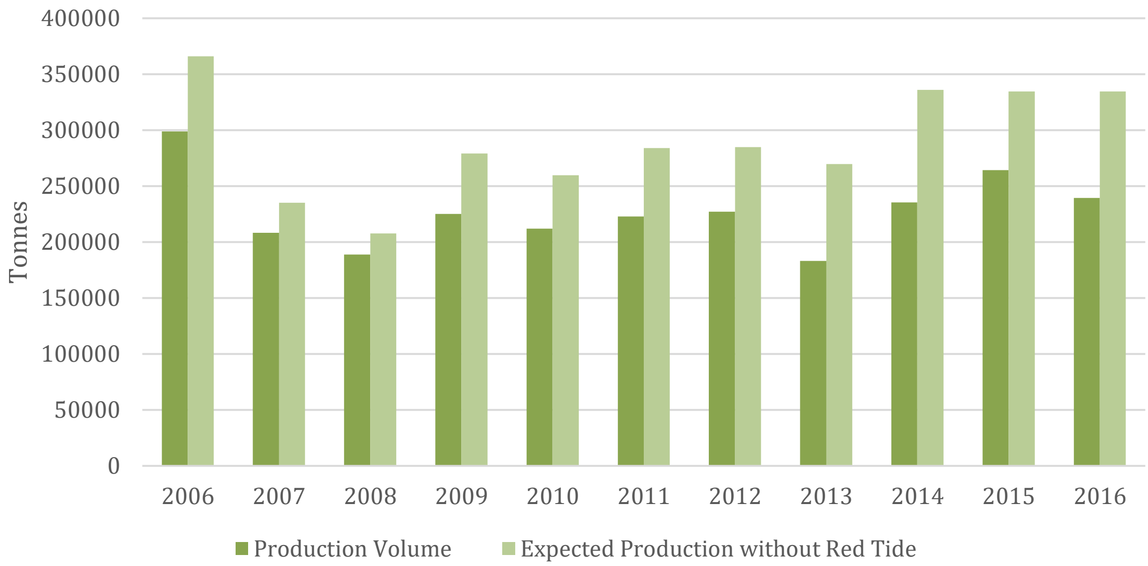

Figure 14. Comparison between the production of obtained mussels and the expected production without the red tide (2006-2016). Source: Elaboration based on Consellería do mar data and own calcutaltion (2016).

On the other hand, if the incidence rates are applied to the economic value of the mussel sold (euros), we can estimate the commercial losses generated by the red tide. In this case we would be talking about that the Galician mussel industry could be losing annually around about 40 million euros, since the value of these round in the last years the 100 million euros.

Figure 15. Comparison between the value production of obtained mussels and the value expected production without the red tide (2006-2016). Source: Elaboration based on Consellería do mar data and own calcutaltion (2016).

In summary, can assure that production and marketing estimates are certainly alarming in recent years, because as mentioned earlier, all these numbers of influence of the red tide on the mussel show an upward trend.

However the influence of the red tide on the mussel industry does not always depend 100% of the closing days of a polygon. The production, the market price and the commercial value of the mussel are linked to a series of environmental and commercial factors that reduce reliability to the previously calculated numbers. To analyze each of these factors and determine the true correlation between the red tide and the closing days of the polygons, I will subdivide this analysis into three sections:

4.1. Influence of the red tide on Galician mussel production:

From the batea to its final consumption, the mussel suffers several environmental and commercial phases. Specifically it is at the time of its extraction when the red tide makes its first negative appearance, preventing the extraction of the bivalve during time and in indeterminate places. In this case, if compare the production and the expected production of mussel (monthly average of production of the previous years) for the years 2010-2016 with the closing rate of the polygons (incidence level) caused by the occurrence of episodes of algal biotoxins, it is possible to verify the relationship between the product harvested and the presence of red tides.

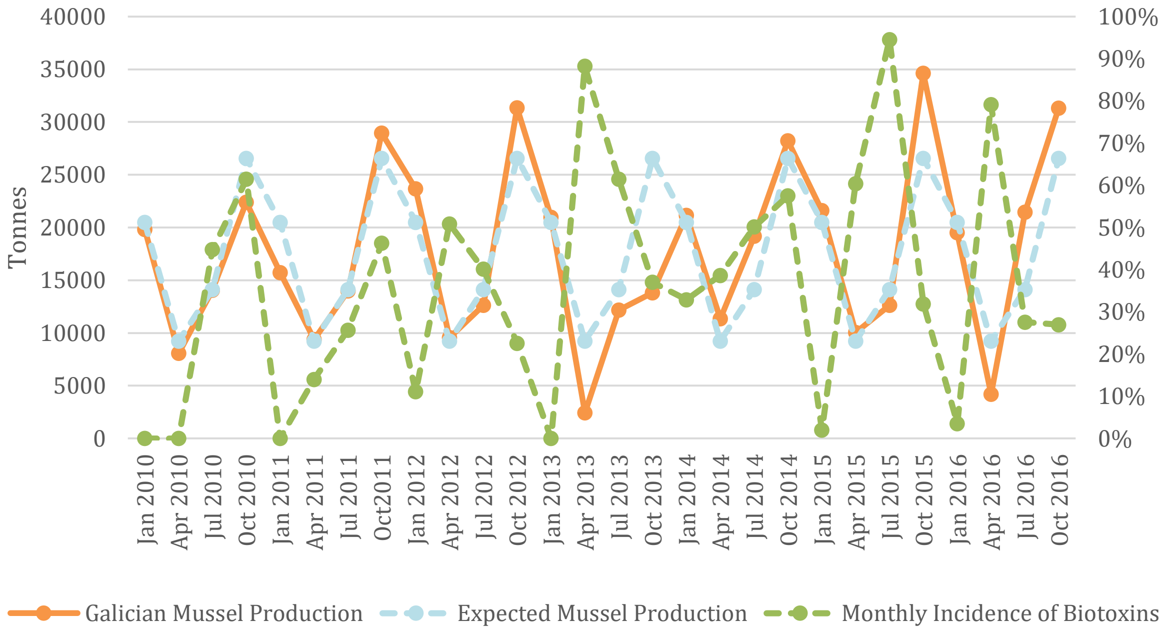

Figure 16. Comparison of mussel production, production expectation and the incidence level of red tide (monthly). Source: Elaboration based on Consellería do mar data and own calcutaltion (2016).

As can be seen in this figure 16, the results reveal that the more pronounced deviations between mussel production and production expectation coincide with periods of high polygon closure rates due to red tides. In this way, observed that in October 2010, April 2013 or April 2016, with high toxicity rates of 61%, 88% and 79%, mussel production was not able to reach production expectations. In addition, if compare the production numbers and the incidence rates can see how they suffer an evolution of inverse character in most dates, increasing production while decreasing the incidence rate and vice versa.

Despite the observations made so far, the statistical significance of the impact of red tides on mussel farming should be confirmed, and for this the correlation between the production rates and the closing days of the polygons was examined of the dates previously seen in the figure 16.

Table 6. Correlation between mussel production and the incidence of biotoxins.

		Mussel Production
Incidence of Biotoxins	**Pearson´s**	-0,33054835
	N	28

Source: Elaboration based on Consellería do mar data and own calcutaltion (2016).

The results confirm the existence of an inverse relationship between the volume of production and the incidence of red tides, although as shown in Table 6, the values are moderate (r = -0.3305). In this way and as a first conclusion we can say that in effect the red tide influences production, but undoubtedly is not the only determining factor, given that at certain times and in the face of strong demand is able to overcome high rates of toxicity. And it is at this moment that I should point out that most of the Galician mussel production is oriented towards the end of the year (October, November and December) on the occasion of the Christmas holidays. However, this sales cycle does not understand the incidence of biotoxins, since it is in the month of October of each year when the production of mussel increases until reaching its annual peak. Specifically in October 2010 and 2014 the level of biotoxins paralyzed the extraction of mollusc by 60%, however this did not prevent production levels increase to reach their highest numbers in the year, with 22,000 and 28,000 tons respectively.

This fact is possible thanks to the availability of information that the producers have on the evolution of the red tides (through INTECMAR). In this way they are able to anticipate or postpone the extraction of the bivalve before a forecast of closure of the polygons, intensifying the work in the days adjacent to the closing period. In addition, the experience acquired by the producers in recent years helps them to be over-alert to the occurrence of red tides in certain months for possible and rapid extraction.

