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ASSESSMENT OF THE NON-INDIGENOUS SPECIES IN RIA FORMOSA

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Dedicated to my family and

in memory of my father

Love you

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RESUMO

As espécies não-indígenas (ENI) são consideradas como sendo um problema prioritário nos ecossistemas e na biodiversidade a nível global. A principal peça de legislação europeia na questão das águas e sua gestão – a Directiva Quadro de Água (DQA) – tem como principal objectivo atingir um bom estado ecológico para todas as massas de água. As ENI podem ser consideradas como sendo uma pressão antropogénica nas diversas massas de água, e assim sendo, fazem aumentar o risco do principal objectivo desta legislação não ser cumprido. Foi recolhida e compilada toda a informação disponível sobre ENI no Parque Natural da Ria Formosa (PNRF), e novas informações foram reunidas a partir dos diversos *stakeholders* através de entrevistas feitas com o objectivo de avaliar a situação actual da laguna em relação às ENI e as respectivas consequências com respeito à DQA. O estudo focou espécies aquáticas: 15 foram introduzidas nas últimas duas décadas, em locais onde até 1990 apenas se observava em média 1 espécie/década. O grupo biota bêntico é o maioritário (80%), principalmente algas e molúsculos (26% cada um). Importantes actividades económicas estão envolvidas com as espécies introduzidas. 73% das espécies presentes estão dentro do grupo dos piores invasores. Contudo, não são considerados perigosas pelo PNRF ou como representando um risco de falha na concretização dos objectivos da DQA pela maioria dos *stakeholders*. Esta contradição poderá estar relacionada com a falta de conhecimento que existe acerca do assunto. Há uma grande incerteza, falta de informação e de dados empíricos básicos sobre as espécies, o que dificulta uma avaliação correcta. Há uma clara necessidade de aumentar a investigação científica integrada e de incluir as ENI no plano de gestão do PNRF.

Palavras-Chave: Espécies Não-Indígenas; Directiva Quadro de Água; Gestão; Ria Formosa.

ABSTRACT

Non-indigenous Species (NIS) are considered a major hazard for ecosystems and biodiversity worldwide. The main European water legislation, the Water Framework Directive (WFD) has the goal of achieve the good ecological status of all water bodies. NIS can be considered a potential anthropogenic pressure over water bodies, which increase the risk of fail this goal. All available information on NIS in the Natural Park of Ria Formosa (NPRF) was compiled and new information was gathered from stakeholders through interviews in order to evaluate the current situation of the lagoon regarding NIS and the consequences towards the WFD. The study was focus on aquatic species; there are 15 species introduced, 8 of them in the last two decades, whereas it used to be on average of 1 specie/decade before 1990. Benthic biota is the main group (80%), mainly algae and mollusk (26% each one). Important economic activities (aquaculture and shipping) are involucrate in the introductions. 73% of the species present are considered among the worst invaders. However, they are not considered dangerous in NPRF or a direct risk of failure WFD's objectives by the majority of the stakeholders. It is may be because the situation concerning NIS is largely unknown, there is a big uncertainty and lack of information and basic empirical data about the species; which inhibit a proper assessment. There were not previous studies on this topic in the lagoon. There is a clear necessity for more integrated scientific research and to include NIS in the management plan NPRF.

Keywords: Non-Indigenous Species; Water Framework Directive; Management; Ria Formosa

TABLE OF CONTENTS

1. Introduction

Nowadays introduced species are considered the second cause of biodiversity loss worldwide (García-Berthou et al, 2005). Everyday there is more evidence to consider them a big threat for ecosystems and native biota. The impacts of non-indigenous species (NIS) are diverse and severe, ranging from for instance displacement of indigenous species, competition, predation, vectors of diseases, damages on structures to loss of genetic integrity (Streftaris et al, 2005).

Impacts of alien species affect not only ecosystems, but also human activities and structures. The damage on structures by some "engineer species", and the loss of crops by weeds and diseases cost millions of dollars in the USA only. For instance zebra mussels, which attach to structures, engines and pipes, cost hundreds of millions dollar per year in the USA (Wittenberg and Cock, 2001).

Not only terrestrial systems are affected, but aquatic environments as well. Hundreds of NIS have established in coastal waters, especially bays and estuaries, over the entire world. In many cases communities are dominated by the established NIS (Ruiz and Hewitt, 2002). However, recent reviews show that the processes involved in marine invasion are not fully understood and there are several knowledge gaps, like not enough empirical data, that need attention (Ruiz and Hewitt, 2002).

With the new millennium the European Union has set its goal to improve the status of all its water bodies. This goal has been specified in the Water Framework Directive (WFD) as the main legislation that has the objective of achieves a good ecological status of all water bodies by 2015. To reach this water bodies need to have "*the values* *of the biological quality elements for the surface water body type show low levels of distortion resulting from human activity, but deviate only slightly from those normally associated with the surface water body type under undisturbed conditions*" (European Commission, 2000). The conditions of the physic-chemical and hydro-morphological quality elements have to be consistent with the achievement of the biological quality elements. Each water body has to achieve the same condition of each of its quality elements. The reference conditions are designated for each type of water body and for each geographical area, in an intercalibration process. Non-indigenous species can affect and disturb any of these quality elements. Furthermore, NIS are introduced by humans, intentionally or accidentally, they form a threat and a pressure on the environment (UKTAG, 2004). In the Annex II of the WFD it is stated that "other significant anthropogenic impacts on the status of surface water bodies" have to be identified and assessed. NIS can be considered a pressure that can put water body in risk of not achieving the condition of good ecological status. These facts make the NIS an issue of concern in the WFD and in the management plans of the water bodies (UKTAG, 2004). The Biological Quality Metrics (BQM) of the WFD include percentage cover, biodiversity indices, presence of opportunistic species, etc. All them can be disturb by Non-Indigenous Species.

Although, a lot of effort has been put into the development of assessment methods and control measures, there is still a lot of work to do. In Europe, there is still a lack of knowledge about the NIS and their impacts especially in marine environments (Ruiz and Hewitt, 2002, Leppäkoski et al, 2002). Additionally, more management, control and conservation measures control should be included in more laws and directives as WFD, or develop new one (Genovesi and Shine, 2003).

The awareness and management of NIS is especially important in protected areas, as Ria Formosa. The Natural Park of Ria Formosa (NPRF) is an important ecosystem for Portugal and Europe, due to its complexity, high productivity and high biodiversity (ICN, 2004). It is the host of threaten plants and animals; it is an important habitat for birds and a nursery for fish (ICN, 2004). Additionally, Ria Formosa is considered in good ecological status under the WFD process, since it is the only coastal system that has good conditions for Biological Quality Elements as well as Hydro-morphological and Physic-Chemical Elements (Newton et al, 2007). Within the Ria Formosa (RF) the Ponte of the Praia de Faro is proposed to be a reference point for benthos and it is part of the intercalibration process (Newton et al, 2007).

In an ecosystem like Ria Formosa, NIS can produce severe and huge impacts and should be taken into account in the management plans.

The main goal of this project is to assess the current situation of the non-indigenous aquatic species in Ria Formosa as a factor that can affect the ecological status element for the EU Water Framework Directive. The objectives are:

1. Create a list of non-indigenous species present in the aquatic environment of RF and make a compilation of the information available.
2. Evaluate the impacts produced and the potential risk of these species.
3. Identify the management actions for the non-indigenous aquatic species

2. General information

What do you consider an alien species? Can we consider all alien species undesirable? Large number of question and discussion arise around the alien species topic. Different definitions are given for alien species in different documents, articles and laws, and even different considerations are taken for different organisms (Carlton, 2002). As Copp et al (2005) said the confusion originates more from political than from bio-geographical definitions.

The definition used for this study is the one given by the Convention of Biological Diversity (CBD) in the Guiding Principles for the prevention, introduction and mitigation of the impacts of alien species that threaten ecosystems, habitat and species. This definition has been accepted as well by the Global Strategy on Invasive Alien Species, published by the International Union for Conservation of nature and Natural Resources (McNeely et al., 2001), and the European Strategy on Invasive Alien Species published by Genovesi and Shine (2003). The term used will be **non-indigenous species** (NIS), defined as: *a species, subspecies or lower taxon, introduced outside its natural past or present distribution; includes any part, gamete, seeds, eggs, or propagules of such species that might survive and subsequently reproduce.* Synonyms of non-indigenous species are: non-native, alien, foreign and exotic.

There are other definitions based on a specific date to considered a specie native or not, for instance the definition given by Allard and Alouf in 1999 they assume that NIS are the ones that have colonized since the Neolithic, 6000 BP (Copp et al, 2005). However, for most of the species there is not enough data to use criteria like this. Some species are defined as cryptogenic because there is not definitive evidence of their introduction and for species which introduction was before 1800 has not been witness (Streftaris 2005). When a NIS is considered invasive has been also discussed by several authors and it is a controversial topic (Carlton, 2002). The definition used by the European Strategy on **Invasive Alien Species** is: *an alien species whose introduction and/or spread threaten biological diversity*. Invasive alien species have a negative, harmful and risk attached to its definition (Richardson et al, 2000). However, this term is used broadly without a connotation of impact (Richardson et al 2000). This term have to be used carefully because when a NIS threat the biodiversity is not defined quantitatively and can have different interpretations (Carlton, 2002). If we use the definition above not all alien species are invasive. Some definitions emphasize the economic, human health and social negative impacts of the invasive alien species, like USA and Canadian definitions; (US National Aquatic Invasive Species Act of 2003 and Canadian Biodiversity Strategy, 1995, respectively) (Copp et al, 2005). For instance the USA definition states "... the introduction of which into and ecosystem may cause harm to the economy, environment, human health, recreation, or public welfare" (Copp et al., 2005).

Definitions play an important role especially for management and policy reasons (Richardson et al, 2000). Rules and decisions have to be based on clear definitions and usually in quantitative ranges, this will be always discussible under a scientifically point of view. The major impedimenta in the control of NIS is the definition of what is a NIS or which NIS are acceptable, as examples between others (Copp et al, 2005; Richardson et al, 2000). Due to it lot of work have been done in define all terms (e. g. Copp et al, 2005). Nowadays, the international strategies have achieved some agreements, as the definitions given before from the CBD (Genovesi and Shine, 2003).

One easy and good way to understand NIS establishment and invasion process is that biological invasion can be seen as a process of overcoming barriers (Copp et al 2005). Richardson et al (2000) develop the simple conceptualization of the process for plants (McNeely et al., 2001); however, it can be use generally (see Fig.1.). Following this concept, invasion is a process where the alien species overcome biotic and abiotic barriers. The first barrier to overcome is geographical, intracontinental or intercontinental; this barrier is overcome if the species survive in its travel to the new area transported by human activities (intentionally or accidentally). The following barriers are to survive in the new habitat; success in the reproduction; dispersal in the new region conditions; adapt and survive in disturbed habitats; and finally adapt and survive in the natural habitats. Species that overcome the first barrier are considered alien in the new geographical area. The second step is the establishment or naturalization of the specie, it means that the population is self-sustaining and reproductive (Garcia-Berthou, et al 2005). The third stage is when the population growths and spreads everywhere (barrier E and F) becoming an invasive species when it threatens biodiversity (Fig.1). However, this classification in introduced, naturalized and invasive, have to considered carefully. There is little evidence or theoretical basis for determine when a specie can be called naturalized, and that have not more impacts (Carlton, 2003). At the same time, which degree of impacts can be considered that threat the biodiversity is also controversial, and it is defined differently by each author (Carlton, 2002).

The stage of the introduction or invasion is important to clarify definitions, but it is also important for management. When studying an “alien species case” it is important to know in which step it is, in order to know the magnitude of the problem and therefore manage it in the best way (prevention, early detection, eradication, etc.) (Wittenberg and Cock, 2001). Prevention, early detection and rapid response have been highlighted as the best option to control an introduced species, and sometimes it is the only viable one (Genovesi and Shine, 2003; Hulme, 2006; European Environmental Agency, 2008; Bax et al, 2001).

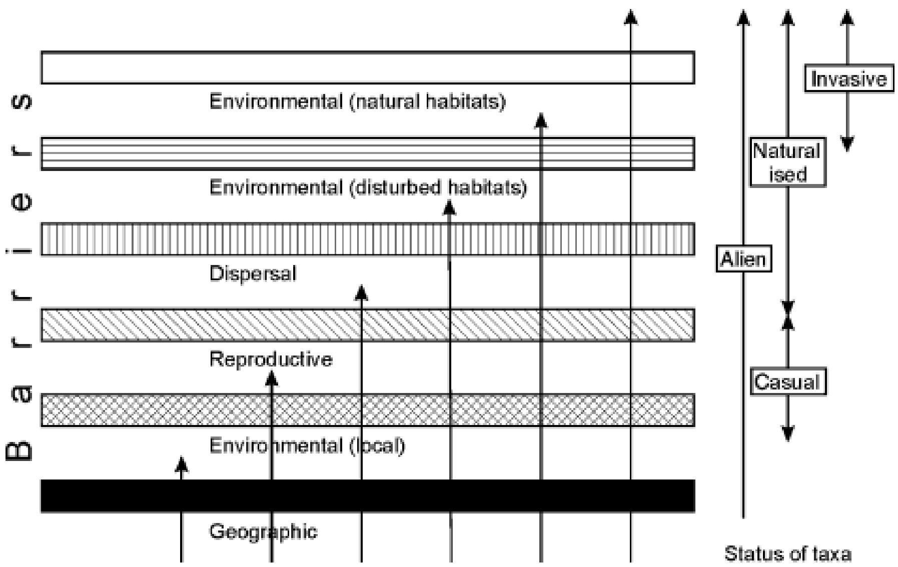


Figure 1. Schematically representation of the barriers that limit the dispersal of fishes as an example of the invasive process. The different stage of the process can be seen in the vertical arrows on the right. Adapted from the work of Richardson et. al. (2000) by Copp et. al. (2005)

It is widely accepted that just a few of the introduced species produce an important impact. It is based in Williamson and co-authors "tens rule", in which 10% of the species goes from one stage to the next one (Garcia-Berthou et al, 2005). However, this study state that between 5 to 20% of the NIS will become in a pest (Garcia-Berthou et al, 2005), it means they will produce a harmful economic effect, but it does not include ecological impacts (Carlton, 2003). Some authors have found exceptions to this rule, for instance: Streftaris et al (2005) or Garcia-Berthou et al (2005). However, the last of them stated that probably their results are biased, because there is more record of success introduction that unsuccessful ones. On the other hand, there are lot of introduction that have not been studied to demonstrate this rule (Carlton, 2003, Garcia-Berthou et al, 2005). Nevertheless, “tens rule” show that by preventing the introductions we will reduce the invasion risk by decreasing the potential number of species that will become invasive. The concept propagule pressure can be used as well; the probability of establishment not only depends of the susceptibility of the environment, but also on the degree of exposure to alien species (Hulme, 2008).

Intentional introductions are different from the accidental ones (Simberloff and Alexander, 1998). The intentional introductions for commercial or sports purposes have three main differences for risk assessment (Simberloff and Alexander, 1998). However, two of them are essential for the establishment process as well. When an introduction is intentional with the objective to create a new population for aquaculture or fishing the introduction itself will bring the establishment. It is because at least enough individuals will be introduced and usually it will be reintroduced until the population is established (Simberloff and Alexander, 1998). Secondly, these species have been chosen to be able to survive in the receptor environment. Species introduced intentionally overcome the two first barriers in principal by humans help (Garcia- Berthou et al, 2005).

What makes some species succeed and invade a new environment is an important issue that has been studied by the scientific community. There are many examples of it, especially for weed risk assessment (e.g. Pheloung et al. 1999, Koike and Kato 2006, Nyberg and Wallentinus 2003). The main objective of these studies is trying to predict which species could be a future invader based on the biological characteristics of the organism; and as well, which characteristics of the host ecosystem make it more vulnerable to the invasions (e.g.: Zaio et al 2006). However, it turns to be difficult to identify the invasiveness characteristics of organism. Results are contradictory, the list of biological attributes has a lot of exceptions, and there is no guarantees (Hewitt and Hayes, 2003 Boudouresque and Verlaque, 2002; Ruiz and Hewitt, 2002). At the same time one species can be benign in one place and become a big problem in other region (Murray et al, 2005). It seems an ecological roulette as was called for Carlton and Geller (1993).

Nevertheless, some species traits have been recognised as favourable for invasion. These are for instance, high rate of reproduction, presence of resting stages, overcome abiotic factors and vegetative reproduction (Streftaris et al 2005; Boudouresque and Verlaque, 2002). As a general principle, species that show well-known r-selected characteristic are theoretically predicted to be more successful colonists in a new environment (Ruiz and Hewitt, 2002). In addition, ecosystems that are more impacted by human activities are more likely to be invaded (Hulme, 2008) or with lower diversity (Ruiz and Hewitt, 2002). Here again there is a difference between the intentional or unintentional introductions, intentional introduction implicate strong selection of species and habitats and are less dependent on the species trait (Garcia-Berthou, et al 2005). All this research is mainly focused on the prevention and prediction of invasions. However, the alien species produce impact even without necessity of have a population established. A good example is the case of the "lighthouse keeper cat", which was able to extinct one bird (Xenicus lyalli) from Stephen Island (BirdLife, 2008; Delibes de Castro, 2001). This example, even anecdotal, shows that the main conclusion is that "the only real trait that predict the invasive behaviour of species, is if they are invasive somewhere else" (Herron et al, 2007; Boudouresque and Verlaque, 2002; Koike, 2006; Genovesi and Shine, 2003).

2.1. Impacts of non-indigenous species

Alien species are the second cause of lost of biodiversity globally (García-Berthou et al, 2005) and one of the four greatest threats to marine ecosystem (Streftaris et al 2005). Global impacts of NIS are the homogenization or globalization of river and seas (Streftaris et. al., 2005 and Ojaverr et al., 2003); and threat to the genetic integrity of the native biota, because there are no geographical boundaries that isolate populations reproduction, which is a major driver of the species evolution (Hulme, 2008; Leppäkoski et al, 2002). NIS has, in many cases, impacts to economies and human health as well (Leppäkoski et al, 2002).

NIS have been called ecological abnormalities (Copp et al, 2005) or biopollution (Ribera and Boudouresque, 1995), to highlight their impacts and the anthropogenic influence on the process. It is impossible to know how a non-indigenous species will behave outside their native region, many aspect of the invasion are unpredictable (Gollasch, 2002). The presence of NIS itself decreases the naturalness of the ecosystem, which is an impact itself (UKTAG, 2004). In addition, the establishment of a specie in a habitat include the use of resources (food, space, light) (Carlton, 2003) which produce an impact over previous biota and on ecosystem equilibrium. Experimental studies have to be done to determine if these alterations are statistically significant (Carlton, 2003). The impacts are negative (displacement of native species; fouling organism in pipes) or positive (create new habitat; commercial value) (Table 1). Impacts on the environment are generally irreversible (Streftaris et. al., 2005, Koike, 2006). Once a species is established in a marine ecosystem it is almost impossible to eliminate, and it is expensive to control and limit its impacts (Ribera and Boudouresque, 1995, Molnar et al, in press). However, in small areas and in an early stage of the establishment it is possible, e.g. *Caulerpa taxifolia* an algae has been eradicated in San Diego, California, (Miller, 2004). Prevention by controlling the pathways is the most effective measure (Molnar et al, in press).

NIS are a very special environmental problem, they can be considered pollutants but they do not behave like chemical pollutants and so they have to be assessed differently (Simberloff and Alexandre, 1998). They are living organism that will reproduce and spread, becoming part of the biota and have uncountable interactions with their environment (Leppäkoski et al, 2002). Moreover, there is a time lag between the introductions and when the population grows, spreads and produces impacts, during this time species are unnoticed (Simberloff and Alexandre, 1998).

Table 1. Impacts (positive and negative) of aquatic non-indigenous species on the environment and socio-economy.