On the other hand, if the mussel production is analyzed according to its destination: fresh or industrial, it is possible to understand a situation in which the industry dedicated to the mussel canning has a greater capacity to adapt its production chain to the availability of raw materials. In this case in times of a large temporary closure of the polygons, it is expected that the industry can make greater in the face of the shortage of product pulling its product already stored. By contrast in times of high sales and a high percentage of closure, the fresh market could lose its commercial position by not having the product at that time. However although a priori this should be the line to follow by the destination of the mussel, the truth is that with the passage of the years the production destined to commercialize fresh has been increasing, while the industry for the canning loses weight year per year. The solution to this incognita is found in a factor that nothing has to do with the red tide. Since 2003, an Association and Free Trade Agreement between the European Union and Chile has been established, leading to the complete disappearance of tariffs from 2007 onwards, thereby stimulating European imports of mussels from Chile to serve as raw material for the canning industry and satisfy the demands of a market increasingly affected by the red tide.

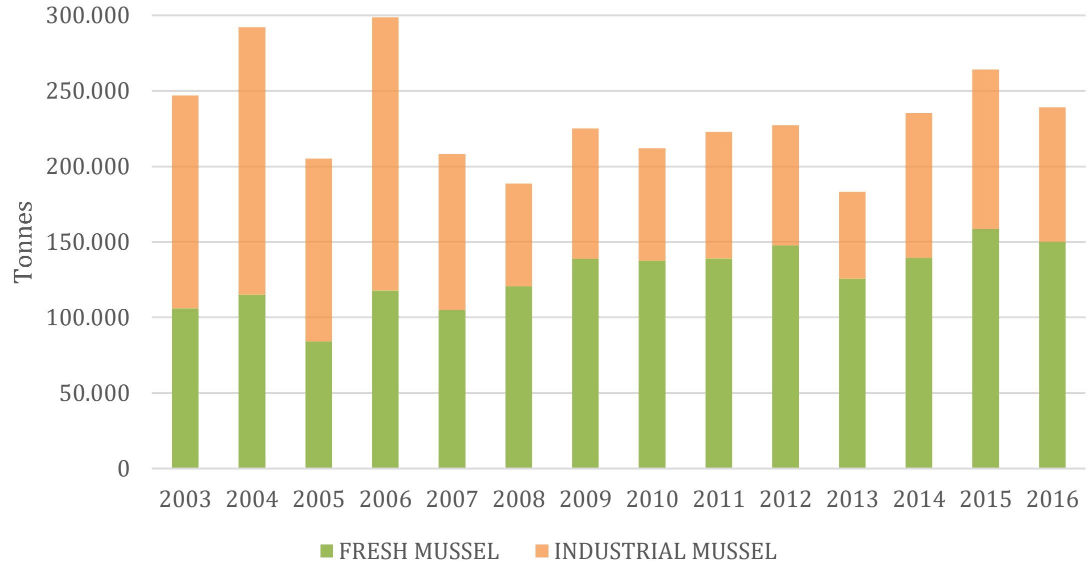

Figure 17. Production according to destination: fresh mussel and industrial mussel (tonnes). Source: Own elaboration based on Consellería do mar data (2016).

In particular, during the last years (2003 - 2016), Galician mussel production reached its maximum value in 2006 with about 300,000 tonnes (figure 17), of which are destined to fresh consumption 39.48% and the supply of industry 60.52%.

From that year onwards, can appreciate the change of trend previously highlighted: on the one hand, production stagnates around 200,000 tons and on the other hand, the redistribution of destination takes place, where the supply of fresh mussels increase and the industry demands every time less raw material. As evidence of this, to note that in 2016 the industrial sector only absorbs 89,171 tonnes, 29% of what it demanded in 2006.

In this way we know that the reduction in production and redistribution of the mussel's destination since 2006 was not only the cause of the red tide, but the industrial sector has decided to opt for a mussel more cheaper and with more reliability of obtaining. In spite of this, it is important to verify the true degree of correlation between the product destined fresh and industrial and the presence of red tides.

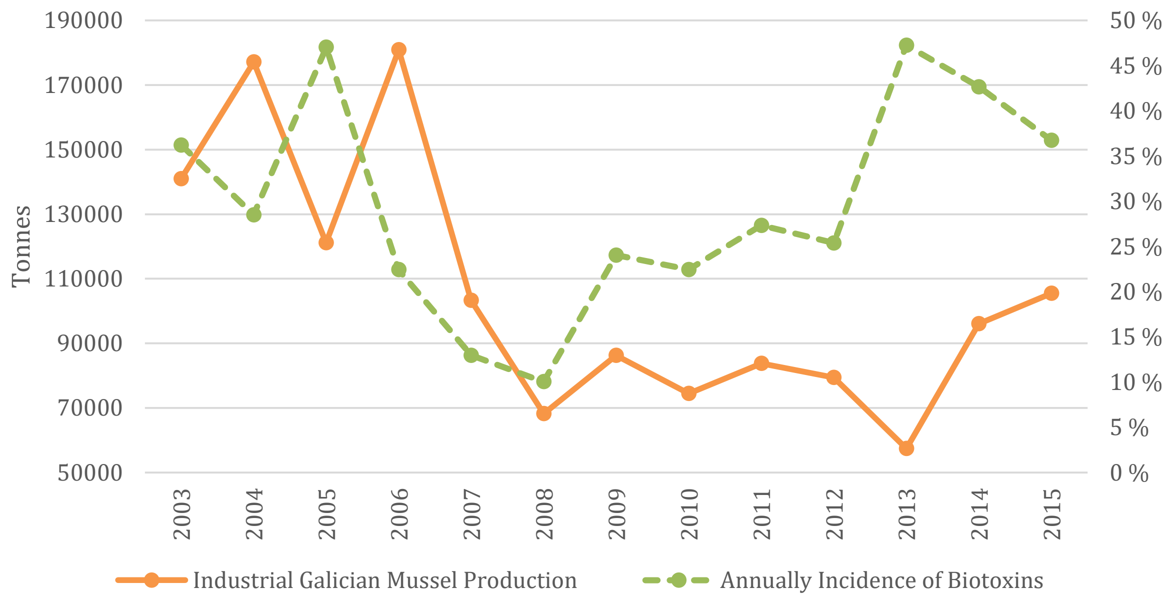

Figure 18. Comparison between industrial mussel production and the incidence level of red tide (Annually). Source: Elaboration based on Consellería do mar data and own calcutaltion (2016).

In fact, as can be seen in figure 18, industrial production has gone from acquiring about 180,000 tons annually in 2003 to 70,000 tons in 2008. The disappearance of the tariff barrier produced a change in this trend that if examine the correlation between industrial production and the closing rate of the polygons, can hardly see a direct relation (r = 0.0303) between the two variables (table 7).

Table 7. Correlation between the incidence of biotoxins and industrial mussel production and fresh mussel production.

		Industrial Mussel Production	Fresh Mussel Production
Incidence of Biotoxins	**Pearson´s**	0,0303713	-0,07186859
	N	13	13

Source: Elaboration based on Consellería do mar data and own calcutaltion (2016).

The same is true of the correlation between the fresh-target mussel and the biotoxin index (table 7). Their interpretation shows us in this case an almost null correlation (r = -0.071) where we observe that like the total production their relation is minimally inverse.

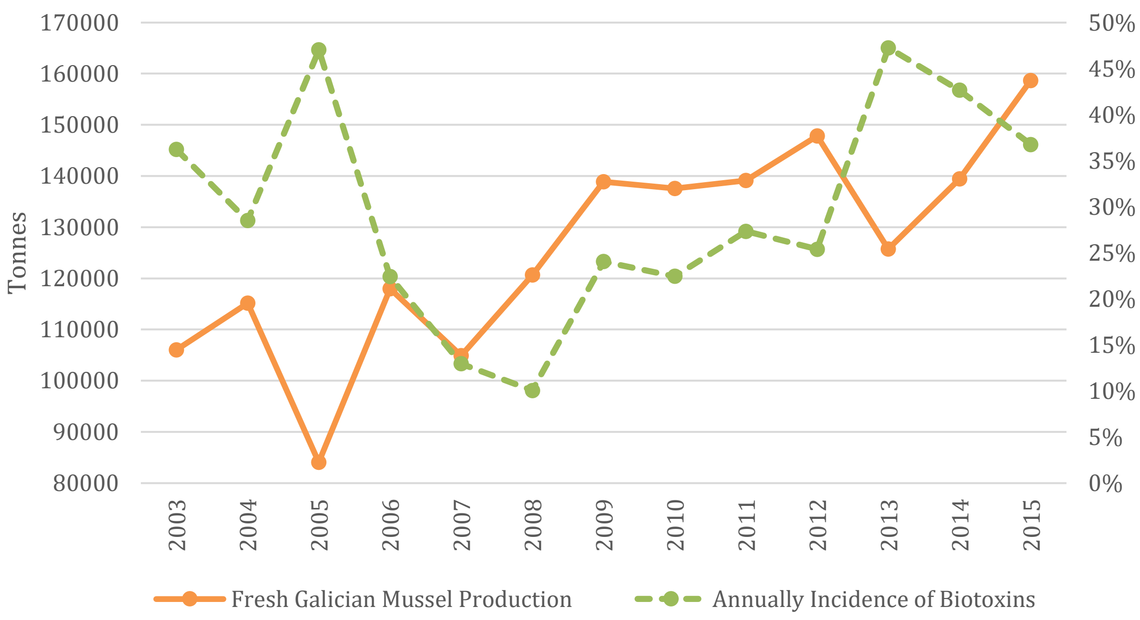

Figure 19. Comparison between fresh mussel production and the incidence level of red tide (Annually).
Source: Elaboration based on Consellería do mar data and own calcutaltion (2016).