Impact	Specie
Displacement of native species, competition for resources	Sargassum muticum (algae)
Displacement by predation	Hemimysis anomala (shrimp), Mustela vison (mammal)
Introduction of Pest and diseases	Procambarus clarkii (crayfish)
Genetic pool degradation of a specie	Spartina anglica (plant)
Changes in the physic-chemical conditions of habitat	Crepidula fornicate (mollusc), Ficopomatus enigmaticus
Bio-engineers	Dreissena polymorpha (mussel)
Changes in community structure	Caulerpa taxifolia (algae)
Changes in the food webs	Mnemiopsis leidyi (jellyfish)
Fouling on ships, marinas, aquaculture structures, etc.	Crepidula fornicate (mollusc), Ficopomatus enigmaticus (polychaeta)
Degradation of structures	Eriocheir sinensis (crab)
Hazard for shipping	Sargassum muticum (algae)
Increase productivity	Zostera japonica (seagrass)
Changes in nutrients/energy flows	Dreissena polymorpha (clam)
Create new habitat	Crepidual fornicate(mollusc)
Provide food	Crassostrea gigas (oyster)
Commercial value	Undaria pinnatifida (algae)
Erosion control	Spartina densiflora (plant)
Toxicity /pests /diseases	Toxic algae bloom Fibrocapsa japonica

JNCC (1997); Ojaveer et al (2002); Nummi (2002); Ribera and Boudouresque, (1995); Gomoiu et al (2002) and Global Invasive Species Database (ISSG), (2005).

There is a long list of impacts that an alien species can produce over individuals, communities and ecosystems; as well as over human health and economy (See Table 1 for examples). The impacts and knowledge of marine environment is poorly known compare with other habitats (Ribera and Boudouresque, 1995). In addition, there are differences in spatial and taxonomic effort done in the study of NIS, and as well lack of quantify and scientific prove data, as showed in (Streftaris et al, 2005; Molnar et al, in press, Bax et al, 2001). Any general conclusion and affirmation should be considered carefully, because most of the invasions have never been study to demonstrate a causative process of the impacts (Carlton, 2003). In addition, for many introductions judgement of impacts are done in correlative, anecdotal or qualitative assumptions (Carlton, 2003).

2.2. Vectors and pathways of introduction

Introduction vectors and pathways are a key issue for the study and management of introduced species (Garcia-Berthou et al 2005, Minchin and Gollasch, 2002; McNeely et al., 2001). The connection between the donor and the receiver regions and how it happens (vector) is important to prevent future introduction and control expansion of the species (McNeely et al., 2001). Direct control over pathways and driver activities will decrease the risk and reduce impacts, and is one of the most effective management actions (Molnar et al, in press).

In the introduction process there is a primary introduction vector of a species after which secondary introduction occurs (Minchin and Gollasch, 2002). Both vectors can be the same or different. S*argassum mutiucm* (algae), for instance, was probably primary introduced with oysters, but its secondary spread all along the European coast was most likely due to natural drift or accidental by shipping. Main activities and vectors for Europe aquatic ecosystems are presented in Table 2. The main transmission vectors in Europe are shipping, aquaculture and aircraft movement of living organism (Minchin and Gollasch, 2002). Shipping is the main vector with difference because it includes ballast water and hull fouling. Furthermore, the increase in ports and ports facilities, and the better water quality in them, create favourable conditions for more introduction and spread of organisms (Minchin and Gollasch, 2002). The less important vectors are aquarium trade, pet trade, bait for fishing activities, even food trade but can cause serious problems related with the transport of diseases, especially if there is no good regulation. However, less attention is paid to these vectors in the regulation or it is poorly applied. Vectors can be overlapping, and usually it is difficult to trade back the real vector in accidental introductions (Minchin and Gollasch, 2002).

Table 2. Main activities and vectors related with the introduction and spread of species.

Activity	Vectors associated
Shipping/ floating structures	Ballast water and sediments, hull fouling, cargo and ship equipment
Aquaculture	Imports for culture, transport equipment, shell fouling, host tissue
Fishing	Equipment, bait, imports for sport fishing
Food processing	Untreated water disposal of imported produce, exportation of tissues
Live food trade	Untreated disposal of tissues/animals and water, escapes, releases
Aquarium trade/pet trade	Escapes, releases, untreated disposal of water and tissues
Stock enhancement	Release, infested stock
Recreation activities	Shipping, hull fouling, fishing equipment
Opening of natural barriers	Water links, canals
Movement of sediments, sand, aggregates	Attached to or living within organisms
New trade agreements	New trade routes, movement of goods, shipping
Research studies	Release, disposal
Political policy	Production of forage species, genetically modify organism
Cultural preferences	Imports of species, food trade, festival release
New fisheries development	Release to the wild and spread

Adapted from Minchin and Gollasch, 2002.

There are main pathways, or routes, in which NIS are transported. In the work of Garcia-Berthou and co-author (2005) they statistically analyzed the United Nations Food and Agriculture Organization's Database of Invasive Aquatic Species (FAO DIAS) to analyzed invasion pathways in Europe. They results show the main routes of spread, donor and receiver regions in Europe (Figure 2). For Portugal the main pathway starts in North America that is a donor region for France, which is as the same time the donor of Spain. Finally from Spain the species are introduced in Portugal (Figure 2).

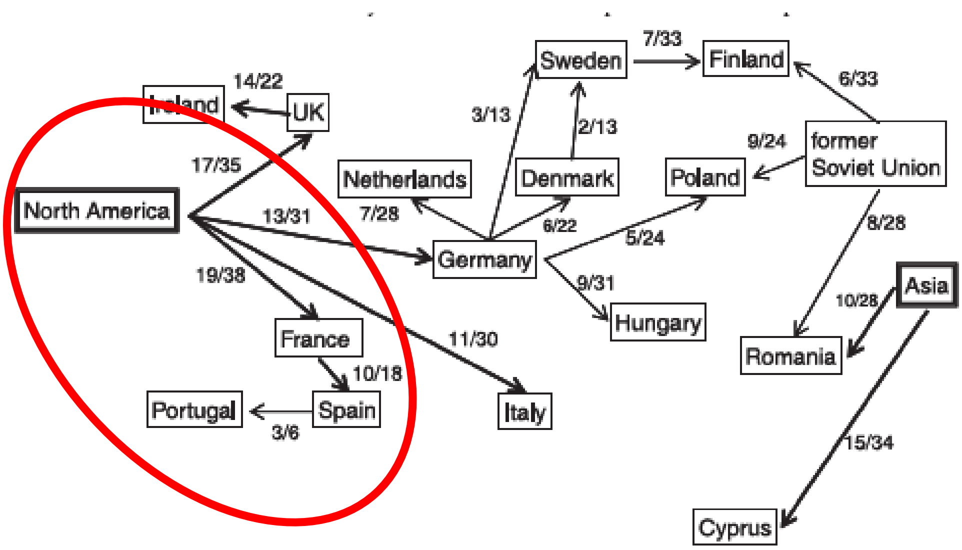


Figure 2. The main introduction pathways of aquatic species within Europe. The fractions denote the number of species introduced from one country to another (numerator) followed by the total number of introductions received, excluding those of unknown origin (denominator).The circle show the main route of introduction into Portugal (Adapted from: Garcia-Berthou et al , 2005)

2.3. Situation in Europe

European NIS introduction have occurred since ancient times, but in the last 500 years it has increased, mainly because the increase in transport and trade (Lepppäkoski 2002). This increase is continuous and more accentuated in recent times (40-50 years) as a result of the globalization and improvement in transports (Genovesi and Shine, 2003;

Streftaris et al, 2005). It has been accepted as an important environmental problem for the conservation of the nature in Europe (Genovesi and Shine, 2003).

The situation of the aquatic NIS of Europe has been reviewed recently (e.g. DAISIE project; Streftaris et al, 2005; Leppäkoski et al, 2003). Streftaris et al. (2005) found 851 NIS, with zoobenthos being the main group. The main period of introduction was 1960-1980 and it is stable nowadays. However, it is not expected that the introduction process is stopped (Streftaris, et al, 2005). On the other hand, the number of introduction in the Mediterranean has doubled each 20 years (Boudouresque and Verlaque, 2002). Main vectors in Europe are: Suez Channel, aquaculture and shipping (Streftaris et al, 2005); all introductions are related directly or indirectly with the process of trade and travel (Hulme, 2008). As explained before, these data and results have limitations and biases, mainly because of differences in study effort in each region and biological group. A lot of work still has to be done, especially for marine environments (Streftaris et al, 2005).

There are already invasive alien species agreements, strategies, programs and legal instruments that highlight the necessity of action on the NIS problem. For instance: Global Strategy of Invasive Alien Species by the Global Invasive Species Program (Mc Neely et al, 2001); the European strategy on Invasive Alien species by Genovesi and Shine (2003); Bern convection; RAMSAR convention; United Nation Convention of the Law of the Sea; and European legal instruments (EC Council Directive 79/409/EEC on the Conservation of Wild Birds, EC Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora, Council Regulation 338/97/EC on the Protection of the Species of Wild Flora and Fauna by Regulating Trade Therein). More information can be found in the European Strategy on Invasive

Alien species (Genovesi and Shine, 2003) or in the Commission's DG Environmental Webpage's. Nevertheless, practical measure for prevention, control and eradication are inadequate, not developed or not implemented (McNeely et al., 2001). All reports highlight the importance of prevention, but it is poorly achieved. There are some weaknesses in the policies: lack of regulation of accidental introduction; some activities are out of regulation because they are important and basic economic activities like forestry and agriculture species; there is not commitment to eradication and control of established NIS; NIS control and management is not a priority for the states (Hulme, 2008).

2.4. Non-indigenous species in the Water Framework directive

The main objectives of the Water Framework Directive can be summarized as: to achieve a good ecological status of all the water bodies of Europe by 2015. The ecological status is measured by biological, physic-chemical and morphological characteristics. The water body definition is: "*a discrete and significant element of surface water such as a lake, a reservoir, a stream, river or canal, part of a stream, river or canal, a transitional water or a stretch of coastal water*; and "*Body of groundwater means a distinct volume of groundwater within an aquifer or aquifers"* (European Commission, 2000). Member states have to achieve a good ecological status of all surface waters and preserve it.

The general definition given by WFD of a water body with a good ecological status is: *The values of the biological quality elements for the surface water body type show low levels of distortion resulting from human activity, but deviate only slightly from those normally associated with the surface water body type under undisturbed conditions*

(European Commission, 2000). The conditions of the physic-chemical and hydro-morphological quality elements have to be consistence with the achievement of the biological quality elements. Each water body has to achieve the good condition for each of its quality elements. The quality elements are, as an example:

- For biological elements: changes in community composition and abundance
- For hydro-morphological elements: structure and conditions of the substrate, and structure of the intertidal zone
- For physic-chemical elements: transparency, nutrients, oxygen, temperature, and salinity.

The ecological quality has to be classified in five quality classes: high, good, moderate, bad and poor. By using the Ecological Quality Ratio (EQR), that is the difference between the reference and the observed conditions, the biological quality elements are classified (Newton et al, 2007; van de Bund and Solimini, 2006). An intercalibration exercise is carried out to determine the boundaries between high-good and good-moderate status for each water body type, and make them consistent and comparable between states (Newton et al, 2007). Comparable indicator, typology and type-specific reference conditions have to be designated for each quality element (van de Bund and Solimini, 2006). Places with undisturbed conditions or minor are selected to be the reference point for high or good status, the reference value is designated by the better value of each indices in the reference site.

Non-Indigenous Species are implicated in two tasks of the WFD: the characterization of the water bodies and the review of the impact of human activity on the status of surface waters (UKTAG 2004). Non-indigenous species can affect the characterization of the water body because as soon as species establish in a new environment it is part of the biota and form part of the community and ecological process, creating a scale of modification and alterations in the pre-existing conditions (Carlton, 2002). As a consequence, water bodies with a number of established NIS do not have biological pristine conditions, the naturalness of the system decreases (UKTAG, 2004). Nevertheless, in the case of shallow water bodies almost all of them have a number of exotic species (Cohen and Carlton, 1995).

Furthermore, the quality elements of a water body (especially biological elements) can even be very disturbed by the impacts for the introduced species. Annex II of the WFD states that “other significant anthropogenic impacts on the status of surface water bodies” have to be identified and assessed. Species are introduced by humans, intentionally or accidentally, they are a threat and a pressure on the environment (biological, chemical and physical characteristics). Another point of view is to consider NIS as biopollution, as stated before. Due to this, it is reasonable to consider NIS a potential anthropogenic pressure over water bodies and their impacts increase the risk for water bodies to fail the objectives of the WFD (UKTAG, 2004). This second implication is what really concerns to the WFD (UKTAG, 2004). Clear tools are needed to assess the effects and risk of NIS on a water body, in order to be able to manage them as it is show in the different strategies and toolkits (Genovesi and Shine, 2003; McNeely et al., 2001; Wittenberg and Cock, 2001).

Effects of anthropogenic activities are usually evaluated using impacts and risk assessment. Nowadays, there are different methods of risk and impacts assessment for

NIS, some are in order to evaluate which species would be allowed or not in a country, like the Australian and New Zealand weed risk assessment (Kato et al, 2006). Other methods, like the UKTAG list try to classify the species in order to act against them or to take them in consideration for the analysis of the water bodies for the WFD (UKTAG, 2004). The biopollution index will be a helpful tool to compare and assess the NIS situation of a water body (Olenin et al, 2007). However, to calculate this index and others, quantitative and qualitative data and information is required on the NIS involved. For instance, to apply the biopollution index the following information is needed: Abundance/distribution; Impacts on communities, habitat and ecosystem for all NIS within a water body. For most NIS there is not complete dataset available and certainly not one that provides data from the screened water body. Some of the methods use specialist judgments instead. New databases have been developed lately that provides centralized dataset of NIS by region, as European level by DAISIE (2008). However, specific-site data is usually not available.

It is important to say that WFD is not the only legislation or law where NIS could be included. International convection and European directives and programs which their main objective is nature conservation should, if they have not already, consider introduced species in their agenda (e.g.: Convection of Biological Diversity; Convention of Wetlands (RAMSAR)). At the same time specific NIS strategies have been develop in recent years, like the Global Strategy on Invasive Alien Species (McNeely et al., 2001), and the European Strategy on Invasive Alien Species (Genovesi and Shine,2003). However, the WFD is the most important directive on water bodies' conservation and quality improvement in Europe. In addition, it is an international law, already working and being implemented by all States members in all water bodies, due to this, it is extremely important to considerer NIS within it.

The first step to develop a management plan for NIS is to do a preliminary assessment with the information available and develop an inventory listing all introduce species present, and as well abundances, distributions, impacts, and pathways of introduction, (Genovesi and Shine, 2003). This project is the compilation all the available information for the Ria Formosa; it is focused on aquatic and mainly on the marine ecosystem part of the system. However, terrestrial species were found as well and have been included for a general view of the situation.

2.5. The Natural Park of Ria Formosa

The Natural Park of Ria Formosa (NPRF) is a shallow mesotidal lagoon (Michler, 2003; Newton et al, 2007). It is located in the south coast of Portugal, in the Algarve region. It is the biggest lagoon in Portugal (Pereira and Duarte, 2006) and part of 5 municipalities; Loule, Faro, Olhão, Tavira and Vile Real de Santo António. It has 5 dune barriers, from east to west: Barreta, Culatra, Armona, Tavira y Cabanas; one artificial inlet, and 2 peninsulas Ançao in the east and Cacela in the west that separate it from the open ocean (Newton et al, 2007; Michler, 2003).

The system can be considered a real barrier island, with the follow elements: mainland, barrier islands, back barrier lagoons, inlet deltas, barrier platforms and shore face, with extensive mud flats, sand banks, dune systems, salt marshes, and substantial seagrass beds of Zostera (Michler, 2003). The drainage basin of RF is about 854, 07 km^2, but it is a system without significant freshwater inputs. There are mainly small and not-permanent streams, only Gilão River is a relevant freshwater input for RF (ICN, 2004).

Figure 3. The Natural Park of Ria Formosa (in green) (ICN, 2004).

The Ria Formosa lagoon (RF) has a very important natural value. In 1987, it was established as a Natural Park (Decreto-Lei nº 373/87 de 9 de Dezembro), following the former 1978 Natural Reserve ordinance, and has been recognized internationally as well. RF is a wetland of international importance under the Wetland Convection (RAMSAR) since 1980 (RAMSAR, 2008). It is also part of the NATURA 2000 network, under the Habitats and Birds Directives; the codes are PTCON0013 and PT2PE0017 respectively (Community Directive 79/409/EEC and 92/43/CEE).

The Ria Formosa has a high productivity environment and an important value because of its biodiversity. The most important group is the avifauna, especially aquatic species (more than 200 species). It is an important breeding and migratory route for European and African species. Furthermore, there are in total 93 species present in RF that are also included in the Habitat or Bird directive in different categories, 59 of them are birds (ICN,2004).

Table 3. Resume of the main characteristic of Ria Formosa lagoon.

Ria Formosa lagoon characteristics	
Location[1]: Longitude **Latitude**	8º 2'W to 7º 32' W 36º58' N and 37º03'N
Climate [3]	Mediterranean
Long [2]	55 km
Width [1]	5-6 km max.
Area [1]	160 km^2
Drainage basin [4]	854,07 km^2
Salinity [2]	35.5 to 36.9 PSU
Tidal range [2]	2.8 to 0.6 m (spring tide and mean neap tide)
Water exchange with open ocean [2]	50-75% each tidal cycle
Residence time of water [2]	½ day – 2 days
Water temperature [2]	12ºC in winter- 28ºC summer
Mean depth [1]	1.5 m
Maximum depth [1]	19 m
Average depth in channel [1]	3.5 m
Area of the Natural Park [1]	78 000 ha

Data from: Newton et al 2007 (1); Michler, 2003 (2); Serpa et al, 2005 (3); ICN, 2004 (4).

There are also threatened mammals and herpectofauna in RF; especially: European otter (*Lutra lutra*), common genet (*Genetta genetta*), Eurasian badger (*Meles meles*), chameleon (*Chamaleo chameleon*) diverse bats species, European pond turtle (*Emys orbicularis*) and some marine turtles that can use this habitat too. PNRF vegetation is diverse, contain several plants endemism: 10 for Europe; 28 for the Iberian Peninsula and 4 for Portugal; some of which are threatened. There are also Iberian endemic animals as *Talpa occidentalis* and *Lepus granetensis* (mammals) and *Chalcides bedriagai* and *Blanus cinereus* (reptiles) (ICN, 2004). However, the marine habitat is the most ecological and economic important. The aquatic habitat of the lagoon is highly productive and is an important nursery place for a lot of species. There are 99 listed fish species and a large number of macro benthos and bivalves species.

Figure 4. Satellite image of Ria Formosa lagoon. Barriers and main canals are visible. Airport and towns are market (Google Earth).

In the context of the WFD, RF is considered a coastal water body for the WFD due to its salinity and water exchange with the ocean there is not enough salinity gradient to be classified it as a transitional water (Newton et al, 2007). Ria Formosa is considered in good ecological status under the WFD process. It is the only coastal system that has good conditions for Biological Quality Elements as well as Hydro-morphological and Physic-Chemical Elements. The site Ponte da Praia de Faro within the Ria Formosa is proposed as a reference point for benthos (Newton et al, 2007).

Socio-economy:

The high productivity of the lagoon and its beautiful landscape and beaches make RF a very important resources source for the region. Aquaculture (clams and oysters mainly) and fisheries are very important activities. The aquaculture in Algarve forms the 40% of the national production and it has the highest percentage of people working in fishing and aquaculture activities direct or indirectly in the nation (Michler, 2003). The main fishery ports of the region are inside the Ria Formosa lagoon. There are 3000 families registered as fishermen in RF, however, it is thought that 8000 to 10000 families depend on the fishery activity due to illegal activities (Michler, 2003). However, there are several problems that stakeholders state for this activity: over-exploitation, lack of control, illegal fishing and non-declaration products (Michler, 2003)

The Algarve region has increased its population and development in the last 30 years (Figure 5) (ICN, 2004). This produces a high urban pressures and important changes in land use. The number of construction licenses in Algarve has double in less than 10 years. Between 1960 -2001 the number of buildings has increase 52, 8% in the drainage basin of the lagoon (ICN, 2004). The Ria Formosa is an important area, mainly due to the touristic offer (Serpa et al, 2005).

There is a seasonal variation in the population in Ria Formosa due to non-resident population. During high touristic season population almost double in the lagoon, data from 2001 show an increase of population in local houses of the lagoon from 150 000 in winter to almost 250 000 in summer (Serpa et al, 2005).

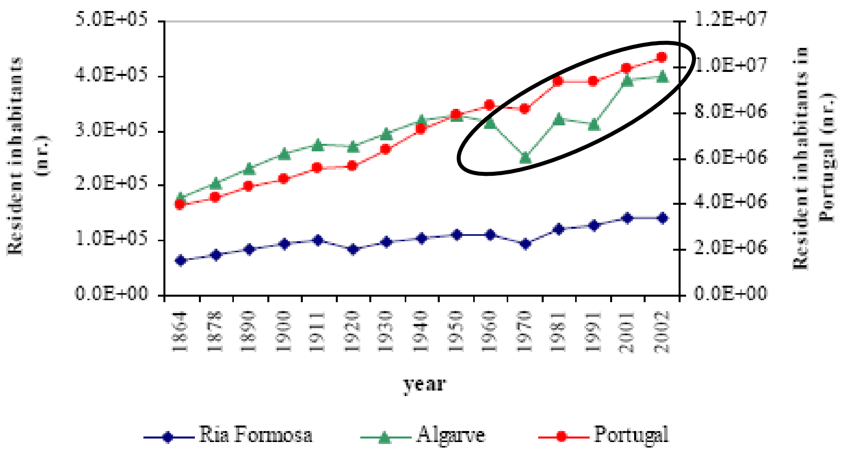


Figure 5. Population evolution in Ria Formosa watershed, Algarve region and Portugal from 1864 to 2002. (Serpa et al, 2005)

The tertiary sector is the most important in the Algarve based on the Report of the environmental status of Algarve, 2003 (Anonymous, 2005). In 2001, the 70% of the population work for the tertiary sector. The tourism has become the main activity in the Algarve region in the last decades, and forms the main driver of development (Serpa et al, 2005)

The marine traffic is mainly due to fishery, leisure, and passenger transport (public or private). There are a big number of fishery boats and ships, but it is underestimated, as stated before, because there are fishermen without license (Michler, 2003; ICN, 2004). Marine traffic increases a lot in the summer months because of touristic activities (ICN, 2004). The destination are mainly regional, however there is no data about the origin or destination of the traffic. The infrastructures for nautical sport and leisure ships are abundant inside the lagoon (ICN, 2004). There are up to 24 structures that include marinas and docks, as well as 15 tie up points and shipyards. Olhão and Tavira are the more important ports and marinas for fishery. There are several plans for enlargement and construction of new nautical structures (ICN, 2004).

The Faro port is the only commercial port in the study areas. It is one of the most important in Algarve region, and a secondary port at national level. However, its traffic is small, the number of ships that enter in RF was 50 ships in 2003. 83% of the goods transported are gasoline for Faro airport and gas stations. The port has commercial relations with 14 ports; just one for exportation and the rest are importation of goods. The 73% of the traffic is with the Sines port, in Portugal, 13% with France, 7% with UK, others ports are in Belgium, Spain, Germany and Holland (Sério, 2004). Finally, point out the importance of the Faro airport, which activity has increase in the last years. It is important for the tourism and the development of the region (ICN, 2004).

The Ria Formosa lagoon gives lot of resources and in its area coexists several activities all of them related with the lagoon. There are a big number of stakeholders that have to be taken into account for its management. Main institution involve in the management of the lagoon: Natural Park of Ria Formosa (Parque Natural da Ria Formosa, PNRF); Institute of Nature Conservation (Instituto de Conservação da Natureza, ICN); General Directorate of Fisheries and Aquaculture (Direcção Gerald das Pescas e Aquicultura, DGPA); Regional Directorate of Environmental and Land Planning (Direcção Regional do Ambiente e Ordenamento do Território, DRAOT); Universidade do Algarve; Research Institute of Fisheries and the Sea (IPIMAR).

The activities that are the main pressures on the lagoon include: urbanization, intensive agriculture, coastal engineering, wastewaters, tourism and conversion to intensive aquaculture (Michler, 2003, RAMSAR, 2008; ICN, 2004). However, the high flushing regime of the lagoon and the absence of important industry make RF be classified as showing low human impacts (Newton et al 2003).

The legal framework of the NPRF is complex due to the high number of governmental institutions that regulate the different activities. The non-indigenous species count with a national law (Decreto-Lei No 565/99) that regulates the introduction in the wild of non-indigenous plants and animals, with the exception of species that are important for agriculture or forestry.

Table 4. Main economic activities in Ria Formosa.

Main Sector	Activities
Fishery and Aquaculture	Fishing, Aquaculture, Harbours and traffic for vessels of fishery
Tourism	Touristic development, Recreational Navigation, Marinas, Golf courses, Beach tourism, Other nautical sports
Research	University of the Algarve and IPIMAR
Urbanization	Infrastructure construction for access and for waste water
Nature Conservation	Management and planning
Shipping Ports and Harbours	Vessel traffic, Petrol and Chemical Terminals
Transports	International Airport
Agriculture	Intensive and extensive agriculture in the watershed (pig and chicken farms)
Sand extraction	Sand extraction out of the major channels but also other parts of the Ria for construction purpose etc.
Salt extraction	Traditional and mechanical salt extraction

Adapted from Michler, 2003.

3. Method

This project is a review of the available information on the situation of introduced species in the Ria Formosa Natural Park. The information for this project has been compiled from a wide variety of sources; due to the variety of species and information required, ranging from databases and literature to personal interviews which were done with several stakeholders for the collection of general information and to record their opinions.

The first step was to obtain a list of species present in RF. The principal documents used were Machado and Abreu (2000) for benthic communities and Plano do Ordenamiento do Parque Natural da Ria Formosa (ICN, 2004) for vegetation and vertebrate fauna. Other bibliography used was: Erzini *et al*. (2002) for fishes; Calvario (1995) for benthic communities; RIAGRAD report of 2000 and EVODRAG report of 2002 (Sprung et al, 2002) for an update of benthic communities; Furtado 1989, Mendes 1999 and Viegas 2007 for dune vegetation. Algae update list was provided by algae research group of Sea Science Group of Algarve (CCMAR) in personal communication. Plankton species and microorganisms (virus, bacteria) have not been included because of the high uncertainty in the identification and in the arrival pathway for these species expressed by the local research specialist for these species (Barbosa, Dominguez, and Fonseca pers. Comm.)

After construction the Ria Formosa species list was matched with Portuguese, Spanish, Iberian-Peninsula, European and International Non-Indigenous Species (NIS) databases in order to come to a list of introduced species in RF (Box 1). Several databases were used because none of them showed a complete and reviewed list, resulting in some groups of species being missed out or not matched completely with the geographical situation of the RF. The location of the RF is considered to be the European North Atlantic Ocean region, being the most southerly part of it. However, it is also the most northern distribution limit for some African species and the western distribution limit for some Mediterranean species (N. Grade and L. Fonseca, pers. Com.). For this reason each species listed as introduced in Portugal, Iberian Peninsula, North Atlantic or Europe when present in the Ria Formosa was included in the list of NIS of the RF, and subsequently its native distribution was researched carefully to verify that the RF could not be considered historically part of its native distribution.

Some NIS were not found in any published data, but their introduction is known and/or has been identified by UALG professors, members of CCMAR or PNRF workers and therefore were also included. It is important to notice that the spread vectors are supposed for the accidental introductions based on the vectors known somewhere else.

This study focused on the aquatic ecosystem of the RF, and mainly the marine habitat. So for each of the aquatic NIS of the RF, the following main characteristics, considered essential for the NIS assessment and NIS risk assessment, were researched: its introduction history and pathways in Europe, Portugal and RF, first record in RF (when available), its main biological traits like reproduction, tolerance and diet; the life cycle of the specie; impacts on ecosystems and on socio-economic activities in the RF or somewhere else; and the current distribution and abundance in RF (when available). This information was also collected from a wide range of sources; articles, databases, institutions reports, WebPages, and personal communications with expert on NIS topic, and as well researches and workers of the Ria Formosa Natural Park. As an approximation of the introduction date was done by research of the first record of the specie in Ria Formosa. This data is unknown for some of the species. However, when no record is available an approximation can be retrieved by personal communication with the stakeholders in Ria Formosa.

Main Non-indigenous Species Databases and species information sources used

- FAO species fact sheet aquatic commercial species. Fisheries and aquaculture department of FAO. (FAO 2000-2008)
- Database on Introduction of Aquatic Species (DIAS). Fisheries and aquaculture department of FAO. (FAO 2000-2008)
- The Global Invasive Species Database (GISD) by Invasive Species Specialist Group (ISSG). (Available at: http://www.issg.org/database)
- Delivering Alien Invasive Species Inventories for Europe (DAISIE) database. (DAISIE European Invasive Alien Species Gateway. Available at: http://www.europe-aliens.org/)
- Joint Nature Conservation Committee (JNCC) database of NIS. (JNCC Crown copyright. Available at: http://www.jncc.gov.uk/page-0)
- Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme by Marine Biological Association of the United Kingdom. (Available from: http://www.marlin.ac.uk/species/Alcdig.htm)
- Especias Exóticas Invasoras de la Península Ibérica, InvasIber. (Available at: http://hidra.udg.es/invasiber/presentacion.php)
- Mediterranean Science Commission (CIESM) Atlas of Exotic Species. (CIESM, 2005. Available at: http://www.ciesm.org/index.htm)
- AlgaeBase. (Guiry, M.D. & Guiry, G.M. 2008. Available at: http://www.algaebase.org)
- Plantas invasoras em Portugal WebPages. Project INVADER and INVADER II. Available at: http://www1.ci.uc.pt/invasoras/index.php
- Spanish list of invasive alien species. (Capdevila Argüelles *et. al*., 2006)
- Alien Marine Species in Mediterranean- the 100 “worst invasive” and its impacts. (Streftaris and Zentos, 2006)
- Non-native marine species in British water: review and directory. Edited by JCNN (1997)
- Decreto-Lei nº 565/99 de 21 de Dezembro. Law about NIS in Portugal.

Box 1. Main Non-Indigenouis Species databases and species information documents and webpages consulted for the construction of the NIS list in RF

NIS and NIS assessment are relative new and still under development. Several of these assessment methods were reviewed and tested for their applicability. Biopollution Index of Olenin et al (2007) and the generic non-indigenous aquatic organisms risk analysis develop in USA (Orr, 2003), were used to identify knowledge gaps and difficulties in the risk assessment application.

The impact on the ecosystems has been classified in 3 levels of ecosystem organization, as used in the biopollution index of Olenin et al. (2007):

- Impacts on species and communities: changes caused in native species composition and abundance, including shift in type-specific communities
- Impacts on habitat: habitat alteration or loss.
- Impacts on ecosystem: impacts on ecosystem processes and functioning

This classification was required to improve the knowledge of the impacts and to construct results helpful for future studies and future assessment. As well, these 3 levels of impacts help to see the impacts of NIS on the WFD quality elements and parameters. The impacts on communities will disturb the biological elements, and impacts on habitat will disturb the hydromorphological and physic-chemical elements.

During all the process different interviews and personal communication took place with different stakeholders. Several professors of University of Algarve were contacted and interviewed, as well as workers of the Ria Formosa Natural Park and shellfish collectors from Olhão and Faro. In order to make the communication with the local shellfish collector easier, I used a questionnaire in Portuguese and identification charts for the different invertebrate species (Annex III).

For each species a risk level is given, which is the general risk of the species to produce important harmful impacts on the ecosystem and/or to become invasive. The general risk is how the species is considered from a global point of view. The data to assess the risk level have been taken from international databases, reports and articles that state its harmful effect somewhere else. The best trait that identifies a species as an invader, and the only factor highly correlated with invasiveness, is if the species is an invader somewhere else. This principle is widely accepted (Wittenberg and cock, 2001; Boudouresque and Verlaque, 2002) and it is also applied here.

The high uncertainty about the situation of the NIS in the Ria Formosa makes it impossible to assess the real impact or risk. Due to this, the potential impact in RF is based in general information about the species. The criteria used for the impact assessment is based in the categories used in the "Guidance on the assessment of alien species pressures by UK Technical Advisory Group on Water Framework Directive (UKTAG, 2004):

- Unknown impact: alien species those are invasive and produce major impacts somewhere else, but whose probability of do so is unknown in Ria Formosa, and for which a full risk assessment is required.
- Low impact: alien species known to have low probability of becoming invasive or produce major impacts, and where field observations have shown no adverse impacts over many years of establishment.
- High impact: alien species, known to be invasive or produce major impacts, which have caused documented harm in Ria Formosa.

The general situation of the non-indigenous species in Ria Formosa was assessed after all the information cited above was collected.

4. Results

4.1. Non-Indigenous Species of RF

37 non-indigenous species have been found as NIS inside the RFNP limits and there is a dominance of the terrestrial species (54%), followed by marine and freshwater species (38% and 8% respectively) (Fig 6 A). Grouping the species by phylum, the dominant group is terrestrial plants 41%; follow by algae 13%; and mollusc and crustacean 11% each one (Fig 6 B).

Although, there are only a few freshwater NIS, one has to take into account that in RFNP exist just a few freshwater habitats, and just one permanent freshwater flow, Rio Gilão in the east part of the lagoon. In relative number, and comparing with the importance and magnitude of the other ecosystems, it is a high number, especially because all of them are considered invasive.

The importance of the NIS inside their phylum is variable. As an approximation, NIS reptiles are 10% of the total reptiles in RF; vascular plants are the 7 %; mammals the 6 % and macroalgae the 5%. Other phylum has less percentage of NIS: introduced crustacean 2%; molluscs are the 2 %, and birds are only the 0,0056% of the total number of birds.

There are 3 cases of historical introduction or antique, the chamaeleo (*Chamaleo chamaleo)*, and the 2 mammals, gener (*Gineta gineta)* and egyptian mongoose (*Herpestes ichneumon)*; it is likely that introduction took place before or in Roman’s time. Historical introductions have not been classified as accidental or intentional, because it is unknown. However, it is believed that these species were introduced intentionally for hunting or as pets. There are 10 cases of accidental introduction; all of them concern aquatic species (Fig 7). The vectors of accidental introduction are not clear and there is no evidence. The main accidental vectors are shipping (hull fouling and ballast water) and aquaculture, but also fishing activities, live food trade and natural dispersal. The most likely introduction vector is described in Table 5 for each species.

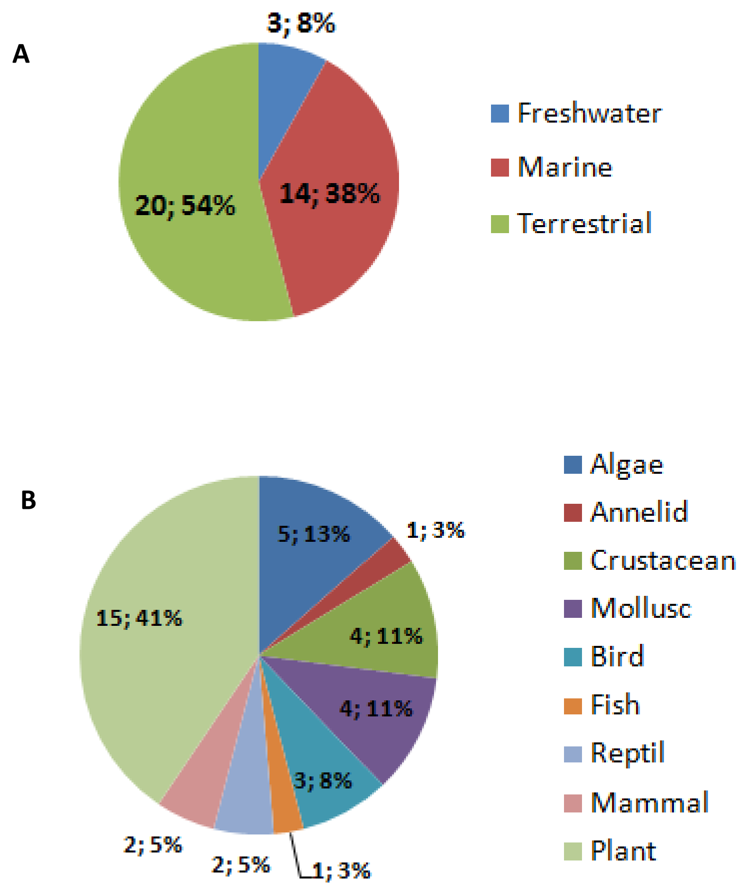


Figure 6. A. Percentage of NIS that belong to each ecossytem. B. Percentage of NIS that belong to each Phyum. First number show the number of species and the second one is the percentage that represent inside the NIS.

Most of the recent introductions are intentional 71% (24 species of 34). They are dominated by intentional terrestrial introductions 50%, whereas aquatic are 21%. The intentional introduction activities for terrestrial species are mainly garden and pet trade; and aquaculture (3cases) for aquatic ones. Other activities like fishing, health security, pet trade and research, all of them have all equal importance (one case each).

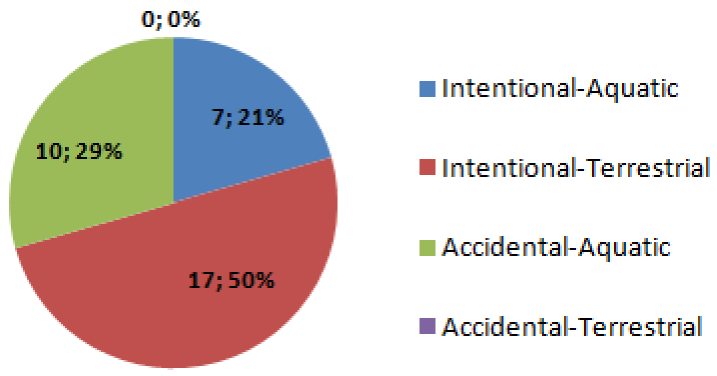


Figure 7. Relative distribution of the type of introduction of all terrestrial and aquatic non-indigenous species in RFNP.

The native region of the species is divided by oceans for marine species, and by continents for terrestrial species (Fig. 8, A and B). All freshwater species originated from North America (not shown). For both groups the native region is diverse without significance main region. For marine environment 36% of the species come from Pacific region, 29% from Indo-Pacific, 21% from other areas of the Atlantic Ocean and 14% remind unknown. 30% of the terrestrial species come from Australia, 25% from Africa, 20%from South America and just 10% from Asia. However, the Pacific with Asia and Oceania regions all together would be the principal donor region for Ria Formosa (Fig. 8). For some species the native region is unknown; in the case of terrestrial species they are the historical introduction, the aquatic species are the polychaeta *Ficopomatus enigmaticus* and the algae *Antithamnionella ternifolia*, however, both species are supposed to come from the southern hemisphere.