4.2. Influence of the red tide on the prices of the Galician mussel:

When analyzing the price of the Galician mussel must take into account for your better understanding, that this based mainly on two factors which determine their final price. As for any product that comes to the market, supply and demand is the first pattern by which price must be guided. From the outset, there has been a direct relationship between the volume produced and the prices for the industry, in other words, as mussel production increases, prices also do or otherwise, if bivalve production decrease, prices will also decrease in a parallel way.

Table 8. Correlation between mussel production and the Galician mussel price.

		Mussel Production
Galician Mussel Price	Pearson´s	0,2257873
	N	11

Source: Elaboration based on Consellería do mar data and own calcutaltion (2016).

On the other hand, another factor that determines the prices for this activity are the natural conditions, in particular the red tides. As we have analyzed in the previous section the relationship between production and the index of biotoxins, then will do the same with the price. In this sense, it is plausible that, faced with a reduced of the demand of the product derivated for the presence of red tides, producers tend to reduce their prices in order to place production on the market, so that in times of increased incidence of biotoxins they must coincide with lower production prices.

To verify if this trend is real we can observe the following figure 20, which shows the prices (€ / kg) for the mussel compared to the percentage of incidence of the red tide. The period to study are the last 6 years, showing the data every 3 months for a better example staging.

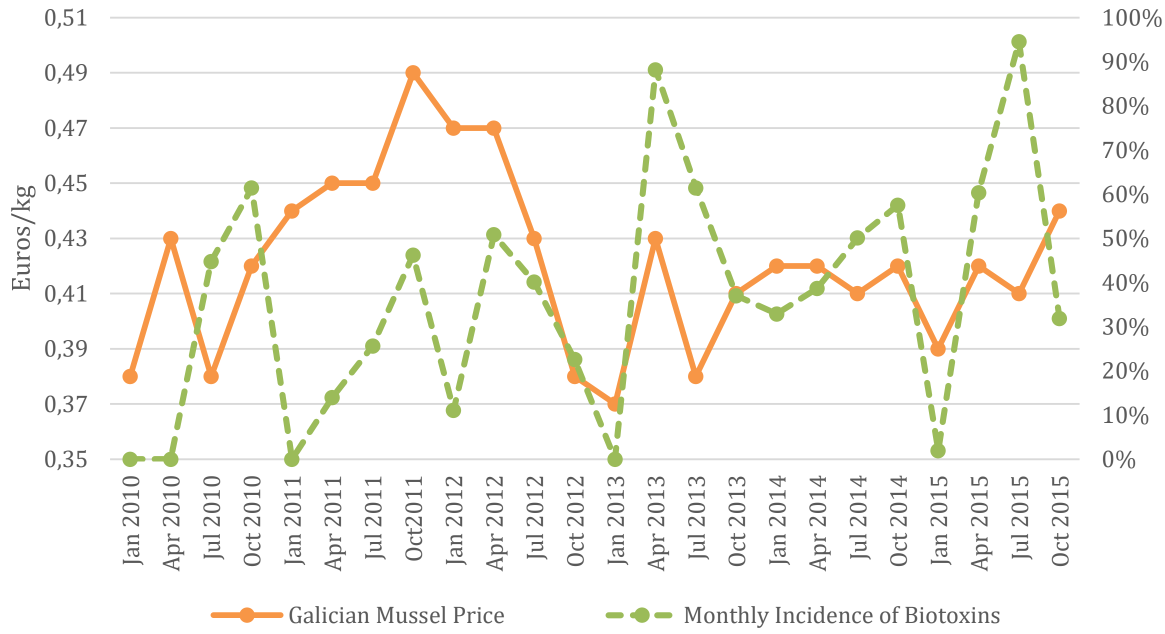

Figure 20. Comparison between Galician mussel price and the incidence level of red tide (monthly).
Source: Elaboration based on Consellería do mar data and own calcutaltion (2016).

As we can see in figure 20, from 2010 to the present, the fluctuation of prices with respect to the percentage of incidents undergoes different variations in an irregular way. If we focus our attention on the months of greater influence of the red tide such as October 2011, April 2012, April 2013 or October 2014, we observe how in the months after these high peaks of incidence the price of the mussel tends to decrease their numbers. In contrast, if we look at the months in which the toxin barely affected bivalve extraction (January 2011, 2013, 2015), we see that the price trend for subsequent months is clearly positive.

Table 9. Correlation between Galician mussel price and the incidence of biotoxins.

		Galician Mussel Price
Incidence of Biotoxins	Pearson´s	-0,30976509
	N	11

Source: Elaboration based on Consellería do mar data and own calcutaltion (2016).

In addition, if to do correlation between these variables for the last 11 years (2006-2016), verified what was previously interpreted in Figure 20. The correlation, although presenting moderate values (r = -0.30976), shows an inverse relationship between the two variables. In this way we can ensure that the red tides are able to affect the price of the mussel, adopting an inverse relationship between prices and biotoxins no matter what the time of year.
Then, in order to shed further light on the ultimate goal, will analyze separately the relationship between the biotoxin index and the prices of the fresh mussel and industrial mussel.

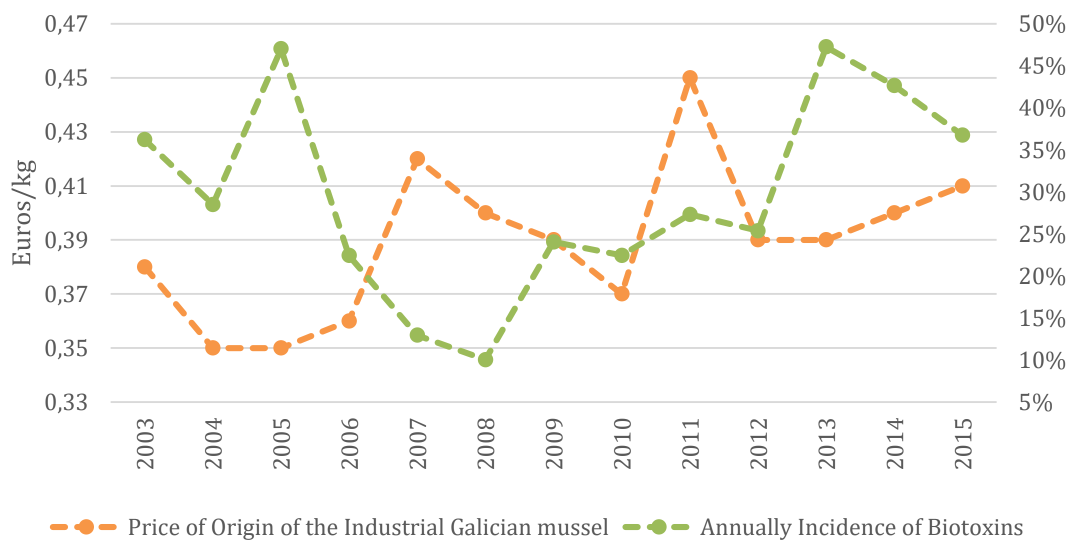

Figure 21. Comparison between Price of mussel destined for industry and the incidence level of red tide (Annually). Source: Elaboration based on Consellería do mar data and own calcutaltion (2016).

Always focusing on prices of origin (direct sale price of the batea), observe in the figure 21 (industrial mussel) we find that there is a high correspondence between the prices reached annually and the incidence of the red tide. As we can see in the figure 21, those years with high biotoxin indices have an average annual price around 0.35-0.39 € / kg whereas in years that the incidence does not exceed 27% of annual influence, prices Are in the range of 0,40-0,45 € / kg. In this way, after verifying their correlation (table 10), we can verify that there is also an inverse but moderate relation (r = -0.21853) between the industrial mussel price and the biotoxin index.

Table 10. Correlation between the incidence of biotoxins and industrial mussel price and fresh mussel price.