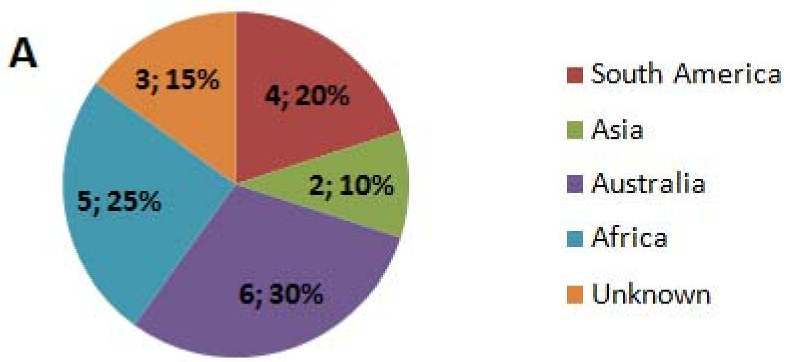
There is little management of the introduced species in the lagoon. Only 3 of the 17 aquatic species reported are considered a problem in the RF: the algae *Sargassum muticum* is being studied and removed from some parts of the lagoon; for the turtle *Traschemys scripta* is planned its future management; and the clam *Ruditapes* *philippinarum* is considered a problem for the shellfish collectors and IPIMAR institute. The salt marshes plant, *Spartina densiflora,* is not considered a problem in RF, however its invasiveness is well known and studies are carrying on by the Seville University in collaboration with CCMAR in closer areas to RFNP. For terrestrial ecosystem just the plant *Carpobrotus edulis* is considered a problem and is being managed, it is removed for some areas just to control its distribution. For other species, like Acacias genus and *Oxalis pes-capraea,* there are also planned eradication plans (Grade, pers Comm.). The introduction of terrestrial plants and animals and some freshwater species is regulated by the Portuguese law of introduced species.

4.2. Aquatic NIS (freshwater and marine environment) of Ria Formosa

Benthic species is the main group 82% (14 of the 17 species), with in it, benthonic fauna it is the main group with 9 species, and benthonic flora has 5 species. Grouping the species by phylum, algae is the main group, 29% (5 species), follow by mollusc and crustacean, 23 % each one (4 species each one) and annelid, fish, reptile and plant are a 6 % each one (Table 5 and 7).

The date of introduction of the aquatic species shows a strong increase since 2000 (Fig. 9). Before the 60's only two species were recorded, the fish *Gambusia affinis* and *Spartina densiflora*. In the 70's and 80's just one specie was recorded, the oyster *Crassostrea gigas* and *Antithantionella ternifolia* respectively. During the 90's the first records started to increase to 3 (*Ficopomatus enigmatucus*, *Balanus Amphitrite* (barnacle) and *Ruditapes philippinarum*) and since 2000 there have been 6 new species recorded (the limpet *Crepidula fornicata*, the prawn *Penaeus japonicus*, the whelk *Bucinum undatum, the turtle Trachemys scripta and the algae Sargassum muticum* and

Gracilaria vermiculophylla). The first date of introduction of three species was not found, the crustacean *Corophium sextonae*, the crayfish *Proclambus clarkii,* and the algae *Colpomenia peregrina* and *Asparagopsis armata*, the last one was cultivated in south Portugal for research purpose after 2000 (Schuenhoff et al, 2006).



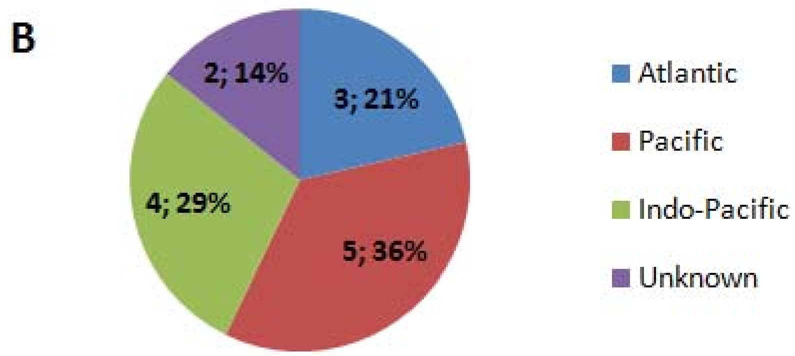


Figure 8. Relative distribution of the native region of non-indigenous species in PNRF. A/ Terrestrial species; B/ Marine species. First number show the number of species and the second one is the percentage that represent inside its group (marine, terrestrial)

The origin of the introduction in RF is unknown for most of the species. The most probable origin is somewhere in Europe, where the NIS were introduced by primary movements and then after spread secondary to other regions. Based on the first records for the NIS is different European countries, most of the species arrived primary to

England or France, and as well to Spain but in less proportion (Fig. 10; see Annex I for references).

On the other hand, there are exceptions, aquaculture species introduced intentionally, like *Crassotrea gigas, Penaeus japonicas* and *Ruditapes philippinarum*, which are known to come from France and Spain or Tunisia, respectively. Species used in the pet trade are usually introduced from their native country and then raised in captivity, as Trachemys scripta.

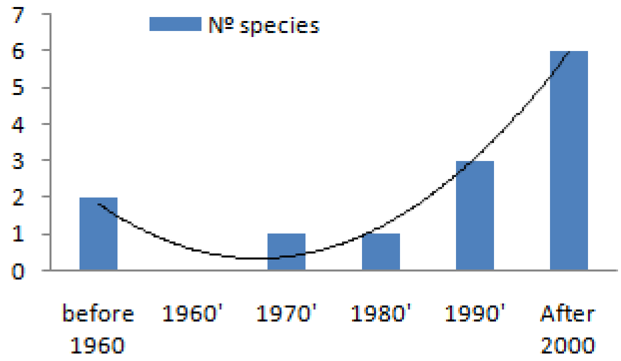


Figure 9. First record of non-indigenous species in Ria Formosa. Number of species that were fisrt recorded in each decade.

Most of the introduction (accidental or intentional) of marine species are related with aquaculture activities (oysters, clams, fish, and food for them). The introduction of all mollusc species is related with aquaculture activities, it can be accidentally or intentionally. For algae is probable that they have been spread by regional movement of boats or arrive by natural drift. The accidental introduction of algae with oysters is also possible.

The seriousness of the problem in the RF becomes clearer when the invasiveness of the species was investigated. Of the 17 aquatic species 65 % (11 species) are included in at least one of the "100' worst invasive species" lists; in Global Invasive Species Database (ISSG) at international level, DAISIE at European level, or Streftaris (2006) for the Mediterranean Sea (Table 6).

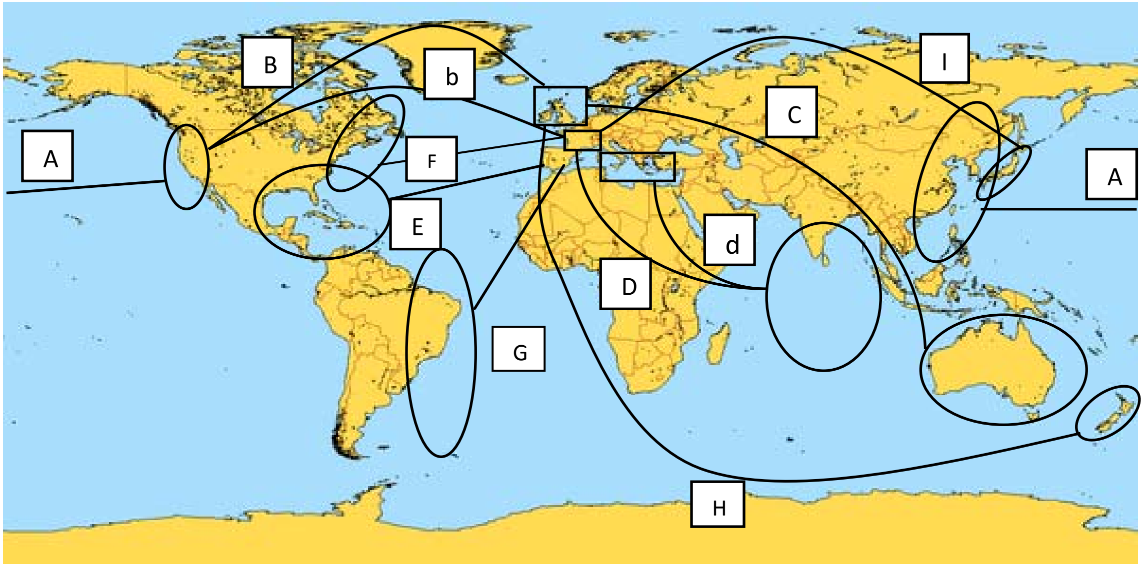


Figure 10. Probable primary introduction of non-indigenous species of RF in Europe. Donor region (circle) and receiving region UK, France, Spain, Portugal and Mediterranean Sea. Lines do not show the route of introduction. A+B) S. *muticum* and *C. gigas*; B) *B. Amphitrite*; b) *C. peregrina*; C) *A. armata*, *A. thernifolia* and *F. enigmaticus*; D) *T. philippinarum*; d) *P. japonicas*; E) *G. affinis*, *T. scripta* and *P. clarkii*; F) *C. fornicate*; G) *S. denfiflora*; H) *C.sextonae;* I) *G. Vermiculophylla* (this specie could have arrived by A+b).

Although the NIS present in RF show a high invasiveness, the potential risk of the species in Ria Formosa is mainly unknown: 65 % of the species has unknown impacts (11 species), 6 % has high impacts (1 species), and 29 % has low impacts (5 species) (Table 5). In most of the cases there are not impacts reports for RF or these are assumed by some of the stakeholders but without empirical support. 82 % (9 species) of the species which it is unknown the impacts are considered high risk somewhere else (See table 5 and Annex I). However, they are classified as unknown because the information is contradictory or there is not data about the specie in RF lagoon. For instance *C. fornicate* is considered very harmful (JNCC, 2007; Campbell, 1994), but the only information about it is the personal observation of scientist of Ria Formosa. *Penaeus* *japonicus* can create major impacts but its presence and abundance is controversy due to the similarities with the native species (see Annex I).

Table 6. Invasiveness of the introduced species in RF. Yes means that the specie is included in the 100' worst invasive species lists. Invasive alien species of Europe database DAISIE, 2002; Mediterranean species list Streftaris et al 2006; and Global invasive species database, ISSG, 2005.

Species	100' worst DAISIE	100' worst Med	100' worst ISSG
Sargassum muticum	-	Yes	-
Colpomenia peregrina	-	Yes	-
Asparagopsis armata	-	Yes	-
Antithamnionella ternifolia	-	-	-
Gracilaria vermiculophylla	-	-	-
Spartina densiflora	-	-	-
Ficopomatus enigmaticus	Yes	Yes	-
Penaeus japonicas	Yes	Yes	-
Procambarus clarkii	Yes	-	-
Balanus Amphitrite	-	-	-
Corophium sextonae	-	-	-
Crassostrea gigas	Yes	Yes	-
Ruditapes philipinarum	-	Yes	-
Buccinum undatum	-	-	-
Crepidula fornicate	Yes	-	-
Trachemys scripta	yes	-	Yes
Gambusia affinis	-	-	Yes

Table 5. Aquatic non-indigenous species in Ria Formosa. Freshwater species are in bold. Reference of presence in RF (Ref); Introduction type: Accidental (A) and Intentional (I); Introduction status: introduce (Intro.), establish (Est.), non current empirical data (?); Introduction vector: Natural spread (Nat.), Health Security (H.Sec.), shipping (Ship), Aquaculture (Aq.), erosion control (E. crtl), release, research and unknown; Impacts: has a known impact (yes), has not impact (non), not data available (ND), ? it is unknown in RF, positive socio-economic impact (+), negative socio-economic impact (-)

NIS	Ref.	Introduction region	Introduction type	1st record RF	Distribution	Abundance	Intro Status	Introduction vector	Invasion barrier	Impact				Potential Impacts RF	Risk
										Community	Habitats	Ecosystems	Socio-Economic		
Sargassum muticum	A. Engelen, 2003	W Pacific	A	2006	Local	Very abundant	Est.	Nat.	Hard substrate	Yes	Yes	Yes/ ?	-/?	High	**High**
Antithamnionella ternifolia	Machado and Abreu, 2000; DAISIE 2008	South Hemisphere	A	1988	Unknown	Unknown	Intro. ?	Ship	Non	ND	ND	ND	-/?	Low	**Low**
Spartina densiflora	ICN, 2004	WS Atlantic	A	Before 1960	Everywhere	Abundant	Est.	E. crtl.; Nat.	Flood	Yes	Yes	ND	-	Low	**High**
Ficopomatus enigmatiucus	Machado and Abreu 2000,	South Hemisphere	A	1994	Unknown	Unknown	Est.	Aq; ship	Salinity	Yes /?	Yes/?	ND	-/?	Low	**High**
Gambusia affinis	Grade, pers Comm.	N America	I	Before 1960	Everywhere	Common	Est.	H. Sec.	Non	Yes	ND	ND	ND	low	**High**
Balanus amphitrite	Machado and Abreu, 2000	SW Pacific, Indian Ocean	A	1994	Unknown	Unknown	Intro ?	Ship	non-data	ND	ND	ND	-/?	Low	**Low**
Procambarus clarkii	Grade, pers Comm.	N America	I	Unknown	Local	Abundant	Intro.?	Unknow	Salinity	Yes/ ?	Yes / ?	Yes /?	- /?	Unknown	**High**
Trachemys scripta	Grade, pers Comm.	N America	I	Recent years	Local	Unknown	Intro. ?	Release	Salinity	Yes /?	ND	ND	+	Unknown	**High**
Colpomenia peregrina	Engelen, pers comm.	Pacific	A	Unknown	Everywhere	Low abundance	Est. ?	Aq; Ship	Hard subtrate	ND	ND	ND	- /?	Unknown	**High**
Asparagopsis armata	Engelen, pers Comm.	Indo-Pacific	I	Unknown	Everywhere	Common	Est. ?	Aq; Ship; Nat.; research	Non	Yes /?	Yes /?	ND	+	Unknown	**High**
Gracilaria vermiculophylla	Engelen pers comm	Pacific	A	After 2000	Local	Abundant	Est.?	Aq.; Ship.	Non	Yes	Yes	Yes	+ / - ?	Unknown	**High**
Penaeus japonicus	A. Newton, pers. Comm.	Indo-West Pacific. Japan	I	2000	Everywhere	Abundant	Intro. ?	Aq	Temp/ salinity	Yes /?	ND	ND	+	Unknown	**High**
Ruditapes philipinarum	Campos and Cachola, YEAR??	Indo-Pacific	I	1990'	No data	No data	Intro. ?	Aq	Non-data	Yes	ND	ND	+	Unknown	**High**
Crassostrea gigas	A. Newton 2007. Gonçalvez 2000	Pacific	I	1970'	No data	No data	Est.?	Aq	Non	Yes	Yes /?	ND	+	Unknown	**high**
Crepidula fornicata	Afonso,pers. Comm.	NW Atlantic	A	2004-2005	Local	Low abundance	Intro. ?	Aq. ;Nat.	Non	Yes / ?	Yes/?	ND	-/?	Unknown	**High**
Corophium sextonae	Gamito, 2008	S Pacific	A	Unknown	Unknown	Unknown	Est. ?	Ship Aq	Non	ND	ND	ND	ND	Unknown	**Low**
Buccinum undatum	Afonso,pers. Comm.	N Atlantic	A	Few years ago	Local	No data	Intro. ?	Aq	Temp/ intertidal conditions	Yes /?	ND	ND	-/?	Unknown	**Low**

Table 7. Biological characteristic of the aquatic non-indigenous species in Ria Formosa. Freshwater species are in bold. This table follow the same order than the table above. Tolerance to different physical conditions: high tolerance (High); low tolerance (Low); adapt to a wide variety of substratum (All); special requirements are specificity. Reproduction: sexual reproduction (Sex); vegetative reproduction (Veg).

NIS	Habitat	Taxonomy	Feeding	Tolerance			Reproduction	Uses	Comments
				T (ºC)	Salinity	Subtratum			
Sargassum muticum	Benthos Intertidal-subtidal	Brown algae	Photosynth	High	High	Hard	Sex Veg.		
Antithamnionella ternifolia	Benthos	Red algae	Photosynth	High	High	All	Veg		
Spartina densiflora	Littoral intertidal	Vascular plant	Photosynth		High	-	Sex Veg		Colonist; No tolerant to floods
Ficopomatus enigmatiucus	Benthos low intertidal-subtidal	Annelid Polychaeta	Filter-feeder	+18º	Low for reproduction	Hard	Sex		
Gambusia affinis	Pelagic freshwater bodies	Chordata Fish	Eggs larvae	High	high	-	Sex	Mosquito control	40-70mm length
Balanus amphitrite	Benthos intertidal	Arthropoda Crustacean	Filter-feeder	23º C optimus	Moderate	All	Sex hermaphrodites		
Procambarus clarkii	Freshwater bodies	Arthropoda Crustacean	Plants and detritus	High	Freshwater	-	Sex	Fish	Survive in terrestrial habitat
Trachemys scripta	Freshwater bodies	Chordata Reptil	Omnivorus Oportunist predator	Moderate	Freshwater	-	Sex	Pet	
Colpomenia peregrine	Benthos	Green algae	Photosymth	Moderate	Moderate	Hard	Sex		
Asparagopsis armata	Benthos infralittoral	Red algae	Photosynth	High	Moderate		Sex Veg	Cosmetic medicine biofilter	
Gracilaria vermiculophylla	Benthos intertidal	Red algae	Photosynth	High	High	High	Sex Veg	Agar	Difficult to identify
Penaeus japonicus	Benthos	Arthropoda Crustacean	Omnivorus	Low	Low	-	Sex	Fishery	nocturnal
Ruditapes philipinarum	Benthos intertidal	Mollusc Bivalve	Filter-feeder	Moderate	Moderate	Sandy muddy clay	Sex	Fishery	
Crassostrea gigas	Benthos intertidal	Mollusc Bivalve	Filter-feeder	Low	Low	All	Sex hermaphrodites	Fishery	High reproductive/grow rates Planktonic larvae
Crepidula fornicata	Benthos	Mollusc Gastropod	Suspensión feeder	High	High	High	Sex hermaphrodite		Form agreegates Pelgic larvae
Corophium sextonae	Benthos	Arthropoda Crustacean	Suspensión deposit feeder	Moderate	High	Shoft	Sex		5mm length
Buccinum undatum	Benthos subtidal	Mollusc Gastropod	Carnivores	Low	Moderate	-	Sex	Fishery	Variable morphology

5. Discussion

5.1. Discussion of the results

37 NIS have been found in RF, results show that terrestrial species are the biggest group (54%), being terrestrial plants the most introduced. However, this result could not show the real situation. Terrestrial plants could be overestimated because it is a good studied group, whereas others group less or not studied would be underestimated.

There are more intentional introductions (71%) the majority of them are terrestrial introductions for ornamental purpose. On the other hand, main vectors of aquatic intentional introductions are important economic activities, like aquaculture (e.g. oysters, fish and polychaetes as food for the other two) and fishing. This makes more important and complicate the management of aquatic species. The management of activities that are important for the economic is more controversial, and usually affects a big group of the population. Additionally, marine and freshwater ecosystems are threatened by accidental introductions; control and management of accidental introductions is less developed. There are not specific regulations and control of NIS on the marine activities in RF, especially for control the accidental introductions. Only aquaculture is regulated, but there is not a real control, in accordance with the stakeholders there are illegal aquaculture activities. Accidental introduction control should be a priority in the development of new control measures for NIS.

The old introductions, accidental or intentional, are not considered a problem because of the long time that the species are in RF. I consider them as not priority species for management because it is not causing impacts nowadays and they are already well established in the ecosystem. However, this supposed naturalization has not any scientific corroboration, little empirical evidence or theoretical basis exit to fix a time period after which introduced specie can be considered naturalized (Carlton, 2003).

I would like to highlight that these results underestimate the number of species introduced. Some groups are not represented (plankton) and other there is not good and specific studies about the possible introduced species. As well, the number probably has increased since the bibliography and databases were update. For instance, terrestrial plant and birds are really good studied groups, and as well are the only groups that have a former list of NIS in Portugal. However, it is possible that the number of them is also underestimated for RF. There are 16 species of introduced bird reported for Algarve in 1994 (Diaz Pastor, pers Comm.) but just for 3 we have found a record in Ria Formosa. For terrestrial plants 60 alien species have been identified in RF but just 10, that are considered invasive, were found in the Planning of the NPRF (ICN, 2004) (see Annex II).

Aquatic species

Benthic communities are the biggest group; mollusc, algae and crustacean. Zoobenthos is the dominant group; this is in accordance with the results on other European studies, as in the Mediterranean Sea, Atlantic sea and North Sea (Streftaris et al, 2005; Reise et al, 2002). This result can be argued that is biased because more attention can been paid to these organisms, however good databases as the ones in Mediterranean and Baltic seas support the dominance of mollusc (Streftaris et al, 2005). There are not any marine fishes in the list. However, some alien marine fishes were found, but they are migrant species and are not considered introduced or non-indigenous in RF. This is the case for *Sparrisoma cretense*, a Mediterranean parrot fish species that was first recorded in 2005 for RF (Abecasis et al, 2006). It is not considered an alien species, because RF is considered the western distribution for some Mediterranean species. However, it is important its presence shows clearly the possibility of establishment of Mediterranean species towards the west, where they would be non-indigenous. This could be due to climate change, or even these species have a sporadic present in Ria Formosa but it has not been notice before (Fonseca and Grade, Pers comm.). Ria Formosa is a vulnerable ecosystem to the climate change, the establishment of new species will be another factor that affect this vulnerability, and should be consider for scientific discussion.

There was a clear increase in the number of species in the last years. This may be because of the increase in the research projects and published reports of RF. However, the presence of most of the species have been noticed by the local populations in the last 10 years, which show that probably there is real increase in the NIS introductions. This is supported by the fast economical development of the region, for instance the increase of aquaculture since 70's. More recently, tourism has become one of the main economic activities, and the activity of large boats has increased as well (Michler, 2003). The observed pattern that increased NIS records increase when the economic development increase is in accordance with data from other regions. Areas with more human activities and for long period present highest number of NIS, as Mediterranean Sea or Atlantic French coast, were numbers started to increasing in the last 50 years, with a peak between 1960-1980 (Streftaris et al. 2005; Ribera Siguan, 2003; Goulletquer et al, 2002). The relative late increase in Ria Formosa is in the 90's, maybe because of the delay that Portugal had in its development in comparison with other European countries.

Indo-Pacific and Pacific regions together are the native region from most of the introduced aquatic species. This result has been observed as well by other studies. Goulletquer et al, (2002) in their study of the introduced species in the Atlantic coast of Europe found that the 63% of the species come from Indo-Pacific and Pacific region. For some groups like macrophytes results in RF show that there is a dominance of Asian species 80%, (*Sargassum muticum*, *Asparagopsis armata*, *Colpomenia peregrina and Gracilaria vermiculophylla*), this result is showed as well in Williams and Smith, (2007) study of the global introduced seaweeds.

Nevertheless, it is important to highlight that most probable origin of the introduction in RF are secondary movements of the species from closer areas and regional movements, as was explained above. It is in accordance with the study of Garcia-Berthou et al (2005), as explained before (Fig. 2); they proposed Spain as the main donor for Portugal, and France the main donor to Spain. Species with wide distribution in nearby regions of Iberian Peninsula are assumed to arrive by regional spread vectors, as fishery activities and leisure boats and transport, or by natural spread as *S. muticum* which can spread long distance naturally. This fact is important to restrict the control of donor regions to national and European regions.

There are lot of gaps in the knowledge in general and site-specific of RF (Table 5). The distribution and abundance is unknown, except for *Sargassum muticum* and *Spartina densiflora*. For the rest of the species there is little information for RF, and the data showed are an approximation done for stakeholders. There is the same situation for the introduction status. For most species there is just a record of the presence, and their establishment is accepted but not proven by scientific studies. For the bivalves it is unknown whether or not the populations are sustained by continuous illegal introduction for its harvesting. The status is known only for four species because they are old introductions or have been studied, they are *S. muticum*, *S. densiflora, F. enigmaticus* and *G. affinis*. There is little empirical data from recent studies. Scientific research is needed in order to clarify the situation of the species. To develop a risk or impact assessment it is necessary to know if the population is established or if it is becoming abundant in their communities.

A big amount of information about NIS can be found in the databases that different research groups have in internet. However, this information is not complete and/or update. Some of the lists are focus only in some groups of individuals or just for the coast of one country. Even, if these are really useful, it do not say anything about the species out of that country borders, or do not have site specific information. The species guides, reports or articles rarely difference between introduced species and native ones. In addition, I have notice that good databases of species or NIS have been not update for some countries, as Portugal, and due to this there is a gap of knowledge for the country. The participation of the different research groups (different places, different species groups) on these databases, the update of the information and the publication of species list will be a good improvement of the knowledge and really helpful for management.

Direct talk with stakeholders was one of the main sources of information on NIS in RF. During the interview with different stakeholders I found different and contradictory information. For example for *P. japonicus* abundance (Annex I). This controversy may be because of the different point of view of the stakeholders. For shellfish collectors may be it is not abundant specie because it is not enough for commercial propose, whereas for the scientific community it is abundant in relation with the community structure and assemblage. However, a real change in the abundance of the species is possible.

An important point to be discussed is the situation of some cryptogenic mollusc. For instance the case of *B. undatum*: for scientist it has been introduced in RF (Afonso pers. Com) and its distribution is clearly for north Europe (Annex I). On the other hand other scientists are not sure that it is non-indigenous specie (Grade and Fonseca pers com.). The opinion of shellfish collectors is also contradictory, they do not recognised *B. Undatum*, and state there are 2 other species of whelks that start appearing last years and come from other countries, as Angola. This species where identify in the university as common and native from RF, *Hexaplex trunculus* and *Stramanita haemastoma*. Another example is *Littorea littorina* which was indentify as non-indigenous by scientist. Its distribution is mainly in north Europe, but it is stated that is native species from all Portuguese coast in mollusc guide book (Macedo et al, 1999). It is possible that these species have been always present in Ria Formosa but in low density and they have not been notice (Grade, pers comm.). However, these species have not been identified in the several benthic community studies of RF (e.g.: Machado and Abreu, 2000; RIAGRAD report, 2000 and EVODRAG report, 2002). These contradictions increase the uncertainty involved, and show the lack of data and register, that makes impossible to verify the situation.

These species are examples of other species that have been not included in this research for the same reasons. The collaboration of specialist in the different species groups and the research on unpublished data will be required to reduce the uncertainty. As Mr.

Fonseca stated there is a lack of studies on systematic, and for some groups there is a lack on identification until specie level. For instance, this species are present in RF and in NIS databases: *Glycera dibranchiate*, *Corophium acherusicum*, *Corophiium multisetosum*, *Syllis gracilis*, between others; but their identification as real non-indigenous in RF was not possible. Additionally, all species register as NIS for Portugal in DAISIE and in the Spanish list should be considered carefully for Ria Formosa.

The impacts of the species in RF are unknown; most of the impacts reported in Annex I are the impacts known for the species somewhere else. Table 5 shows if there is data or not for Ria Formosa. For 5 species there are no ecological impacts reported anywhere, these are: *Colpomenia peregrina*, *Antithamtionella ternifolia*, *Balunus Amphitrite*, *Corophium sextonae* and *Buccinum undatum*. The reason for the lack of impacts reported for *B. Undatum* is because it is not considered as NIS in any database.

11 of the 17 aquatic species are in a list or several of the 100's worst species, but none of the marine species appear in any Portuguese regulation (e.g.: Exotic species law (lie das exoticas)); and just one of them, *S. muticum* has been studied as NIS in RF by CCMAR. *S. densiflora* has been studies as well (Redondo, pers comm.). Furthermore, 65 % of the species have unknown impacts in Ria Formosa; and almost all of them (9 of 11) are considered high risk somewhere else. This result is important to emphasize the necessity of increase the control measures and the management action for NIS; and as well, to be aware of the potential high risk that they are.

5.2. Assessment of the Non-Indigenous Species situation of the lagoon

The characteristics and situation of the lagoon may be the reason of the low establishment success of NIS compared with the number of species established in nearby Europeans seas; more than 300 for Mediterranean Sea and more than 100 in Atlantic Sea (Streftaris et al, 2005). RF presents warm water temperature compare with North Atlantic Ocean, and other parts of the coast in Iberian Peninsula. At the same time it has a wide tidal range, specially compare with the Mediterranean conditions. Some species cannot survive under these situations (Grade and Fonseca pers. Comm.). In addition there is little maritime traffic of large vessels; it is mainly local fishery and leisure boats. From the point of view of the stakeholders, Faro port has not a big activity and just received a low number of large commercial vessels each year, maybe 3-4 (Grade pers. Comm.). However, the study of Sério (2004) state that there were 50 ships coming to Faro port in 2003. The maritime traffic to the port should be consider as well on the vector analysis.

Aquaculture was the first introduction drive activity that was developed in the lagoon, in the 70's and 80's, it was follow by the high increase in tourism. Aquaculture is expected to increase (Michler, 2003) and it is planned to enlarger ports and marines; it will bring more facilities for shipping (ICN, 2004). Tourism is increasing as well; more yachts and boats will travel all around the Portuguese and Spanish coast being a good spread vector (ICN, 2004; Serpa et al, 2005). There are as well other new activities linked with the development and economy growth of the area that increase the risk of new introduction (Rosemary Luis pers. Comm.). These activities can be sport fishery, pet trade, and new species in the food trade. For example, a market that is increasing is the importation of polychaetes to be used as bait and food in aquaculture. For example there are 2 species of polychate and one sipunculan introduced weekly in Portugal from their native region with this purpose (Fidalgo e Costas et al, 2006). The sipunculan, *Sipunculus nudus*, is present in RF, however it is a cosmopolitan species and its origin is not clear. Nevertheless, individuals of this specie arrive weekly to the Lisbon airport from Vietnam to be sold in Spain and Portugal (Fidalgo e Costas et al, 2006). One of the 2 polychaetes, *Perinereis aibuhitensis*, is cultivated in Tavira (RF) by IPIMAR. This species has not been detected in the wild, but it is possible that is already present. These species are also risk species for the introduction of diseases (L. Fonseca, pers. Comm.). As Luis Fonseca comments the change in the environment conditions (chemical and physical conditions) make the lagoon more vulnerable. These changes could create better conditions for the introduced species or worse conditions for the native biota. For instance, RF region is suffering from change in the land use and urbanization, and increase in human pressure, as was presented in Ria Formosa description (Michler, 2003; Serpa et al 2005).

This is correlated with the finding that more GDP of a country more introductions, related with trade, consumerism and urbanization (Hulme, 2008). As well, due to the climate change species from south latitude could arrive and develop here, while the species from north Atlantic would not survive (Fonseca and Grade pers. Comm.). These changes in the biodiversity and changes in the distribution of the species due to climate change have been stated as an important problem for the future by the stakeholders (Fonseca and Grade pers. Comm.). Nowadays, it is considered by the stakeholders that RF has not a current bad/problematic situation about AS. However, the high rate of dangerous species presents in NPRF show the opposite.

The real situation of RF is unknown, and it is not possible to do a confident affirmation because there is a high uncertainty in the results. Most of the studies of NIS state that the number of introduced species is usually underestimate (Bax et al, 2001; Streftaris and Zenetos, 2006; Streftaris et al, 2005), our case it is not an exception. It is so difficult to be sure when the species have been introduced and its effects and impacts because the lack of studies about these NIS in the lagoon. Furthermore, there is required more awareness about the introduction of new species in the RF lagoon as was comment above.

There is little management and regulation of the introduced species. The current legislation is not in accordance with the reality of the RF lagoon. The Portuguese law only regulates plants and animals that are consider invasive or harmful and that are not of interest for agriculture or forestry. Only 4 of the non-indigenous aquatic species appear in this law as invasive or dangerous for ecosystems, which mean that are forbidden: *P clarkii, Spartina densiflora, Gambusia holbrokii* (considered a sub-specie of *G. affinis*) and *Trachemys scripta*. No marine species appear in the law; this shows the lack of regulation on this topic for the marine ecosystem. It is required more consideration of the marine ecosystem and activities in the regulation in all legislation levels for NIS problem. As Miss Luis state there is not regulation for the marine environment as for terrestrial habitats; in terrestrial environment there are land use regulations, urban programs, or regulations of all activities inside the boundaries of terrestrial natural parks. There are less method, strategies and tools for regulate the marine habitats; the engineers, technicians or managers in charge are not use to control and regulate marine environment (Luis pers. Comm.). In addition, the regulation of accidental introductions by hull fouling for instance is more difficult than deliberated activities.

The management of activities which are related with the introduction of NIS should be improved in order to control the pathways and vectors of introduction. Ships and leisure transport can enter and leave the RF without any control. The marine authority, Capitanias, has a register but not all fishermen register its boats, and due to the free transit the real number of boats and ships in the lagoon is unknown (Michler, 2003). There are illegal aquaculture activities that are considered a problem by stakeholders (Michler, 2003). The commercial port is of small traffic and introduction by ballast water is less probable (Grade, pers comm.). However, it is considered second importance in the country and ships come from other European important ports.

The situation of the RF is complex because all activities and interest come from the lagoon. Tourism and aquaculture are important business, but they can perturb each other (Michler, 2003) at the same time that both of them create big environmental problems and put in risk the conservation of the lagoon. These activities are the key factors for the economy, key activities for the NIS introduction and for environmental conservation. If the lagoon is not managed properly and in a sustainable way the situation will become unfavourable for any of the activities.

Another management difficulty is the communication between the different stakeholders. The information and research is done separately between the scientific community at UALG, the natural park, administration and other research institutions. It can be noticed in the different opinions of the stakeholders, and a clear example is *R. philippinarum*; in the report of Campos and Cachola (2006) is reported the impacts as disease transport specie and its continuous introduction. These facts were not state by any other person or document. The communication, transparency and the collaboration in the research is a key issue for any environmental management, and it is especially important for the conservation of a natural area.

The current situation of knowledge and control of introduced species in the RF lagoon is in conflict with big value of RF, especially the aquatic environment. 11 of the 17 non-indigenous aquatic species are in one or more 100's worst NIS list. Nine of them have negative impacts on the socio-economy of the region; all of them were introduced accidentally. It makes the accidental aquatic introduction a big potential threat for the RFNP environment and socio-economy, but it is not being managed. Introduced terrestrial plants also represent an important risk, all of them are already forbidden by law. However, there is not current management for all of them. RF is a natural park and it is considered in a good ecological status, preservation should be the first goal and all potential threat should be assess and control.

In Ria Formosa the only management option that can be suggest in the current situation is to **start to be concerned** about invasive species problem. The best way would be start the **development and implementation of a management plan on NIS**. First objective would be *increase the knowledge* by:

- Assess the current situation by scientific research on species and vectors.
- Identify donor regions and which species could be introduced in the future.

These first actions would avoid the uncertainty and contradictory information. Precautionary principle should be adopted while management actions are taken. Main findings of this study can be used to prioritize first actions. The NIS management actions should be part of an integrative management plan for the lagoon, which regulate all activities in a sustainable way.

Main Finding:

High uncertainity

More introductions of NIS in the last decades

Mainly aquatic accidental introduction

Zoobenthos is the main group introduced

Aquaculture and regional shipping main vectors

Secondary regional movements of NIS

Illegal activities that involucrate NIS (aquaculture)

These main finding are similar to the situation in other regions as Mediterranean Sea (Streftaris and Zenetos, 2006) and with the general situation of Europe. Strategies, methods and tools implemented in other areas could have success in Ria Formosa as well.

The Ria Formosa has good conditions and recent introduction, it could be a good "laboratory" to study the impacts and apply successfully control and management measures. Different scientific areas are involved in these studies (ecology, environmental science, biology, physiology, zoology, botanic, etc.), all stakeholders and different areas of knowledge and science have to get include.

Suggested early actions for management of non-indigenous species in Ria Formosa

- Collaborated and participate in existing programs. Update NIS Portuguese list and information in international and regional work groups, programs, and databases. Especially in Iberian Peninsula and North East Atlantic ones.
- Create a unique database of Ria Formosa species list. Update and coordinate sampling and identification process by the different research groups. It would homogenize the information, reduce the effort and avoid taxonomic problems.
- Develop a list of specific donor regions and risk assessment of them.
- Develop a list of most probable species to be introduced in the near future and risk assessment of them.
- Implication of all organization, administration and research groups (RFNP, UALG, IPIMAR, etc.) in the management by collaboration in the programs (e. g. research, monitoring). This collaboration could benefit all, will divide the effort, at the same time all information is compiled. There is a wide range of information sources for NIS due to the variety of organism and its relevance for the economy or the human health. By the collaboration and sharing information the knowledge gaps would be fill in faster and contradictory information would be avoid.
- Stakeholders' implication in the management program. The consensus in the measures and the active implication in the development of the program are very important for the future success of it.
- Public awareness. Public aware will make easy the implementation of the measures, will produce a responsible consume, less individual risk activities (e.g. sport fishing with alien species bait) and will increase social control on the risk activities, citizens monitoring. General public have especial implication in pet, aquarium and garden trade.
- Implement existence law and control illegal activities (aquaculture, fishing).
- Increase the management and control of the marine activities inside the Natural Park, as a protected area. For instance maritime traffic should be control and regulated inside the lagoon, (regulated the number of boats,

Box 2. Suggested management actions that could be implement in RF as first and early measures in the management of non-indigenous species

Ria Formosa is not considered in risk of failing the objectives of the WFD because of the introduction of non-indigenous species. It is important to underline that NIS are not specifically taken into account in the WFD process, due to it the possible influence of introduced species in the ecological status is not recorded. Results show that there are dangerous introduced species but the lack of empirical support makes it uncertain the situation and inhibit the proper assess. However, NIS are a high potential risk in the Ria Formosa.

In addition, Ria Formosa has been proposed as a reference site for coastal waters benthic invertebrates, and has two intercalibration points for the boundaries between the classes of ecological status. Non-indigenous species are not included in the biological parameter to classify the biological status of a water body. However, the assessment scheme of coastal water benthic invertebrate also includes both disturbance taxa and taxa indicative of pollution (European Commission, 2000). NIS could be included in these parameters as species that show disturbance of the water body by human activities. If future measures are taken in that way, this would have more implications for the RF lagoon which is proposed as reference point for benthic invertebrates in other water bodies. It means that the conditions of the Ria Formosa lagoon are considered in good status, including number of NIS and the actual composition and structure of the benthic community. Other areas of the North East Atlantic that have more number of introduced species would be compared with RF lagoon in the WFD process.

Ria Formosa lagoon is an important water body for the WFD. Introduced species should be taken into account in the WFD process for the lagoon, because it is an important current and future ecological problem that produces irreversible impacts and are a threat to the good status of the lagoon. NIS should be included in the risk assessment of significant anthropogenic impacts for all water bodies. In addition, NIS situation in the NPRF can have relevant implication for other areas because RF lagoon is a reference point. There is a clear necessity of more integrated scientific work in order to be able to assess the NIS current situation.

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Annex I

Aquatic Non-Indigenous Species in Ria Formosa

Asparagopsis armata (Harvey, 1855)

This opportunistic red algae is native from Western Australia and New Zealand (InvasIBER, 2004). Its common name in English is harpoon weed. It has 2 synonyms: Falkenbergia rufolanosa (Harvey) F. Sctmitz, 1897 and Polysiphonia rufolanosa Harvey, 1855 (DAISIE, 2008).