		Industrial Mussel Price	**Fresh Mussel Price**
Incidence of Biotoxins	**Pearson´s**	-0,21853874	0,09798762
	N	14	14

Source: Elaboration based on Consellería do mar data and own calcutaltion (2016).

On the other hand, the price of fresh mussels hardly shows any relationship with the index of biotoxins. After verifying the correlation between both variables, we observed that the type of relationship that it presents is direct and in very low terms (r = 0.0979). If look at figure 22, we can find the answer between 2003 and 2008 where prices tend to decrease continuously regardless of the incidence of biotoxins. Although it is true that from 2008 there may be an inverse relationship between price and index, it is not sufficiently pronounced to ensure such a relationship.

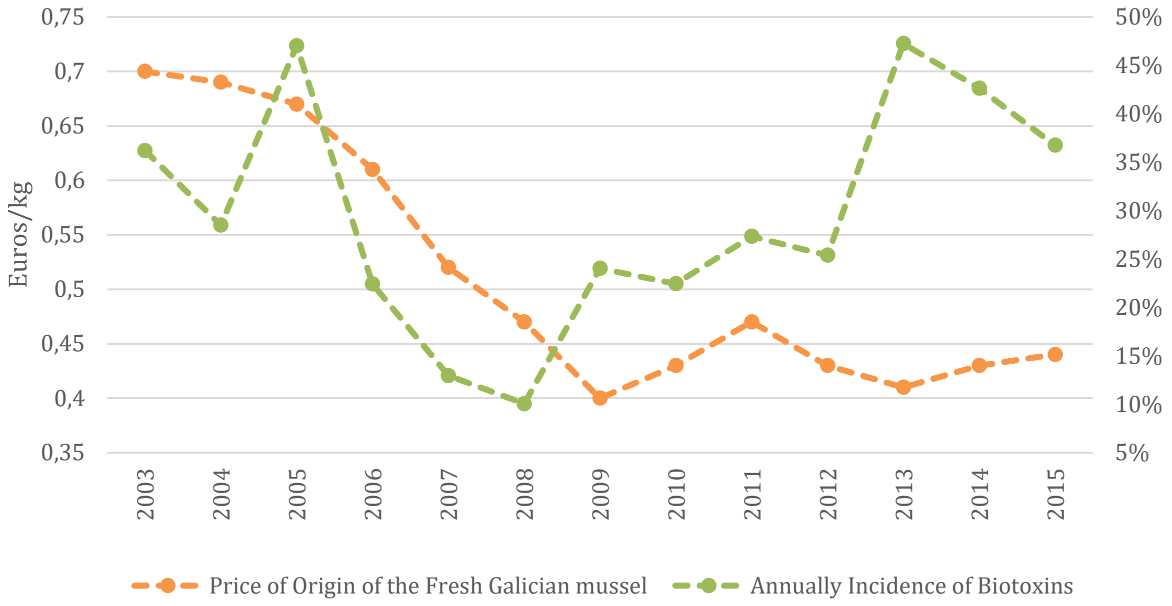

Figure 22. Comparison between Price of mussel destined for fresh and the incidence level of red tide (Annually). Source: Elaboration based on Consellería do mar data and own calcutaltion (2016).

In other words we can say that the normal situation would have been in which the price of the fresh mussel would have been affected by the red tide, when talking about a domestic consumer without information and with uncertainty to that problem. So it would be to understand a certain rejection on his part when buying the product, but the truth is that the price of fresh mussels is hardly affected by the red tide, since there is no binding relationship. On the other hand, the canning industry which we can call as an expert buyer and knowledgeable about the red tide, one would expect that its price would not be affected to a large extent by the biotoxin, having more time to buy bivalve. However, the relationship of these prices to the incidence of red tides is certainly binding.

So as a final conclusion we must corroborate that the canning industry plays a significant role in the commercialization of the mussel, since it has the capacity to adapt within the market at higher or lower prices depending on these adverse natural conditions. While the fresh market adopts a state of fragility before the high incidences, which ends up repercussing in a loss in the market positioning.

4.3. Influence of the red tide on the commercialization of the Galician mussel:

The last phase of the Galician mussel, prior to its final consumption is the commercialization. In this phase through the total value of sales can estimate the degree of influence of the red tides on the commercialization of the mussel, and therefore deduce the losses produced by this toxin on the bivalve industry. Thus, if compare the sales value and the sales expectation with the closing rate of the polygons (incidence level), it is possible to verify the relationship between the mussel sold and the presence of red tides. The period to be studied is the last 7 years, showing the data every 3 months for a better example staging.

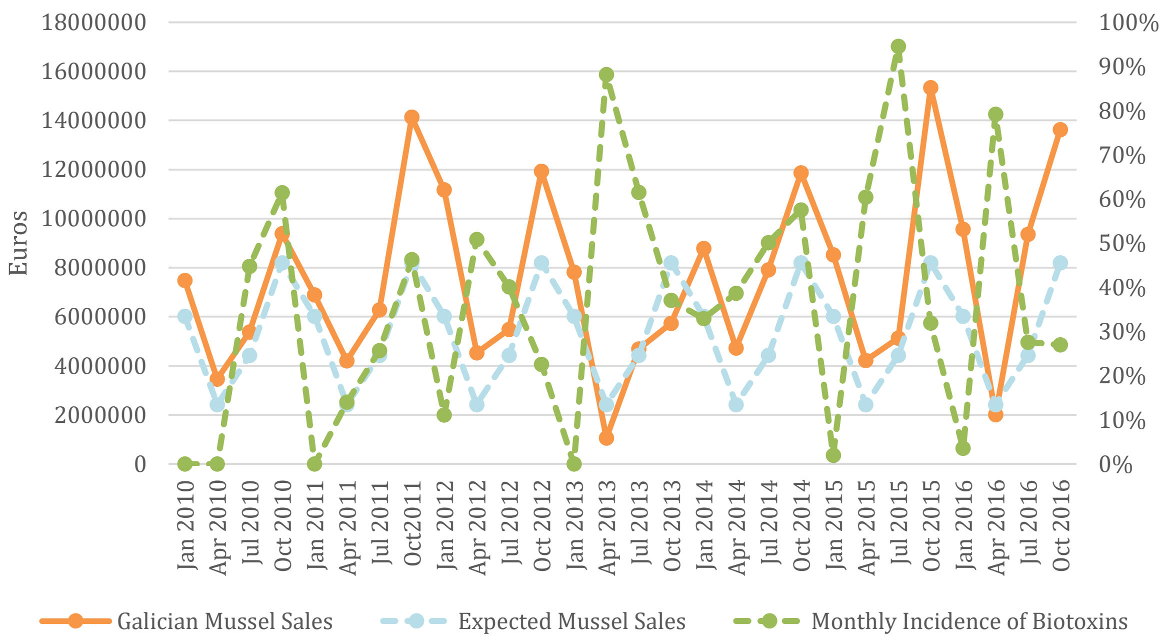

Figure 23. Comparison of mussel sales (euro), sales expectation and the incidence level of red tide (monthly).
Source: Elaboration based on Consellería do mar data and own calcutaltion (2016).

As a starting point when analyzing this figure 23, must look at the value of sales lines and expectation value of sales of mussels. Throughout these 7 years the sale value has exceeded the expectation in all those established dates, except April 2013 and April 2016. Curiously, these two dates coincide with the highest peaks in relation to red tide index, arriving to establish both a paron of the extractive activity of 90%. This fact meant that in both dates it would hardly reach the 2 million bivalve sold, when in the majority of months the total value of mussels sold exceeded 4 million euros.

In addition, as explained in the previous sections, the approximation of the Christmas dates is for many producers the moment to ensure their profits for the whole year, so that the commercialization of mussels can reach 40-50% surpass the rest of the year. If you look at the evolution that undergoes the value of sale of mejillon between July and October of every year observe that it is always positive. This means that as leave the summer behind and are approaching the end of the year, the marketing of mussels increases independently of the red tide.

In this way and as a first assessment, know that the red tide influences the commercialization of bivalve Galician but without doubt there are many other factors that make it possible to rise and fall in sales of mussels. If we examine the correlation between the sales value and the closing days of the polygons (biotoxin index), the results verify the existence of an inverse relationship between the two variables, although as we see in table (11), the values are moderate (r = -0.3148).

Table 11. Correlation between mussel sales value and the incidence of biotoxins.

		Mussel Sales Value
Incidence of Biotoxins	Pearson´s	-0,31482094
	N	28

Source: Elaboration based on Consellería do mar data and own calcutaltion (2016).