Introduction history: *The first A. armata population in Europe was found in Northeast Atlantic in 1925 and in the Mediterranean Sea in 1926 (InvasIBER, 2004). The introduction vector was unintentional and probably was introduced with imported oysters. Secondary introduction and spread have been probably by natural movements, rafting and flouting.*

In 1970 was already reported for Portugal by André, F. (Guiry and Guiry, 2008)

Ecology/ Description: *The asexual (tetrasporangial) phase of Asparagopsis armata was once described as a separate species, Falkenbergia rufolanosa. The gametophyte lives in areas with light and hydro dynamism. Both phases life in the infralitoral, however the tetrasporophyte is able to live at more depth. This species can live from 5 to 25 ºC (InvasIBER, 2004) and has a high spread success due to the possibility of vegetative reproduction of both phases. It produces metabolites to avoid predators (InvasIBER, 2004). A. armata has a similar species, the Bonnemaisonia hamifera in Azores Islands and in north Spain (DOP, 2008; Guiry and Gruiry, 2008).*

This red seaweed produce active secondary metabolites that are used in cosmetic and medicine, it is possible its cultivation as a profitable business (Kraan and Barrington, 2005). Furthermore, the tetrasporophyte phases have been use as a biological filter for the effluents of fish farming. This practice was successfully carry out in Ria Formosa lagoon results show that A. armata is a good bio-filter (Schuenhoff, et. al., 2005).

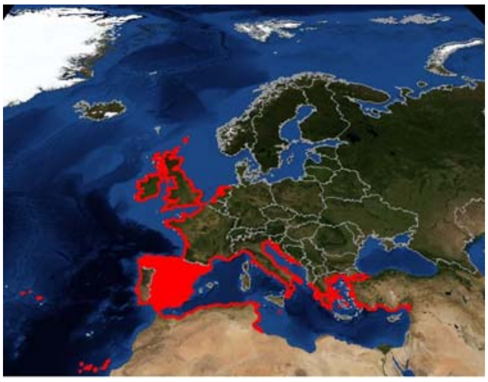
Impacts: *Considered invasive in Mediterranean (Boudouredque and Verlaque, 2002; Streftaris and Zenetos, 2006) because it has important effect on communities and habitat; it becomes dominant and/or takes the place of the keystone specie; it creates dense population and cover the 100% of the upper infra-littoral in NW Mediterranean.*

However it could have positive impacts on the regional socio-economy due to its possible uses described above.

Spread vector in RF: *Accidental introduced. The spread vector is unknown for RF, probably it arrived with oyster, by natural drift or it was release/escape from experimental research facilities.*

Situation in RF: *A. armata is a common algae in RF, it can be found everywhere in the lagoon, but it is not abundant (Engelen, pers. comm.). It was cultivated in Olhão (Ria Formosa) as a bio-filter, the experiment was carried out in Aquamarim*

Lda., it is an aquaculture company (Schuenhoff, A. et. al., 2005).



DAISIE European Invasive Alien Species Gateway, 2008. Aspagopsis armata. Available from: http://www.daisie.ceh.ac.uk/speciesFactsheet.do?speciesId=77 [Accessed 18th April 2008].

Impact assessment and potential risk in RF: *Unknown impact. It has a high potential risk; it is considered 100's worst AS in Mediterranean Sea (Streftaris and Zenetos, 2006). But there is controversy as well, in some databases it does not appear as invasive, and there are no reports of its impacts.*

It is not considered a problem in RF. However there is a possibility of invasive because of its traits: vegetative reproduction; no predators; opportunistic; fast growing rate; regeneration from fragments; low temperature tolerant (InvasIBER, 2004; Asturnatura, 2007)

Management in RF: *There is not current management of this specie. There is a high uncertainty about the situation of this alga in RF. It can have a good and profitable uses, but an environmental impact assessment should be carry out. As well there are not studies about its impacts out of Mediterranean region.*

Info sources: *Global Invasive Species Database, 2005 (ISSG), Joint Nature Conservation Committee (JNCC, 2007 documents and WebPages), InvasIBER database Web Pages (2004), scientific articles about Mediterranean NIS and its applicability for cosmetic and as biofilter.*

Image: DOP, 2008.

Antithamnionella ternifolia (J.D. Hooker & Harvey) Lyle 1847

It is red algae native from south hemisphere, possible Australia (JNCC, 2007). It has several synonyms: Antithamnion sarniensis (Lyle) Feldman-Mazojer, 1941; Antithamnion ternifolium (J.D.Hooker & Harvey) De Toni, 1903; Antithamnionella sarniensis Lyle, 1922; Callithamnion ternifolia J.D.Hooker & Harvey, 1845 (DAISIE, 2008).

Introduction history: *In the work of Streftaris et al (2005) states that first publication record of this species in Atlantic was in 1910, and 1926 for Mediterranean Sea. In Portugal was found before 1970 (DAISIE, 2008). Nowadays it is widespread from Netherlands to Portugal.*

Ecology/ Description: *Antithamnionella ternifolia has fast growth rate. It can grow in all type of substrata even on other algae and animals. It tolerates a wide range of environmental conditions (JNCC, 2007). It rarely reproduces by sexual reproduction, it mainly spread by fragmentation. It is found in lower intertidal zones in New Zealand (Nelson and Maggs, 1996)*

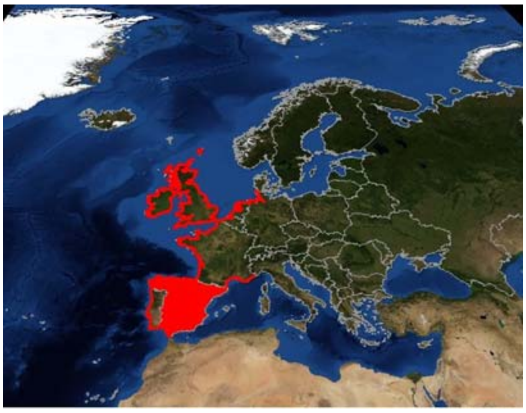
Impacts: *There are not record of environmental impacts. It can have impacts on economic activities as a fouling organism.*

Spread vector in RF: *It was probably introduced accidentally attached on hulls and mooring ropes of ships (JNCC, 2007). It has a fast regional dispersal because it can grow over any surface, ships and fishing material.*

Situation in RF: *First record in RF in Duarte et al 1988 (Machado and Abreu 2000). Registered as invasive for Portugal in DAISIE (2008). Current status is unknown.*

Impact assessment and potential risk in RF: *Low impact. It has a low risk as well. It has not been reported negative impacts on ecosystems, and it is not considered invader.*

Management in RF: *The current situation is unknown; a research should be done to clarify it. However, it is not priority specie.*



DAISIE European Invasive Alien Species Gateway, 2008. Antithamnionella ternifolia. Available from: http://www.europe-aliens.org/speciesFactsheet.do?speciesId=67# [Accessed 19st March 2008].

Information sources: *DAISIE database (2008) and Joint Nature Conservation Committee (JNCC, 2007) documents and WebPages. As well it appears in NIS WebPages of specific places: for instance, Hawaii and San Francisco Bay.*

Imagen: Macaya Horta, 2008.

Gracilaria vermiculophylla (Papenfuss, 1967)

It is a red macroalgae from Japan, the West Pacific (Thomsen et al 2007; Rueness, 2005). It has 3 synonyms: Gracilaria asiatica (Zhang & Xia, 1985), Gracilariopsis vermiculophylla (Ohmi, 1956) Gracilaria Verrucosa (Hudson Papenfuss) (DAISIE; Rueness, 2005).

Introduction history: *Rueness state that the genera gracilaria was found in 1996 in Britany, France (Rueness, 2005). Samples from the Netherland in 1998 and from France in 2001 were identifying as G. vermiculophylla by Rueness (2005). It was discover in Germany in 2002 (Thomsen et al 2007), and in 2003 in Sweden (Rueness, 2005). Nowadays it appears as introduced in the entire European coast from Sweden to Portugal and Mediterranean Spain as well (DAISIE, 2008). It has been also introduced in east Pacific and West Atlantic (Rueness, 2005).*

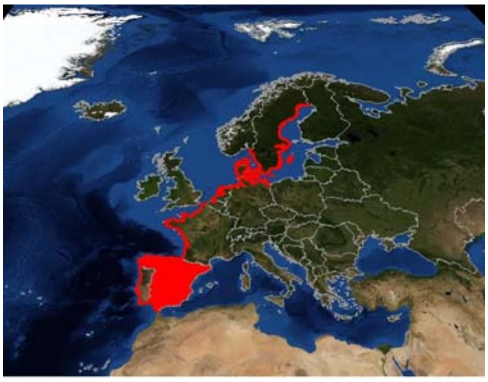
In Ria Formosa, a individual of G. vermiculophylla was found in Faro in 2004 and identify by Rueness (2005).

Its introduction was difficult to detect and follow due to the morphologically similarities with other Gracialis species already common in East Atlantic, like G. Gracilis or Gracilariopsis longissima (Thomsen et al, 2007).

G. vermiculophylla is abundant and has become in one of the most abundant species in the invaded areas, like in Denmark.

Ecology/ Description: *G. Vermicculophylla can have different colours from brown to greyish-red, it depends on the availability of light. G. Vermiculophylla grows to a length of 15–100 cm, with branches around 2–5 mm in diameter. It is irregularly but quite richly branched (resembles a wig), the branching either profuse or sparse depending on how the plant grows and whether it is unattached (Främmande arter i svenska hav, 2006). Loose-lying specimens often lack epiphytic growth. It is not unusual for young germlings to grow as epiphytes on older plants of the same species (Främmande arter i svenska hav, 2006)*

This species occurs in the form of loose-lying plants on mud or fine sand, but may also be attached to rocks or shells (Främmande arter i svenska hav, 2006). G. vermiculophylla has a high success in harbours estuaries and bays. It grows in the intertidal zone, in Europe have been found in the upper intertidal zone, and also in protected zones influences by freshwater (Rueness, 2005). This species is highly resistance to environmental stress and tolerate wide range of temperature and salinity (Rueness, 2005).It can survive desiccation and long dark periods (Thomsen et al, 2007). This species can reproduce vegetative and disperse in small fragments (Främmande arter i svenska hav, 2006). It has the ability to recruit onto patchy substratum in high abundance, and unattached fragments have high growth (Thomsen et al, 2007). It also has spatial fixation on biogenic surface as mussels, this process stabilise local population when it is *possible vegetative growth (Thomsen et al, 2007).*



DAISIE European Invasive Alien Species Gateway, 2008. Gracilaria vermiculophylla http://www.europe-aliens.org/speciesFactsheet.do?speciesId=392# [Accessed 10th September 2008].

Impacts: *G. Vermiculophylla interacts with the native fauna and create new habitat for epiphytes and invertebrates (habitat-former) but it also have potentially with large impacts on ecosystem metabolism (Thomsen et al, 2007). It alters the ecology of shallow bays and estuaries in north Europe (Thomsen et al, 2007). Gracilaria vermiculophylla can form dense mats on eelgrass beds, shading the eelgrass and inhibiting its growth. Usually it grows in the same habitat than Zostera Noltii, to which it is a great threat (Främmande arter i svenska hav, 2006). G. vermiculophylla has high rate of invasion becoming abundant in a few year, as has happened in Denmark.*

There are also records of effect on socio-economic activities. The species fouls fishing gear, causing problems for commercial fisheries and also it has clogged cooling-water intakes in North Carolina, USA (Främmande arter i svenska hav, 2006). On the other hand it also has positive effect; this species is cultivated in Asia as a raw material to the production of agar.

Spread vector in RF: *Unknown. It specie is most probable introduced by aquaculture of oyster, being shipping the most probable vector in secondary introductions (Thomsen et al, 2007). It is also possible the dispersion by currents of small fragments. The fragments can entangled with nets, lines and anchors (Främmande arter i svenska hav, 2006).*

Situation in RF: *It is very abundant on the intertidal mudflats, but not in other parts of the lagoon (CCMAR pers comm.). In 2004 a sample was collected from a population growing as entangled mats on mud flats (Rueness, 2005). However, not empirical data was found. According to CCMAR (pers. Comm..) it is a very common species in the estuaries along the entire coast of Portugal. Possible negative effects on the shallow seagrass Zostera noltii as this has been reported at other locations*

Impact assessment and potential risk in RF: *Impact in RF it unknown. It has a high potential risk because is an invader in other parts of Europe.*

Management in RF: *study the situation in RF and its possible impacts, becoming in an invasion.*

Information sources: *Rueness, 2005; DAISIE, Thomsen et al 2007; Främmande arter i svenska hav (Alien species in Swedish seas) 2006; DAISIE database (2008)*

Picture from www.research.kobe-u.ac.jp

Colpomenia peregrina (Sauvageau, 1927)

It is a brown algae, its English name is oyster thief. C. peregrina is native from Pacific Ocean.

***Introduction history:** The introduction of C. peregrina in Europe has different records, in JNCC (2007) it is stated that it was introduced to France from the Pacific coast of America with juvenile American oysters (Crassostrea virginica). On the other hand, other sources affirm that it was introduced from Japan by exchange of aquaculture oysters (Lüning, 1990). After the first introduction it spread by natural migration or by secondary movement of oysters from France to the British coast (JNCC, 2007). The first record for the Mediterranean is from 1956 (Ribera Siguan, 2002). Nowadays it is considered alien in entire Europe (Streftaris 2005). De Mesquita Rodrigues, (1963) recorded it for Portugal (Guiry and Guiry, 2008).*

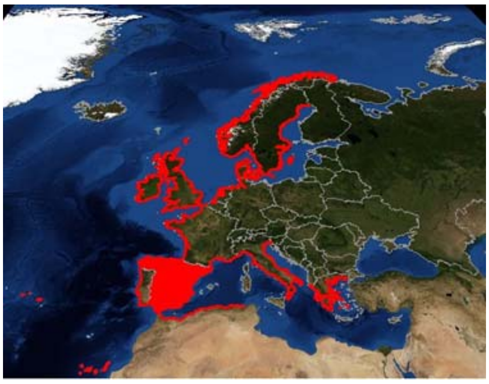
***Ecology/Description:** C. peregrina is a non-gelatinous green alga (Oakley, 2006). It grows in the epiphytic area, from mid-tide to sub-littoral areas. It can occur on different substratum as rocks, shells and seaweeds. It grows good in protected areas (Oakley, 2006).*

***Impacts:** The impacts on the ecosystem are considered negligible (insignificant) by JNCC (2007). However, it has socio-economical impacts like foul the aquaculture shellfish facilities (Streftaris et al., 2006). On the other hand, it is considered one of the 100 worst in the Mediterranean Sea (Streftaris, 2006). Its impact and level of them change from one place to another (CCMAR algae group, pers com.)*

In RF it is not considered problematic specie (Engelen, pers. Comm.).

***Spread vector in RF:** It is unknown how it arrived in RF, but it usually spread with oysters, in boats or by natural drift.*

***Situation in RF:** C. peregrina can be found everywhere but in low abundance. It needs hard substrate that is not common in RF. C. peregrina size is smaller in RF than in Japan (Engelen, pers Comm.).*



DAISIE European Invasive Alien Species Gateway, 2008. Colpomenia peregrina. Available from: http://www.europe-aliens.org/speciesFactsheet.do?speciesId=234# [Accessed 19st March 2008].

***Impact assessment and potential risk in RF:** Unknown impact. It is considered a high impact species by one of the 100 worst alien species in Mediterranean Sea, but on* *the other hand it has negligible impact for UK. The possible impacts in RF are unknown.*

Management in RF: *the current situation is unknown. It should be research its current situation and impacts because it is a high risk specie.*

Information sources: *Joint Nature Conservation Committee WebPages and Document (JNCC, 2007) and Marine Life Information Network (Marlin) WebPage; Algaebase WebPage (Guiry and Guiry, 2008).*

Image: Ignacio Barbara, Asturnatura, 2007.

Sargassum muticum (Fensholt, 1955)

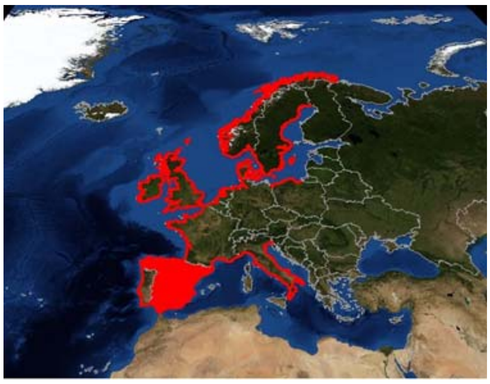
Sargassum muticum is large brown algae native from Japan, nowadays widely distributed and continuous its spread. Sargassum kjellmanianum f. muticum Yendo, 1907 is a synonym.

Introduction history: *The first report for North Atlantic was in 1973 in England (Guiry and Guiry, 2008), but it is also state that was introduced in France in the 70's with imported oysters (Lüning, 1990). 30 years later of its arrival in Europe S. muticum can be found from Norway until south of Portugal (Engelen et al, in press). First record in Portugal was in 1991 (Engelen et al, in press). S. muticum populations were discovered recently, in 2006, in RF. However, local investigations showed evidence that they first established in 2002 (Boavida, 2007).*

Ecology/ Description: *S. muticum is 1 to 2 meters length (Cohen, 2005), but it can reach 16m (Guiry and Guiry, 2008), this large size is a distinctive characteristic. It can survive and reproduce in wide range environmental conditions (algaebase.org and Streftaris, 2005). However, it needs hard substrata and large size stones to attach; it is not possible in grave or sand (Global Invasive Species Database, 2005). It grows fast, up to 10 cm per day (Guiry and Guiry, 2008). It has as well a high reproductively potential since its first year and it is self-fertile (Global Invasive Species Database, 2005; Lüning, 1990). It spreads fast by its air bladders (Lüning, 1990) that allow the fronds to drift; this is a key fact in its dispersal (Global Invasive Species Database, 2005), but it also spread by zygotes that can spread up to 1.3 km (Lüning, 1990). All this makes of S. muticum very invasive; it is a hard competitor and creates dense monoespecific stands (Global Invasive Species Database, 2005; Streftaris, 2005, Engelen et al, 2003).*

There are two near species in RF region, S. Flavifolium in Spain and Portugal and S. vulgare in Morocco (Lüning, 1990). S. Vulgare is present in RF (Machado and Abreu, 2000).

Impacts: *S. muticum produces changes in the community structure, decrease of biodiversity by outcompete other plant species, change in the physical habitat by create dense stand. It has been reported that epiphytic communities are not affected by Sargassum (JNCC, 2007).*



DAISIE European Invasive Alien Species Gateway, 2008. Aspagopsis armata. Available from:http://www.europe-aliens.org/speciesFactsheet.do?speciesId=860#

However, all these effects could produce broader change in the ecosystem. For instance S. muticum can replace Zostera marina, (JNCC, 2007; Kraan, in press) which has important role for ecosystems. Z. marina is also present in RF (Machado and Abreu, 2000). All this effect has been wide reported and several examples can be found.

Furthermore, socio economic impacts are important and negative as well some examples are: physical obstacle for boats engines; congestion of pipes; floating mats foul commercial fishing lines nuisance commercial fisheries, concentrate and create undesirable visual effect; accumulate on shores creating smelling problems; decrease the recreational potential of the waters and shores; hinder the harvesting of shellfish and create problems on oyster cultures (Global Invasive Species Database, 2005; JCNN, 2007; Kraan, in press).

Spread vector in RF: *It probably arrived by natural drift in RF (Engelen, pers comm.). Once it is establish it has an effective natural dispersion and spread; floating plants and fragments that can survive up to 3 months (JNCC, 2007). The spread have been calculated of be around 2-3 km/year (Kraan, in press). However it can have a maximum of 30km/year, calculated for the English, in American coast it is even higher having an average of 60km/year (Kraan, in press).*

Situation in RF: *In RF S. muticum grows where there is hard substrate available, mainly oyster shells, pebbles and urochordata (Engelen, pers. Comm.). Also temperature affects its growth rates (Boavida, 2007), theses parameter will control the spread in RF.*

The study by GIS mapping of the Ria Formosa population revealed an invaded area of 4339 m^2, with a mean density of 107 individuals/m^2 (± 87 individuals/ m^2) revealed a total population size of 462834 individuals (Boavida, 2007). S. muticum is established and very abundant, however its distribution is localized (Engelen, pers comm.).