When analyzing the sales value of commercial fresh and industrial mussel, we must take into account several factors that have previously been exposed. Firstly, we must understand that the mussels destined to the industry adopt a price inferior to the fresh mussels at the time of its commercialization. In addition, another factor that we must not forget is the increasing import of Chilean mussels for the canning industry. This fact diminishes the value of industrial commercialization since 2006 as can see in the figure 24. In it it can be appreciated that until the year 2006 and from the year 2012 the index of biotoxins exerts a small inverse relation. As the days of closing of the polygons increase, the commercialization is smaller, and otherwise as the red tide ceases to appear, the commercialization of industrial bibalvo increases.

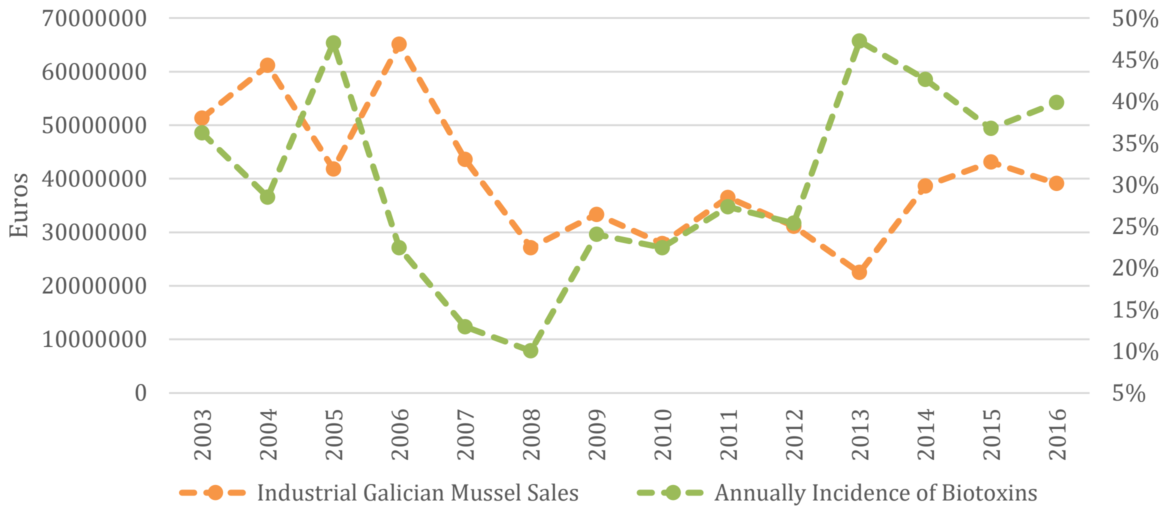

Figure 24. Comparison between industrial mussel sales (euro) and the incidence level of red tide (Annually).
Source: Elaboration based on Consellería do mar data and own calcutaltion (2016).

On the other hand the marketing of the fresh mussel seems to ignore the biotoxin indices. If we look at figure 25 below, even in the years when the red tides present percentages close to 50% or on the contrary, they barely reach 10%, the sales values hardly fluctuate in relation to the adyacient years.

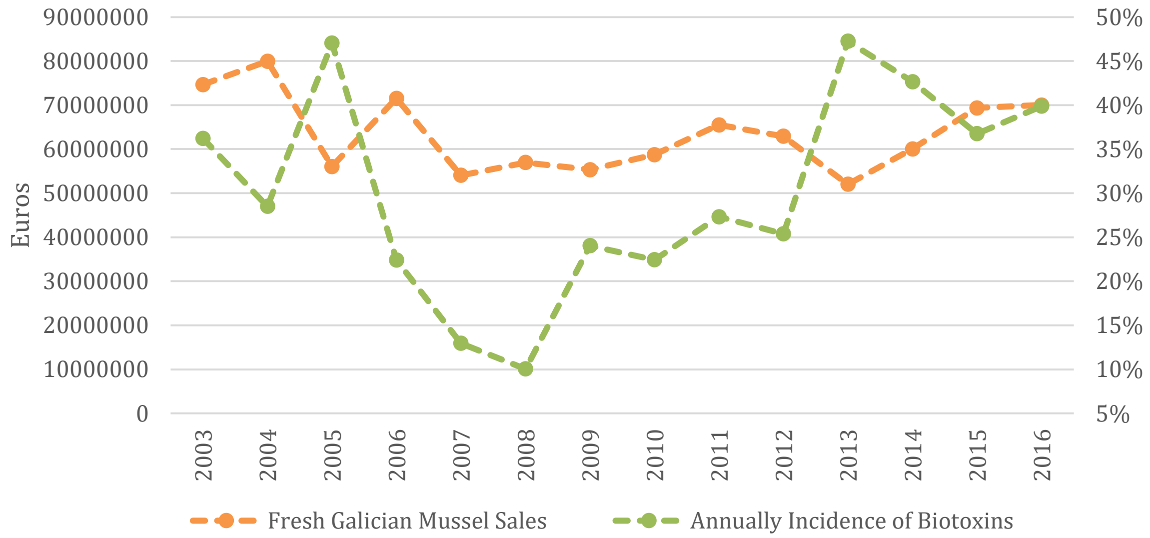

Figure 25. Comparison between fresh mussel sales (euro) and the incidence level of red tide (Annually).
Source: Elaboration based on Consellería do mar data and own calcutaltion (2016).

In spite of this and although at first sight in both figures (fresh and industrial) it seems that the red tide does not exert any kind of salient effect on the commercialization of the mussel, I must calculate the correlation to verify or to deny this affirmation.

Table 12. Correlation between the incidence of biotoxins and industrial mussel sales value and fresh mussel sales value.

		Industrial Mussel Sales	Fresh Mussel Sales
Incidence of Biotoxins	**Pearson´s**	-0,02769298	0,06987552
	N	13	13

Source: Elaboration based on Consellería do mar data and own calcutaltion (2016).

In this case and as have been able to emphasize in the previous figures, observed that the commercialization of the mussel for both variables, hardly presents any type of relation with the index of biotoxins. After verifying the correlation separately for the industrial and fresh sales value, we observe that the type of relationship presented for both has very low terms of (r = -0.0276) and (r = 0.0698) respectively.

5. CONCLUSION

The objective of this thesis has been to find out the true influence that the red tide exerts on the Galician mussel industry. After having performed the individual analyzes for the production, price and commercialization of the mussel we can ensure that the red tide is an influential factor in any of the three named variables. However, although it exerts its effect on any of the three, its relation with each of them presents moderate levels.

In the case of production, must point out that although in recent years the influence of red tide has been increasing, annual production numbers barely have varied around 225,000 tons. Put simply, the red tide only has been able to influence on expected production through very high or very low incidence rates. The explanation for these results of moderate character, can base it on factors such as: the time of the year in which the red tide appears are not usually times of strong extraction or the increasing degree of knowledge of producers, which allows them to anticipate the tide before its possible appearance.

With regard to the price of the mussel, as we have been able to analyze over the years, there is a direct relationship between the volume produced and the prices for the industry, which means that according as mussel production increases, prices also they do and vice versa. In this way, it is understood that in view to lower demand for the product derived from the presence of red tides, the producers tend to reduce their prices in order to place the production in the market, so that in times of increased incidence of biotoxins must coincide with lower production prices. This inverse but moderate relationship serves to certify true degree of influence of the red tide on the price of the mussel.

The analyzes regarding the commercialization of mussel seem to go hand in hand with the already previously mentioned of production. The moderate character of the inverse relationship between the sales value and the incidence level of the biotoxins does not allow us to speak of a large number of losses due to the red tide. But it is true that the estimates previously calculated coincide in some way with the level of correlation obtained. With this can dare to say that at present we could be talking about around 40 million euros or of what is consequence, a 40% influence of the red tides.

Finally, it should be noted that the analyzes carried out according to the destination of the fresh or industrial mussel, have shown mostly a null correlation. With this can conclude that the final destination of the mussel does not produce any type of effect in any of the three variables analyzed: production, price and commercialization.

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APPENDICES

APENDIX A: Data on the closure of production areas.

Table 1A. Number of days of closure of the diferent mussel harvesting areas in Galicia in the period 2006-2016

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1. *Ría Betanzos*											
Sada A	139	90	83	102	82	116	168	188	131	124	144
Sada B	115	67	49	79	18	113	91	158	114	73	107
2. *Ría Corme*											
Corme B	149	95	117	137	116	131	286	267	365	365	366
3. *Ría Muros-Noia*											
Muros A	125	51	29	126	117	186	133	219	149	170	201
Muros B	159	57	50	135	135	225	190	240	158	208	217
Muros C	-	-	-	-	-	44	184	206	152	179	218
Noia A	125	51	-	70	96	142	140	194	145	171	170
4. *Ría Arousa*											
Ribeira B	62	49	16	17	64	85	66	161	152	75	129
Ribeira C	58	55	16	80	67	72	62	175	142	91	123
Puebla A	-	23	-	-	-	32	-	69	40	69	48
Puebla B	16	21	-	3	22	29	53	95	99	63	62
Puebla C	11	26	-	8	26	26	-	105	85	61	46
Puebla D	13	27	-	47	38	24	-	135	117	73	77
Puebla E1	19	6	-	31	25	35	8	115	84	29	33
Puebla E2	-	-	-	-	-	-	-	-	-	33	56
Puebla G	11	17	-	-	0	24	-	83	57	62	43
Puebla H	56	50	-	38	24	42	53	160	138	79	98
Villagarcia A	11	-	-	-	13	-	4	99	89	41	52
Villagarcía B1	13	3	-	18	34	22	-	133	97	42	119

Villagarcía B2	-	-	-	-	-	-	-	-	-	41	46
Cambados A1	17	26	-	58	47	32	52	155	131	74	107
Cambados A2	5	-	-	8	-	-	51	62	28	41	41
Cambados B	46	37	23	69	76	36	-	160	141	88	119
Cambados C North	68	55	35	109	101	69	71	205	164	101	136
Cambados C South	65	50	31	92	77	61	64	198	153	87	127
Cambados D	-	44	7	-	51	37	-	104	125	60	60
Grove A	19	48	-	-	63	32	25	133	195	55	63
Grove C1	120	60	43	169	113	153	116	212	188	115	185
Grove C2	164	71	49	140	137	162	120	225	209	130	204
Grove C3	112	64	45	125	120	144	113	222	212	111	195
Grove C4	145	66	52	145	130	152	116	231	232	135	193
5. *Ría Aldán*											
Cangas A	174	77	93	195	128	230	203	241	195	243	259
Cangas B	188	87	117	197	155	241	196	250	215	243	275
6. *Ría Pontevedra*											
Bueu B	168	78	120	181	141	229	243	271	238	271	250
Bueu A1	169	92	129	198	147	241	265	271	234	273	279
Bueu A2	174	88	124	187	147	241	235	271	236	288	296
Portonovo A	99	62	40	143	116	153	147	247	222	164	169
Portonovo B	124	77	69	164	127	183	191	250	258	236	266
Portonovo C	127	73	75	166	131	191	156	270	249	224	240
7. *Ría Vigo*											
Cangas F	186	88	87	154	131	231	143	239	239	246	246
Cangas G	170	86	81	133	134	215	130	240	205	247	258
Cangas H	177	90	47	133	131	155	123	221	210	235	216
Cangas C	78	41	19	108	119	56	86	185	186	178	179
Cangas D	74	51	22	123	114	58	91	190	205	200	153
Cangas E	32	22	18	85	66	38	31	130	143	92	89

Redondela A	18	5	-	71	50	10	13	82	125	96	85
Redondela B,G	-	-	-	9	34	10	-	39	64	76	45
Redondela C,F	3	-	-	-	32	9	-	35	53	69	42
Redondela D	4	-	-	24	25	9	-	31	65	80	65
Redondela E	17	-	-	51	64	11	8	107	96	85	67
Vigo A	40	17	23	105	115	60	79	168	196	170	166
Baiona A	147	73	75	108	116	191	140	177	178	214	199

Source: Intecmar 2016

APENDIX B: Calculation annual of the level of incidences of the red tide.

Table 1B. Level of influence of the red tide 2010.

Year 2010	Number of polygons (A)	Closure days a month (B)	Days of the month (C)	Maximum possible incidence of red tides (A × C) = D	Incidence level (B/D) × 100 = %
January	49	0	31	1519	0 %
February	49	0	28	1372	0 %
March	49	0	31	1519	0 %
April	49	0	30	1470	0 %
May	49	0	31	1519	0 %
June	49	51	30	1470	3.46 %
July	49	680	31	1519	44.76 %
August	49	753	31	1519	49.57 %
September	49	1307	30	1470	88.9 %
October	49	933	31	1519	61.42 %
November	49	266	30	1470	18.09 %
December	49	0	31	1519	0 %

Table 2B. Level of influence of the red tide 2011.

Year 2011	Number of polygons (A)	Closure days a month (B)	Days of the month (C)	Maximum possible incidence of red tides (A × C) = D	Incidence level (B/D) × 100 = %
January	50	0	31	1550	0 %
February	50	0	28	1400	0 %
March	50	0	31	1550	0 %
April	50	210	30	1500	14 %
May	50	547	31	1550	35.29 %
June	50	377	30	1500	25.13 %
July	50	398	31	1550	25.67 %
August	50	403	31	1550	26 %
September	50	1240	30	1500	82.66 %
October	50	717	31	1550	46.25 %
November	50	1119	30	1500	74.60 %
December	50	562	31	1550	36.25 %

Table 3B. Level of influence of the red tide 2012.

Year 2012	Number of polygons (A)	Closure days a month (B)	Days of the month (C)	Maximum possible incidence of red tides (A × C) = D	Incidence level (B/D) × 100 = %
January	50	172	31	1550	11.09 %
February	50	130	29	1450	8.96 %
March	50	348	31	1550	22.45 %
April	50	763	30	1500	50.86 %
May	50	941	31	1550	60.70 %

June	50	930	30	1500	62 %
July	50	622	31	1550	40.12 %
August	50	179	31	1550	11.54 %
September	50	190	30	1500	12.66 %
October	50	350	31	1550	22.58 %
November	50	59	30	1500	3.93 %
December	50	0	31	1550	0 %

Table 4B. Level of influence of the red tide 2013.

Year 2013	**Number of polygons (A)**	**Closure days a month (B)**	**Days of the month (C)**	**Maximum possible incidence of red tides (A × C) = D**	**Incidence level (B/D) × 100 = %**
January	50	0	31	1550	0 %
February	50	0	28	1400	0 %
March	50	156	31	1550	10.06 %
April	50	1323	30	1500	88.2 %
May	50	1038	31	1550	66.96 %
June	50	723	30	1500	48.20 %
July	50	953	31	1550	61.48 %
August	50	1148	31	1550	74.06 %
September	50	232	30	1500	15.46 %
October	50	574	31	1550	37.03 %
November	50	1247	30	1500	83.13 %
December	50	696	31	1550	44.90 %

Table 5B. Level of influence of the red tide 2014.

Year 2014	Number of polygons (A)	Closure days a month (B)	Days of the month (C)	Maximum possible incidence of red tides (A × C) = D	Incidence level (B/D) × 100 = %
January	50	510	31	1550	32.90 %
February	50	81	28	1400	5.78 %
March	50	69	31	1550	4.45 %
April	50	580	30	1500	38.66 %
May	50	1371	31	1550	88.45 %
June	50	1351	30	1500	90.06 %
July	50	777	31	1550	50.12 %
August	50	1019	31	1550	65.74 %
September	50	1299	30	1500	86.60 %
October	50	892	31	1550	57.54 %
November	50	113	30	1500	7.53 %
December	50	62	31	1550	4 %

Table 6B. Level of influence of the red tide 2015.

Year 2015	Number of polygons (A)	Closure days a month (B)	Days of the month (C)	Maximum possible incidence of red tides (A × C) = D	Incidence level (B/D) × 100 = %
January	52	31	31	1612	1.92 %
February	52	28	28	1456	1.92 %
March	52	96	31	1612	5.95 %
April	52	942	30	1560	60.38 %
May	52	1469	31	1612	91.12 %

June	52	853	30	1560	54.67 %
July	52	1524	31	1612	94.54 %
August	52	591	31	1612	36.66 %
September	52	422	30	1560	27.05 %
October	52	514	31	1612	31.88 %
November	52	483	30	1560	30.96 %
December	52	286	31	1612	17.74 %

Table 7B. Level of influence of the red tide 2016.