High removal of water in RF is extremely high, between 50 or 75% of water is exchange with the open sea everyday (Newton and Mudge, 2003). It makes more probable new entry of drifting fronds of S. muticum and other species, by currents (Boavida,2007). There are not been important changes in the area occupied by S. muticum, it has a low population growth rate and little substratum available (Boavida, 2007). However, the future spread of S. muticum has been simulated and it is forecast that it will spread to the west of RF and also go out of the RF and spread in the open coast (Engelen, pers. comm.).

Impact assessment and potential risk in RF: *High impacts. S. muticum is high risk specie; it had been reported as a harmful invasive worldwide. It is already establish in RF and it is expected that will spread, which increase the probability of future negative impacts over sea grasses and the native community of RF. However, the lack of hard substrate in the RF lagoon is a spread barrier to other areas inside it.*

Management in RF: *S. muticum is currently removed from some areas by the natural park (Grade, pers. Comm.). The study and control of this species should continuous; it could be done by university and Natural Park in coordination. The eradication of S. muticum is almost impossible. Physical, chemical and biological treatment on this* *species have been tried, any of them with satisfactory results; in addition, chemicals and biological control are not selective.*

Information sources: *There is a lot of information about this specie. As general compilations: Global Invasive Species Database, 2005; Joint Nature Conservation Committee (JNCC, 2007), Algabase WebPage (2007) for references on Portugal and Spain; and CCMAR algae group.*

Image: from www.seaweed.ie; Guiry, 2008.

Spartina densiflora (Brongn)

It is native plant from South America, and is considered an invasive species worldwide. It is present in SW Europe, NW Africa and SW North America (Mateos-Naranjo et al, 2007). In Portugal it is recognized in the Portuguese law as an invasive species and its introduction or cultivation is forbidden, (Decreto-Lei n.o 565/99 de 21 de Dezembro).

Introduction history: *S. densiflora was introduced probably accidentally in Portugal. It is spread all around RF, and in all Algarve region (Redondo, pers Comm.; Plantas invasoras do Portugal, 2007). It appears in 1998 in Franco and Rocha Afonso study of the new flora in Portugal. But other sources state that it was introduced even 200 years ago (Engelen, pers. comm.), as well it is stated that was introduced in Cadiz bay probably in the 16th century (Castillo et al, 2000).*

Ecology/ Description: *S. densiflora is a perennial grass that lives in shallow waters, but can grow in dunes, marshes. It is salt tolerant and grows erect in dense tufted. Their leaves are narrow, long and enrolled, and 3 to 8 mm in width. (Plantas invasoras do Portugal, 2007; Castillo et al, 2000). It has a high production of seed, but can reproduce vegetative as well. S. densiflora is a primary colonist of mud flats that stabilize sediments (Castillo et al, 2000).*

Impacts: *It is considered one of the most important invaders in many estuaries in SW Iberian Peninsula (Mateos-Naranjos et al 2007; Castillo and Figueroa, 2008). It alters the composition of plants communities and disturbs restoration projects (Mateos-Narajos et al, 2007). However, there is not more specific information about its impacts. However, it is considered dangerous in the Spanish checklist of AS plants (Capdevilla-Argüelles et al, 2006).*

On the other hand, Spartina genus impacts are largely reported for the west coast of USA. The Spartina genus is stated in Washington State Noxious Weed Control Board, as being one of the most aggressive invaders in the world. This genus has impacts over the communities and food nets; it can displace native species as Zostera marina, and destroy the refuge and food sources for fish, crabs and others marine organism. Its control and eradication cost hundreds of thousands of dollars to governments and private landowners in Washington. Moreover in San Francisco bay S. densiflora invasion produces effects on some small mammals, as the salt marches harvest mouse (Reithrodontomys raviventris) or the California clapper rail (Rallus longirostris obsoletus). The invasion of the mudflat and the channels may eliminate foraging habitats. This specie can change as well the detrital food web. Moreover this invasion change the habitat by slow down the water flow, it may change the sedimentary dynamics (Invasive Spartina Project, 2006;

Washington State Noxious Weed Control Board, 2008).

DAISIE European Invasive Alien Species Gateway, 2008. Spartina densiflora http://www.daisie.ceh.ac.uk/speciesFactsheet.do?speciesId=1176# [Accessed 19st March 2008].

Economic activities can be affected as well. These changes in the ecosystem and the changes in the navigation routes can affect several human activities as: recreation, tourism, fishing, hunting, boating, bird watching, shell harvesting (Washington State Noxious Weed Control Board, 2008). On the other hand, Spartina genus is positively valued in its native habitats.

Spread vector in RF: *Accidental introduced. It is unknown how arrive in RF, probably by natural spread or regional movement.*

Situation in RF: *S. densiflora is present in all Ria Formosa, it can be found in Villa Nova, Tavira, Rio Gilão, Pedras del Rei and Fuseta (Redondo pers. Com). The current distribution is localized in some point of the RF, in the east part of Faro, but where appear is abundant. S. densiflora covers around the 10% of all RF (general approximation) (Redondo, pers. Comm.; Grade, pers. Comm.).*

Impact assessment and potential risk in RF: *Low impact. S. densiflora is high risk specie, it is forbidden in the exotic law of Portugal. However, it is not considered dangerous specie in RF.*

Management RF: *There are not current management actions on this specie. Prevention measures should be taken to control its spread RF, this specie can produce new impacts over the natural terrestrial and aquatic biota. Study the current situation and forecast the possible spread is recommended. There are several works about its lower distribution and abiotic conditions that affect its development (Castillo and Figueroa et al, 2008, Mateos –Naranjo, 2007; Castillo et al, 2000). The possible collaboration with Sevilla university research project should be taken into account.*

Information sources: *Spartina project in San Francisco Bay WebPages, Plantas invasoras do Portugal WebPages (2007), DAISIE database WebPages (2008).*

Image: Plantas invasoras do Portugal, 2007

Ficopomatus enigmaticus (Fauvel, 1923)

This annelida polychaeta is also known as *Mercierella enigmaticus (Fauval, 1923). Its native distribution is unknown.*

Introduction history: *First notice in Europe was in France in 1921, where was introduced from Australia. However, recent studies state that it was also introduced in Australia. Nowadays it is considered that comes from south hemisphere (Eno et al., 1997). In 1924 appear in the Iberian Peninsula (InvasIBER, 2004). First record in the RF was in 1994 by S. Gamito. But it real introduction date and vector is unknown.*

Ecology/ Description: *Ficopomatus enigmaticus builds and lives in white, calcareous tubes that are about 2 mm in diameter and a couple of centimetres long. It grows in the low intertidal to shallow subtidal on rocks, concrete, wood, shells and other hard surfaces, including pilings and the sides of floating docks, buoys and boat hulls. It can occur as single, separate tubes, or as tangled, agglomerate masses that form incrustations up to 10 cm or more thick. Ficopomatus enigmaticus can survive in ocean salinities, but grows and reproduces only in lower salinities of about 10-30 ppt, and temperatures above 18° C. (Cohen, 2005)*

Impacts: *F. enigmaticus has negative socio-economic impacts on wood structures as a fouling nuisance; it affects ports and ships structures.*

On the other hand it has beneficial effects on water ecosystems. It improves the water quality by reduce suspended particles, increase oxygen and nutrients concentrations, which would be good in eutrophic waters (Eno et al., 1997). This will benefice the benthic communities as well. Whereas it is also stated that a big density of a new filter-feeder will out-compete with the native species and affect the phytoplacktonic community. Furthermore, the faeces and pseudo faeces could move the contaminants from water column to the sediments (Eno et. al., 1997).

Spread vector in RF: *Accidental introduction. The spread vector is unknown but it usually spread by shipping and attach to mollusc shells (Eno et al., 1997).*

Situation in RF: *The current situation is unknown. There are data from local researches from different times that a specialist should review.*

DAISIE European Invasive Alien Species Gateway, 2008. Ficopomatus enigmaticus http://www.daisie.ceh.ac.uk/speciesFactsheet.do?speciesId=363 [Accessed 2nd April 2008].

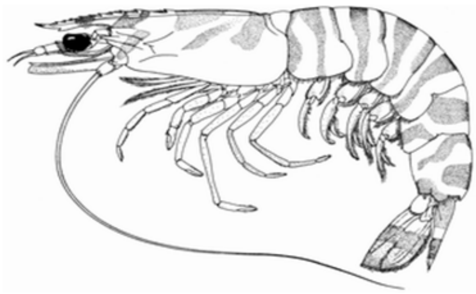
Impact assessment and potential risk in RF: *Low impact specie. It was a long time* *that it established in the RF lagoon. However, it has high risk.*

Management in RF: *There is not current management action, and there is not recommendation due to its low potential impact and that its introduction was long time ago.*

Information sources: *Brittish non-native species review by Eno et al (JNCC, 1997); DAISIE (2008) database WebPages; InvasIBER WebPages (2004); and Guide to the Exotic Species of San Francisco Bay.*

Image: www.ifrimer.fr

Penaeus japonicus (Bate, 1888)



This species of subtropical prawn is also known as Penaeus canaliculatus japonicus (Bate, 1888), Penaeus pulchricaudatus (Stebbing, 1914) and Marsupenaeus japonicus (FAO). Kuruma prawn is its common name in English, and in Portugal it is known as Camarão-japonês. Its natural distribution is in Indo-West Pacific, ranging from South Africa into the Red Sea and from Japan to the North Australia.

Introduction history: *The specie migrates to the Mediterranean Sea through the Suez Canal until the south coast of Turkey (FAO, 2007). It was introduced to Portugal from Spain in 1985 for aquaculture. In 1991 was introduce in the RF experimentally for the same purpose, this was during 1990's (Carlier, 1997; da Silva, 1990).*

Ecology/ Description: *P. japonicus habits in sandy and muddy bottoms and a depth from 0 to 90 m (FAO, 2007). They are nocturnal animals, during the day are burrowing and by night feed and spawn. This group of prawn are mainly omnivorous; they could feed on small shrimps, crabs and mollusc, but also on algae worms and fishes. But the predatory habits depend of the specie. (Hutchins et al., 2003).*

They have restrictive range of salinity and temperature. Between 28 and 30ºC is the optimum, and the production stop at lower and higher temperatures, this data are mainly for the aquaculture purpose. Maximum growth rates are achieved in 27-35 parts per thousand (ppt) of salinity (DAISIE, 2008). These restrictive tolerance could have limit its survival in Ria Formosa, the production stop because it was not well adapted, maybe to the salinity or to the temperature (Grade and Newton, Pers. Com.)

Penaeus japonicus, have a minor fishery importance in general but it is very important in Japan (FAO, 2007). It is also fished in east Mediterranean Sea. Its aquaculture production has increase a lot in the last years (FAO, 207). It has been used as well in aquaculture experiments.

Impacts: *P. japonicus has impact on communities; it can outcompete and replace the native species. In France, Penaeus japonicus has replaced Penaeus Kerathurus (Boudouresque, 2003). However the first attempts of hybridation with the native one produce abnormal offspring (Redon et al., 1997; DAISIE, 2008). It is also associated with the transmission of diseases (OIE, 2006). On the other hand, it has a positive socio-economy impact; P. japonicus can be a profitable business.*

World distribution of Penaeus japonicus, FAO species fact sheet, 2007

Spread vector in RF: *Intentional introduce for aquaculture. The main spread vectors* *are natural spread trough Suez Canal, and aquaculture.*

Image: www.ifrimer.fr

Situation in RF: *The information about the situation in RF is contradictory. During the stakeholders interviews 3 different opinions were registered: it is rare and occasional, being more abundant in winter (Mr. Manjua shellfish collector); it is not present in the Ria, while the native has decrease its number (Mr. Silva shellfish collector); it is abundant in all Ria Formosa and well adapted (Mr. Afonso, university). The different point of view (commercial/scientific) maybe are the reason of this contradiction. The only information about P. japonicus in Portugal was found in DIAS webpage (FAO, 2007), where it is stated that it is not establish in Portugal, that its use in aquaculture is rarely, and the reproduction is assisted or artificial; furthermore it has unknown effects or impacts. Despite all this information, the most credible is the scientific opinion (Fonseca and Luis, pers. Comm.). It is important to highlight that P. japonicus can be confused with Penaeus kerathurus with is native species in the RF lagoon. Specialist in this species should review the available information and old data to can do a judgment.*

Impact assessment and potential risk in RF: *Unknown impact. There is a low risk for the RF due to the habitat requirements. However, the situation is not clear and there is not data to confirm it.*

Management in RF: *There is not current management on this specie. It is necessary more information of the possible establishment and illegal cultivation.*

Information sources: *DAISIE database WebPages (2008), FAO fact sheets and DAIS database WebPages (2007).*

Procambarus clarkii (Girard, 1852)

This crustacean is knows as red swamp crayfish, it is native of north-east Mexico and south-central Florida. Nowadays it is widely distributed in USA and Central America, as well it find in Japan, China, Taiwan, Kenya and Uganda. In Europe it can find in France, Spain, Portugal and Cyprus. (FAO, 2007)

Introduction history: *P. clarkii is introduced from different reasons. In Europe was introduced with commercial purpose because it is a profitable business in USA. But it have been introduced for biological control, live food trade, aquarium /pet trade, smuggling and accidental introductions as well. The introduction in Spain from USA (FAO, 2007) and subsequently into Portugal was in 1973, it has spread and reproduces naturally, nowadays appear in almost all freshwater system of the Iberian Peninsula (Pérez-Bote, 2005).*

Ecology/Description: *P. clarkii lives in agricultural areas, and freshwater bodies; lakes, water courses and wetlands. P. Clarkii can survive to dry periods up to 4 months, due to this it is able to establish in a wide range of habitats, like seasonally flooded swamp (Cruz and Rebelo, 2007). Furthermore it tolerates low oxygen conditions, high temperatures and salinity (Global Invasive Species Database, 2005). Adults feed on plants and detritus, while juveniles feed on animals too. It has a short life cycle and a high fecundity. Birds, mammals and fish can feed on them. It can migrate long distance in land (3km per day) (DAISIE, 2008).*

Impacts: *It is well studied specie and it is easy to find information about its impacts and behaviour. In Portugal it has cause impacts on human's activities like agriculture, especially in rice fields. It can also cause damage on structures, like earthen dykes, levees, and water control structures in irrigated agricultural systems. It has huge impacts on communities; it spread a crayfish disease which have reduce the population of the native crayfish Austropotamobius pallipes that is a threaten specie now in Spain a Portugal. P. Clarkii can also affect gastropods, amphibians and macrophytes (Cruz and Rebelo, 2007)*

DAISIE European Invasive Alien Species Gateway, 2008. Procambarus clarkii http://www.daisie.ceh.ac.uk/speciesFactsheet.do?speciesId=794 [Accessed 2nd April 2008].

In Guadiana River Basin have been reported habitat changes. For instance P clarkii excavate galleries that can alter the hydrology. In Doñana National Park (Huelva, Spain) it is an important *competitor; it adapt fast and successfully to the new environment. In this National Park; P. Clarkii also behave as ecological engineer specie, reducing the macrophytes communities and due to it its change the refuge habitats of other species. It also change the ecosystem energy routes and food resources, it would affect a wide range of species.*

Spread vector in RF: *It is unknown how P. Clarkii arrived to RF, but it is probable by natural spread or by intentional introduction.*

Situation in RF: *This specie is present in several freshwater courses, it is abundant but the population status is unknown (Grade, pers. Comm.). There is no record of its impacts, but it is consider that it has not important impacts. No management is done to it.*

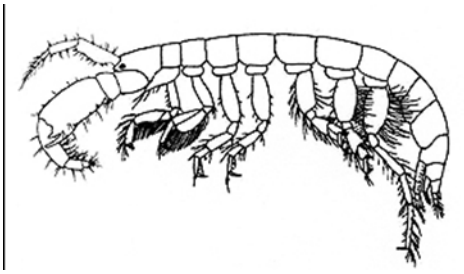
Impact assessment and potential risk in RF: *Unknnown impacts. It is high risk specie; however in RF it is not considered a problem.*

Management in RF: *In Portugal it is forbidden its introduction and trade, but not other specific measure is applied in RF. There are lot of management strategies that could be implemented. A study of this situation is recommended.*

Information sources: *DAISIE (2008), FAO species fact sheets and DIAS database (2007), Global Invasive Species Database, 2005 (ISSG); InvasIBER (2004) databases.*

Image: FAO, 2008

Corophium sextonae (Crawford, 1937)



It is a crustacean amphipoda. It was stated that is native from New Zealand (JNCC, 2007). However, nowadays it is considered cryptogenic, because could be native of North Atlantic coast (Främmande arter i svenska hav, 2006).

This specie is also known as Monocorophium sextonae and Corophium sextoni.

***Introduction history:** It was introduced in the 1930s in England (Plymouth, Devon) from New Zealand. The method of introduction is unknown. In late 1970s or early 1980s was secondary introduced in Ireland (JNCC, 2007). It is possible that this secondary introduction was made by natural spread of the specie. Nowadays it is wide spread in European North Atlantic and even in the Mediterranean Sea (Främmande arter i svenska hav, 2006). It is recorded as dominant specie in Ceuta Harbour (Guerra-Garcia et al, 2003). The probable vectors of introduction and spread are shipping, oyster aquaculture and natural dispersal.*

It appears in Gamito (2008) as present in RF.

***Ecology/ Description:** Corophiidae family has a distinctive large antenna. These species are very tolerant to changes in salinity and are clear likely to be carried by shipping (Hurley, 1954).*

This specie in particular, C. Sextonae, can have a length up to 5mm. It lives in soft bottom on shallow waters; the maximum depth is about 50 m. They built tubes of mud on macroalgae or benthic organisms (Främmande arter i svenska hav, 2006). It is a suspension, deposit feeder and interface grazer (VLIZ, 2005). There is a specific morphological description in Hurley, 1954.

***Impacts:** there are not records of impacts. For Ireland it has been describe competition with native biota. The abundance is increasing in UK and it is possible it would affect Corohpium bonnellii (JNNC, 2007). It is described as non invasive in NOBANIS Webpage.*

***Spread vector in RF:** It is unknown, probably the general vectors explained above.*

***Situation in RF**: establish in RF. The current situation is unknown. There are data from the 90' like Calvario (1995) that specialist should evaluate.*

***Impact assessment and potential risk in RF:** Unknown impact in RF. The situation in RF is unknown, however there is not sing of negative effects, and have been described for Portugal since 1950. Additionally, it is not considered invasive or dangerous, it can be considered low risk.*

***Management in RF:** Study its situation, distribution and impacts, however it is not a priority species.*

***Information sources:** Främmande arter i svenska hav (Alien species in Swedish seas) 2006; DAISIE database 2008; JNCC, 2007;*

VLIZ (Flandes Marine Institution) 2005; NOBANIS WebPages.