Year 2016	Number of polygons (A)	Closure days a month (B)	Days of the month (C)	Maximum possible incidence of red tides (A × C) = D	Incidence level (B/D) × 100 = %
January	52	57	31	1612	3.54 %
February	52	31	29	1508	2.05 %
March	52	181	31	1612	11.23 %
April	52	1235	30	1560	79.16 %
May	52	1372	31	1612	85.11 %
June	52	1268	30	1560	81.28 %
July	52	446	31	1612	27.57 %
August	52	350	31	1612	21.71 %
September	52	598	30	1560	38.33 %
October	52	435	31	1612	26.98 %
November	52	924	30	1560	59.23 %
December	52	590	31	1612	36.60 %

APENDIX C: Statistical results

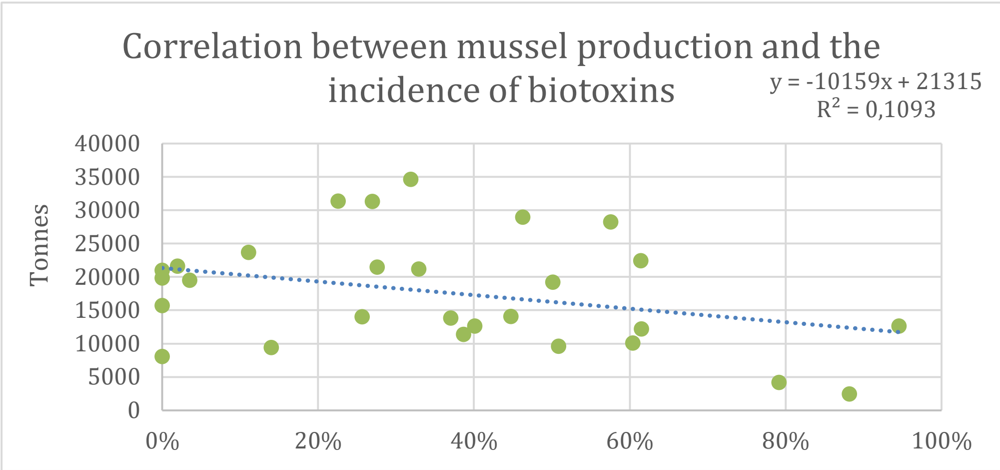

Figure 1C: Correlation between mussel production and the incidence of biotoxins.

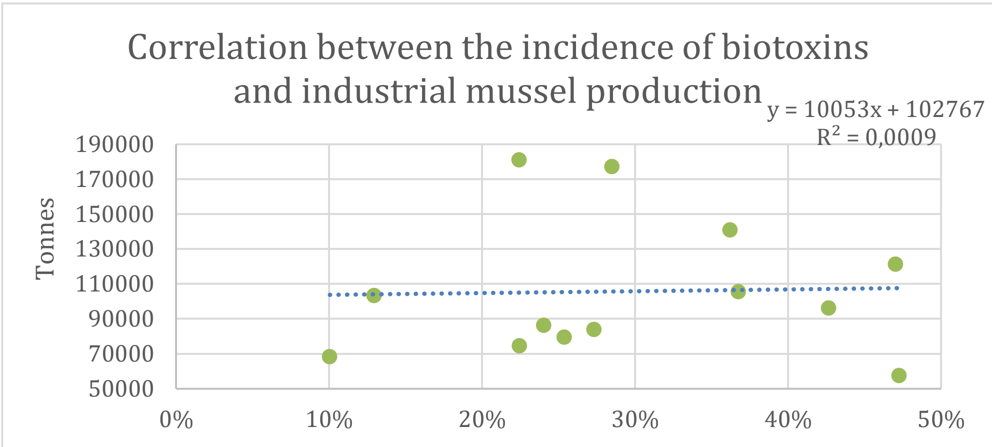

Figure 2C: Correlation between incidence of biotoxins and industrial mussel production.

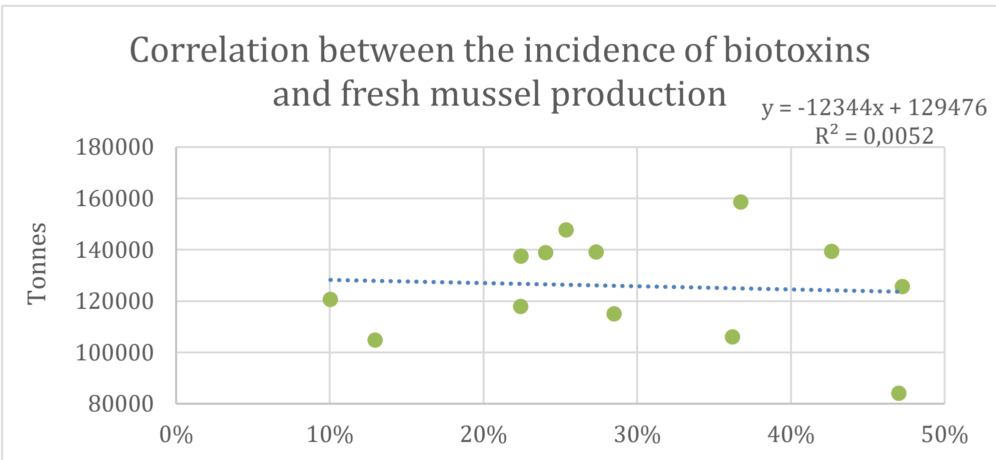

Figure 3C: Correlation between the incidence of biotoxins and fresh mussel production.

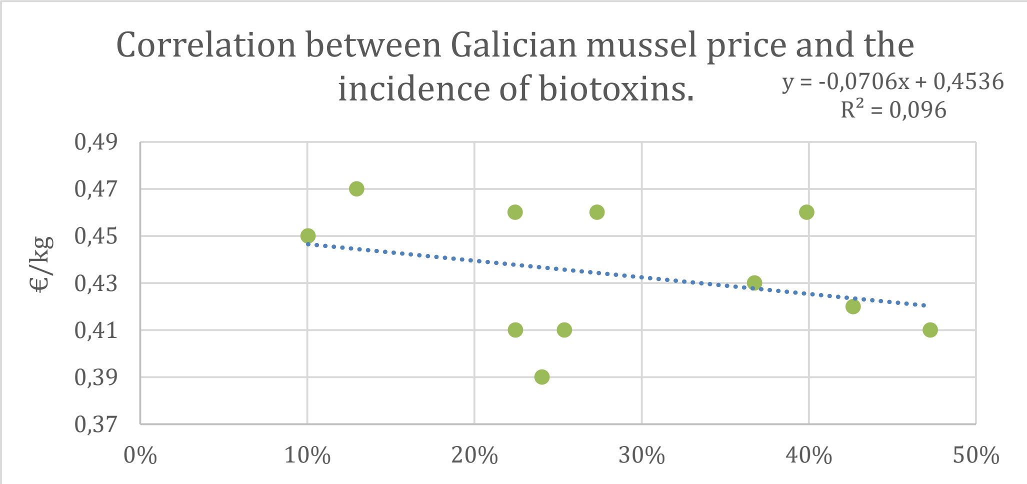

Figure 4C: Correlation between Galician mussel price and the incidence of biotoxins.

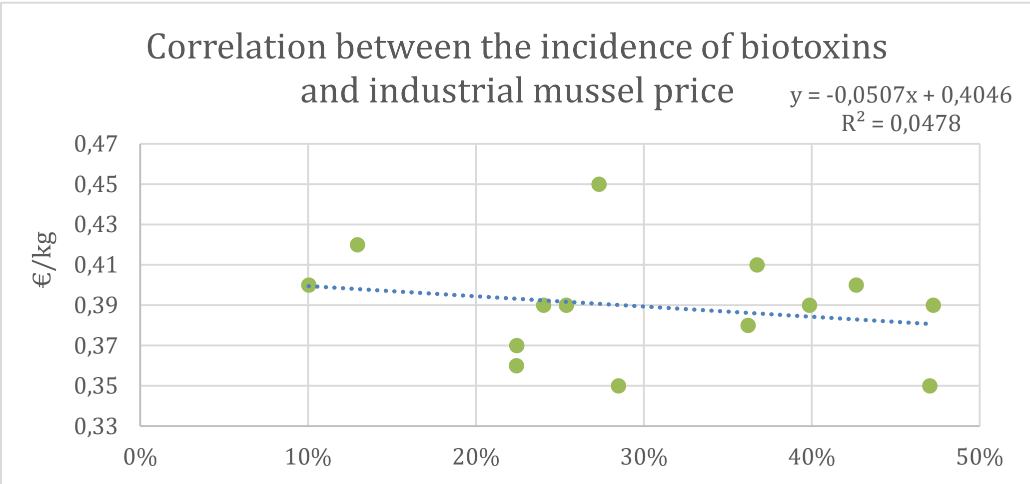

Figure 5C: Correlation between the incidence of biotoxins and industrial mussel price.

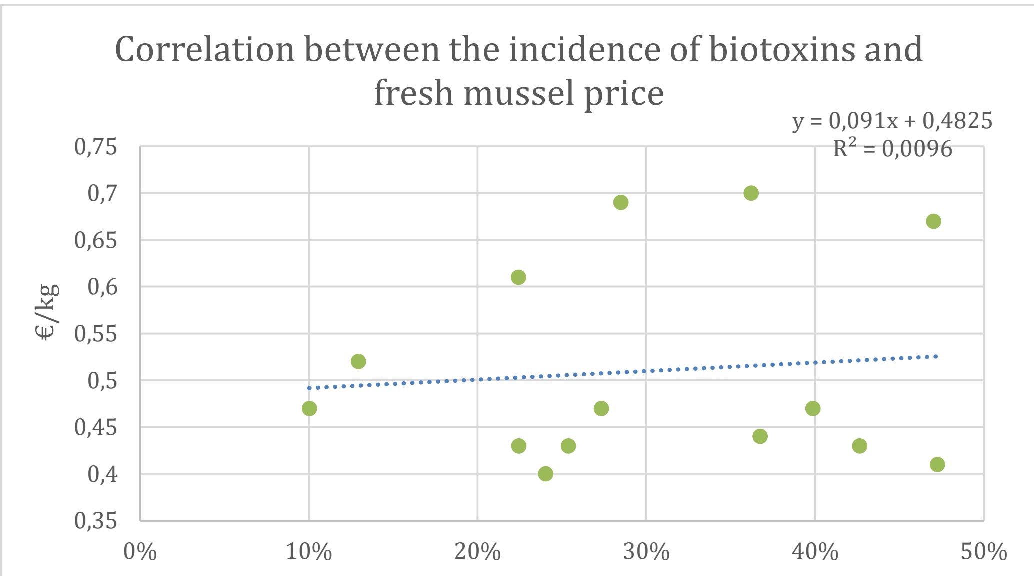

Figure 6C: Correlation between the incidence of biotoxins and fresh mussel price.

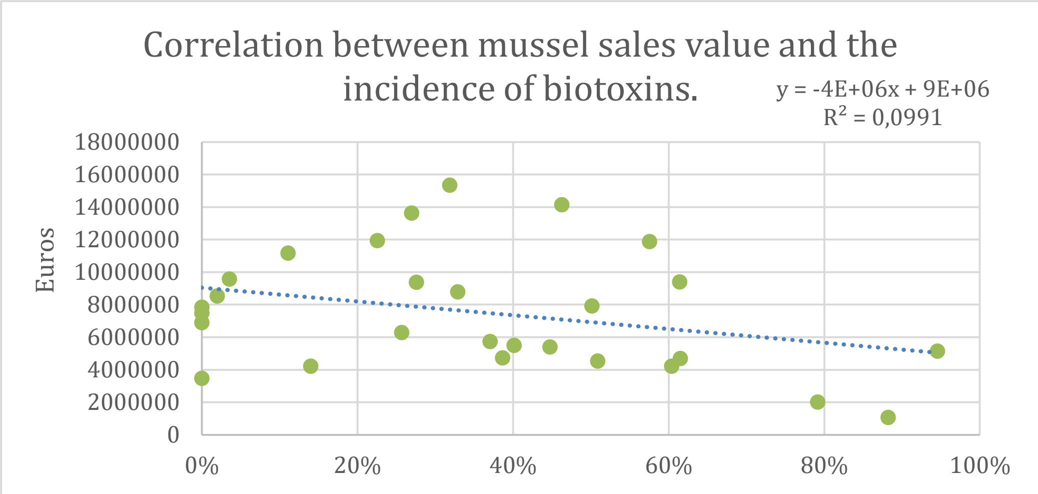

Figure 7C: Correlation between mussel sales value and the incidence of biotoxins.

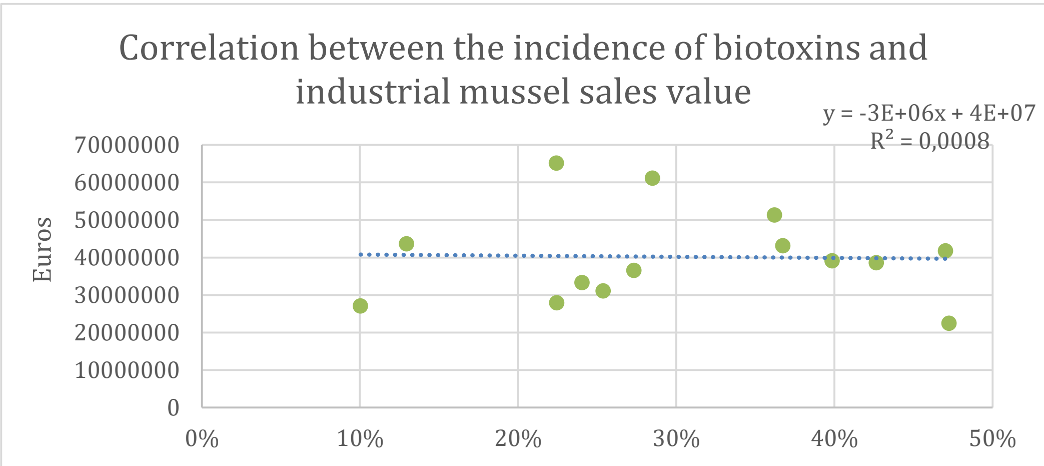

Figure 8C: Correlation betwen the incidence of biotoxins and industrial mussel sales value.

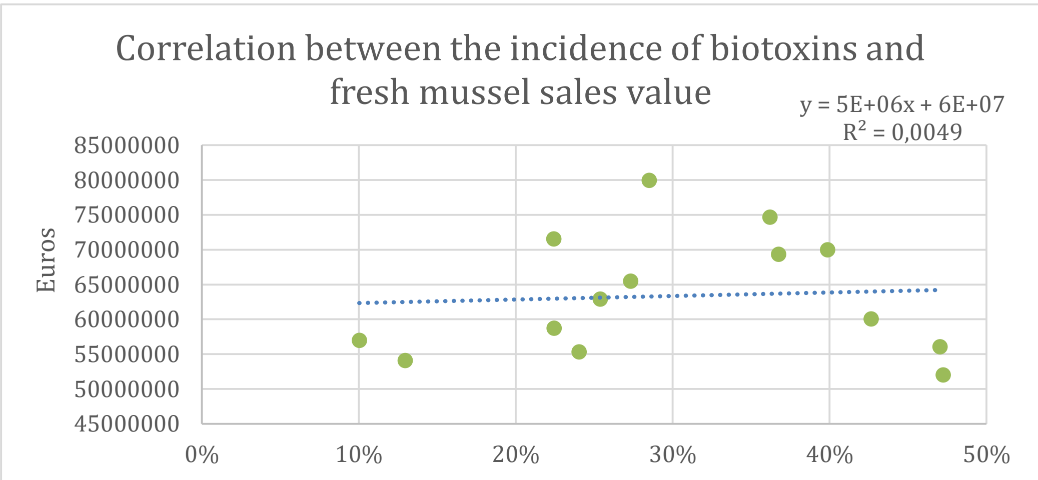

Figure 9C: Correlation between the incidence of biotoxins and fresh mussel sales value.

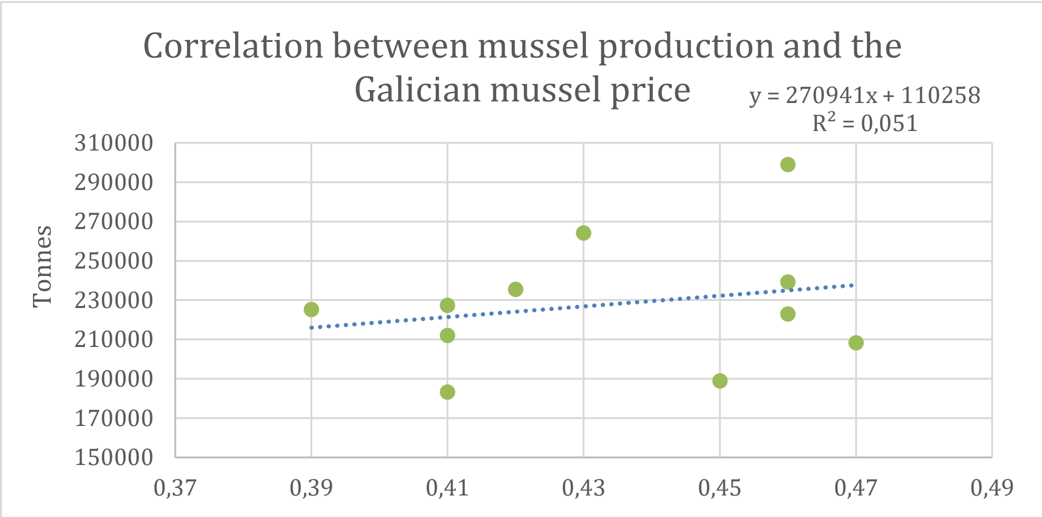

Figure 10C: Correlation between mussel production and the Galician mussel price.