*DAISIE European Invasive Alien Species Gateway, 2008. Corophium sextonae http://www.europe-aliens.org/speciesFactsheet.do?speciesId=253# [Accessed 22nd August 2008***].***

Picture from Stefan Nehring and Heiko Leunch (sewdish page above)

Balanus amphitrite (Darwin 1854)

It is barnacle of the crustacean family which native from southwest Pacific, and Indians Oceans (JNCC, 2007)

***Introduction history:** It was first found in UK in 1937, it is suppose that arrived as an adult attached in ships as fouling organism, or as a larvae in ballast water. It is recorded in Gamito's work in 1994 for RF, and in DAISIE (2008). However, there is not more information about its arrival or introduction pathway.*

***Ecology/ Description:** Balanus amphitrite is a small, conical, sessile barnacle (to about 1.5 cm diameter). It is a filtered of suspended matter. It is very common in the intertidal fouling communities of harbors and protected embayments. It lives attached to any available hard surface, including rocks, pier pilings, ship hull, oyster shells, and mangrove roots. The optimum of temperature is 23ºC. These barnacles are hermaphrodites, but cross-fertilization occurs in dense populations (Gulf State Marine Fishery Commission, 2003).*

***Impacts:** There are no reports of the effects on the environment, but it has negative impacts as a fouling organism on ships and marine structures, and as well on shellfish (JNCC, 1997). There are lots of studies (scientific articles) of its settlement process, and which conditions facilitated it.*

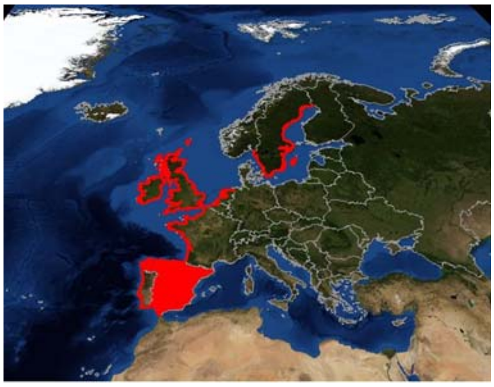
***Spread vector in RF:** Accidental introduced. It is unknown how it arrived in the RF, but most probable by shipping, hulls fouling and/or ballast water (larvae stage).*

***Situation in RF**: Introduced. The first record in RF is in Gamito (1994) (Machado and Abreu, 2000). The current distribution and abundance are unknown. Specialist should review the data from the 90' to assess it.*

***Impact assessment and potential risk in RF:** Low impact. It is has well low potential risk; however the situation in RF is unknown.*

***Management in RF**: There is a not current management action for this species. It should be study its current situation; however it is not priority specie.*

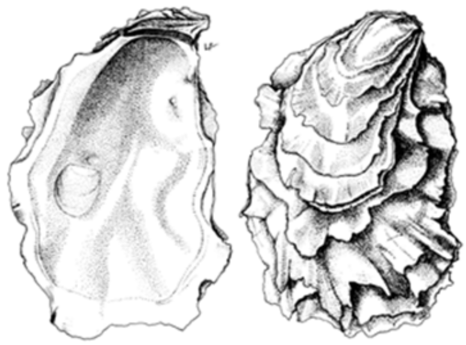
***Sources of information**: Joint Nature Conservation Committee (JNCC) documents and WebPages, and DAISIE database (2008).*



Distribution map. (DAISIE European Invasive Alien Species Gateway, 2008. Balanus amphitrite http://www.daisie.ceh.ac.uk/speciesFactsheet.do?speciesId=100 [Accessed 2nd April 2008])

Image: Cohen, 2005.

Crassostrea gigas (Thunberg, 1793)



Crassotrea gigas is a commercial oyster worldwide. It has been considered native from the Pacific Ocean, but recent studies propose that Crassostrea gigas is the same species that Crassostrea angulata, Lamarck 1819, which is native from the southwest of Iberian Peninsula. It is known as Pacific or Asian oyster. It has several synonyms: Ostrea gigas (thumberg , 1793); Ostea laperousi (Schrenk 1861); Ostrea talienwhanensis (Crosse, 1862).

Introduction history: *C. gigas have been introduced from Pacific Ocean and nowadays the distribution is world widely, being present in Europe and America.*

It was introduced in France from Japan in the 70`s for aquaculture purpose, later at the begging of 1990's, C. gigas was introduced to Portugal from France with the same purpose (FAO DIAS, 2007). However other sources say that in the 70's after the decrease the production of C. angulata, they were brought from France (Gonçalves, 2000). It is probably establish in the coast of Portugal. Other author report the possibility of that the oyster come attached on the ships. (Saldanha, 1995; Macedo and Borges, 1999)

Ecology/Description: *This oyster prefers hard bottoms and shallow waters, and usually it is attached to rocks, other shell or debris in the lower intertidal areas. However it can be also in muddy bottoms, or mud-sand (FAO, 2007). Pacific oysters are protandrous hermaphrodites, they can change sex (FAO, 2007). Temperature is the main regulator factor, (JNCC, 2007), spawn and larval develop need high temperature, more than 18ºC for spawn. Salinity should be between 23 to 28 % (CIESM, 2005). Pacific oyster has high growth rates and high reproductive rates as well. The spawning is of 50 to 100 millions in a single spawning (Global Invasive Species Database, 2005). It is filtering specie, it ingest bacteria, protozoa, diatoms, larvae and detritus as well (Global Invasive Species Database, 2005). C. gigas can colonize areas many kilometers away from the parent organism. The larvae stage is planktonic and under favorable conditions larvae develop can travel long distances (JNCC, 2007). C. gigas has the characteristic of an invasive species (Global Invasive Species Database, 2005).*

DAISIE European Invasive Alien Species Gateway, 2008. Crassostrea gigas http://www.daisie.ceh.ac.uk/speciesFactsheet.do?speciesId=261 [Accessed 2nd April 2008].

Some genetic studies show that C. gigas and C. angulata are the same species, and they have fertile hybrids as well (Huvet et *al., 2000 and Huvet et al., 2002). Some data bases accept them as synonymous, for instance in DAISIE it is stated that C. gigas was first arrived in Portugal as C. angulata from 16th century and subsequently in the 1960s and 1970s. However, for other sources and scientist it is still under discussion.*

Impacts: *Ecological impacts are unknown for Portugal, but probable have some (FAO DIAS, 2007). No impacts have been registering in Europe, however in North America C. gigas form dense aggregations an exclude other intertidal species (JNCC, 2007). It affects other individuals; established organism can smother other organism as scallops and exclude them, this change species balance. It also produce impacts on habitats by destroy the habitat, produce big aggregations and cause eutrophication (Global Invasive Species Database, 2005; Eno et al., 1997). As a consequence of all these impacts, it probably produces changes in the whole ecosystem. C. gigas is considered one of the 100's worst invasive alien species in European water (DAISIE, 2008), and in others world regions as Australia where it is one of the most damaging potential domestic target species (based in the overall impacts) (Global Invasive Species Database, 2005).*

For the socio-economic point of view it specie have been widely cultivated and has an important economic value (JNCC, 2007). The fishery of that specie has increase rapidly since it was introduced in USA where is extensive cultivate. The global aquaculture of this species has multiple since 90's, in 1990 was around 1000 tonnes and in 2000 was 4000 tonnes (FAO, 2007).

Spread vector in RF: *It was intentionally introduced in RF by aquaculture, which is the main introduce vector. It is reintroduced because reproduction in aquaculture is done by continuous imports (FAO DIAS, 2007). However it has been reported that the introduction from France to UK was by ship/boat hull fouling (Global Invasive Species Database, 2005).*

Situation in RF: *The current situation is unknown, the taxonomic controversy increase the uncertainty. There are C. angulata references and records, but after the introduction of the C. gigas in the 80's makes de data uncertain. From the stakeholders interviews it is concluded that the Crassostrea genus is abundant in all RF). However, shellfish collectors make no difference between them, and there is the possibility of its illegal introduction and cultivation. It is supposed to be naturalized and harvested as C. angulata (Manjua, Silva and Grade pers. Comm.). The available data on both controversial speices should be review and evaluate by specialists.*

Impact assessment and potential risk in RF: *Unknown impacts. It is a high risk species, considered 100's worst in DAISIE database (2008) and for Mediterranean region (Streftaris, 2006). The situation in RF is unknown; however it is not considered problematic specie by any stakeholder. Problems of hybridization and displacement of the native oyster are unknown. It could have produce negative impact, but there are not studies about it. Mr. Grade state that C. gigas is an important NIS introduction vector for other species, because the morphological characteristics of the shell other species can come attached to it.*

The socio-economic impact was positive in RF, C. gigas made increase the aquaculture business that was really down in the 70's

(Gonçalves, 2000). Nowadays, it is forbidden its introductions; however, there is the possibility of illegal importation from other countries as Spain (Michler, 2003)

Management in RF: *There is not any management action. It should be control its illegal introduction.*

Information sources: *Global Invasive Species Database (2005), FAO species sheets and FAO DIAS WebPages; DAISIE (2008) WebPages, and as well UK organizations WebPages; JNCC (2007) and MarLin (2007).*

Image: FAO, 2008.

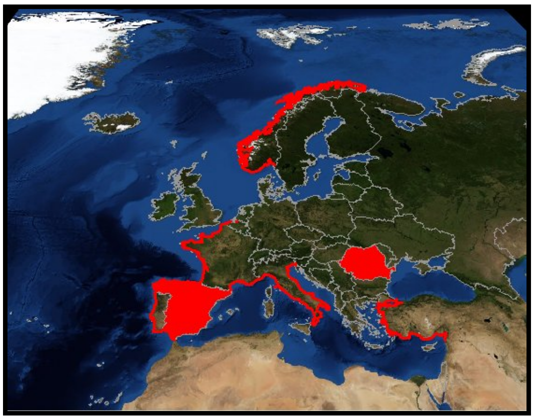
Ruditapes philippinarum (Adams & Reeve, 1850)

As well know as Tapes Philippinarum (MarBEF, 2007); Tapes denticulatus and Tapes indicus (Sowerby, 1852); Tapes quadriradiatus and Tapes viola (Deshayes, 1853); Tapes semidecussatus (Reeve, 1864) (FAO, 2000-2008). The common names are Japanese carpet shell in English and Almêjoa japonesa in Portuguese.

Introduction history: *R. philippinarum is native species from southeast Asia, Indo-Pacific. It was introduced in the Mediterranean Sea and France with commercial purpose. The first introduction was in the eighties, there are two different dates; in 1985 in Italy (FAO, 2007); 1981 in Languedoc, France (CIESM, 2005). Nowadays, it is increasingly common in European waters and as well in the west coast of USA and Hawaiian Islands (FAO, 2007). R. philippinarum introduction in Portugal is controversial in the different databases; it appears as introduced and establish in Portugal in DAISIE database (2008), but it does not appear as introduced in Portugal in FAO DIAS database or Global Invasive Species Database (2005). In a communication on Internet Journal of Food Safety, Campos and Cachola (2006) describe the introduction of R. philippinarum in RF since 1980's for aquaculture purpose. However, there are different opinions about the introduction date; introduced by IPIMAR around 1998 (Manjua, pers Com.); beginning of the 90's by private aquaculture purpose (Grade, pers com.).*

Ecology/Description: *This specie lives in sand, muddy-gravel or clay bottoms of littoral lagoons (FAO, 2000-2008). It lives in the intertidal zone to 4 m deep usually in calm waters. Studies carried out in Thau, France and Venice, Italy, show that the best growth is during the algae bloom period with temperatures from 10 to 20 ºC, and that the reproduction is from May to October (CIESM, 2005).*

R. philippinarum is similar to Ruditapes decussates, a native species of the North Atlantic coast of Europe and of Mediterranean. Different between both species are that R. Philippinarum has much more pronounced dessate sculpture, and its shell is browner and with more stains (FAO, 2007).



DAISIE European Invasive Alien Species Gateway, 2008. Ruditapes philippinarum http://www.daisie.ceh.ac.uk/speciesFactsheet.do?speciesId=844 [Accessed 2nd April 2008].

The fishery of that specie has decrease but have increase the aquaculture in global terms (FAO, 2007).

Impacts: *There is little information about the impacts of this specie. In Campos and Cachola (2006) it is stated that R. philippinarum can be a disease vector and produce food safety problems. There is some information about its good and fast acclimation and spread outside the farming areas when the conditions are favorable (CIESM, 2005). In RF there are also favourable conditions for its reproduction.*

Spread vector in RF: *Intentional introduced for aquaculture, but it could reproduce naturally and spread.*

Situation in RF: *It is consider rare or occasional by the stakeholders. It have been long time since it was cultivated, it survive here but do not reproduce because it is not well adapted (Manjua and Silva, pers. Com.). Mr. Silva said that from his opinion it was a really bad idea to introduce it because it competes for food with the native species Almejio Boa and outcompete it.*

It have been forbidden by Portuguese government (Manjua, pers. Comm.), however it does not appear in the NIS law of Portugal. There are suspicions about a species called "Tapes japonica" cultivated illegally in Ilha do Faro (Afonso, pers comm.). In Campos and Cachola (2006) is reported its introduction the last years, 235 tons in 2002-2003 and 400 tons in 2003-2004 that were imported from Tunisia trough Spain (seeds and adults).

It is important to highlight the high similarity with Almejio Boa, it can be confused. The data on both speices should be study by specialist to clarify the current situation.

Impact assessment and potential risk in RF: *Unknown impact. It is considered a high risk specie, appear as 100's of the worst alien species for Mediterranean Sea (Streftaris and Zenetos, 2006); and has been reported its continuous introduction and the problem of bring diseases (Campos and Cachola, 2006). And it could compete with Tapes decussatum that is economically important in RF.*

Management in RF: *There are not current management option on this specie, but there are already some proposal to the Portuguese authorities by INIAP/IPIMAR: " (a) in the scope of the microbiological monitoring program of bivalve mollusc harvesting areas, new sampling points will be defined in the natural banks of R. decussatus; (b) the species R. philippinarum will be proposed to be included in the list of non-indigenous species of the national legislation; (c) cooperative work will be developed regarding the adjustment of legal regulatory procedures in the process for authorizing new production beds, and thus guaranteeing that each new bed produces only one bivalve species; (d) the process of product certification for R. decussatus from the Algarve will be assisted, guaranteeing its quality and nutritional value; and (e) the environmental awareness of producers and consumers, focusing on the negative impacts from introductions of non-indigenous species, will be promoted" (Campos and Cachola, 2006)*

Information sources: *FAO species sheet and FAO DIAS database WebPages (2007), and DAISIE database WebPages (2008); it appears in food- biosecurity and aquaculture studies as well.*

Image: Terry Wimblenton/JNCC (published on the MarLIN Web site)

Crepidula fornicata (Linnaeus, 1758)

Crepidula fornicata is a mollusk of the class gastropod. This specie is also known as: Crepidula densata (Conrad), Crepidula maculata (Rigacci), Crepidula mexicana (Rigacci), Crepidula nautiloides (auct. non Lesson), Crepidula roseae (Petuch9, Crepidula violacea (Rigacci), Crepidula virginica (Conrad), Crypta nautarum (Mörch) and Patella fornicata (Linné) (Global Invasive Species Database, 2005). Its common name in English is slipper limpet. The native distribution of C. fornicata is the Atlantic coast of North America, West Atlantic (Rayment, 2008).

Introduction history: *It was introduced in Europe from America with imported oysters (Campbell, 1976). Nowadays, it is recorded as an alien species in several European countries; France, Spain, Mediterranean, Sweden, Norway, Denmark, Italy, UK and Netherlands (Global Invasive Species Database, 2005). It is present in west and south Portugal (Macedo and Borges, 1999). It was first notice in RF 4 or 5 years ago, 2004-2005 (Afonso, pers. Comm.)*

Ecology/Description: *Crepidula fornicata is a protandrous hermaphrodite, it start life as male and later change to female (Global Invasive Species Database, 2005). The grow rate, madurity age and reproduction time cycle is difficult to know because of the hermaphroditic (Rayment, 2008). C. fornicate grows commonly in an aggregates form, it forms chains or stacks of individuals ones over others (Campbell, 1976). The ones in the bottom are females and on the top males. It has pelagic larvae that helps to spread fast (JNCC, 2007). These aggregates can have a really high density of individuals, for instance it has been reported an abundance of 4770 individuals per m² in shallow muddy areas (Rayment, 2008).*

C. fornicate is an active suspension feeder, that usually eats phytoplackton and particulate organic food. C fornicata lives in sublittoral and infralitoral in muddy or sandy bottoms. It can be founded in open coast, straits, bays and lagoons. It usually live attached to shells, rocks or on shells of mussels and oysters, like Ostrea edulis (RAyment, 2008). Is a cosmopolitan species that can survive in a wide range of environmental conditions, substrata, waves exposure, salinity and depth. The success of this species can be due to the lack of predators and the reproductive method (JNCC, 2007).

Crepidula Fornicata European distribution map. (DAISIE European Invasive Alien Species Gateway, 2008. Crepidula fornicata http://www.daisie.ceh.ac.uk/speciesFactsheet.do?speciesId=268 [Accessed 2nd April 2008])

Impacts: *This specie can alter the habitat by modify the texture and nature of the sediments (Rayment, 2008); and removing a big amount of organic matter to the water column (Global Invasive Species Database, 2005). C. fornicate affects other species by spatial and trophic competition (e.g. smother of bivalves) (Rayment, 2008). Effects on communities have been reported, however results are contradictory and not all authors agree (Global Invasive Species Database, 2005). It is considered oysters' beds pest; it compete for food and space with commercial oysters, while depositing mud on them (JNCC, 2007; Campbell, 1976). For instance, it has caused the abandon of the oyster fisheries in France (Rayment, 2008). The severity of impacts is different depending on the region and source (Global Invasive Species Database, 2005; Rayment, 2008).*

C. fornicata also has positive impacts, it provides new habitats where other organism as decapods can hide, and increase the species number and diversity.

Spread vector in RF: *Accidental introduction, it was probably introduced with imported oysters or by food trade (trough away with old mollusk and shellfish that have been not sold).*

Situation in RF: *It has been seen the last 3 years, in Tavira area, close to the port and oyster aquaculture facilities. The distribution is local and not so abundant (Afonso, pers comm.). The affirmation of the shellfish collectors is diverse: Mr. Manjua have not notice any new specie, he declare it specie have been always here. On the other hand, Mr. Silva said that this species is not present inside RF, and that other similar species exist in the region. There is a clear problem of identification, maybe due to the survey method.*

Impact assessment and potential risk in RF: *Unknown impacts. It is considered high risk specie. However, this specie does not show the same invasiveness and negative impacts everywhere.*

Management in RF: *First management option should be study its current situation and vectors of introduction. The specie is present in the surrounding country (Spain /France) and in northern countries, which there is maritime traffic with them. It can create serious problems on habitat, and affect the oyster production.*

There are some management options to eradicate it, once it is established and infects oysters' bed. But these options are not really success for the moment (Global Invasive Species Database, 2005). Furthermore, in France industrial collection and treatment programme was carried out by IFREMER in order to use the C. fornicata for agricultural use, and for calcareous and organic ground enrichment (Global Invasive Species Database, 2005)

Information sources: *Global Invasive Species Database Web Pages (2005), Invasive Species Invasive Group(ISSG) Web Pages (2005); DAISIE WebPages (2008); The Marine Life information Network for Britany and Ireland (Rayment, 2008)*

Image: Steve Trewhells/JNCC (published on the MarLIN Web site)

Buccinum undatum (Linnaeus, 1758)

Mollusc class gastropod, its common name is common whelk. It has several synonimus; Buccinum acuminata (Broderip, 1830); Buccinum undatum var. caerulea (Sars G.O., 1878); Buccinum acuminatum (Broderip, 1830); Buccinum undatum var. flexuosa (Jeffreys, 1867); Buccinum undatum var. lactea (Jeffreys, 1867, 1867); Buccinum undatum var. paupercula (Jeffreys, 1867); Buccinum donovani (Sars G.O., 1878), Buccinum fragile (Sars G.O., 1878) and Buccinum pictum (Verkrüzen, 1881) (FAO, 2007). Its natural distribution is the North Atlantic, east and west coast, it is common in the North Sea, being its southern distribution Brittany, France. (FAO, 2007).

Introduction history: *It is cryptogenic specie in RF. It is not considered introduce in other European countries. Therefore, the introduction is unknown, probably accidental by food trace (trough away with food when it has been not sold). It is also possible that arrive by natural spread.*

Ecology/ Description: *B. undatum is an extremely variable species, in shell size, weight, sculpture, shape and colour. It is a large whelk; it can be 10 cm high and 6 cm wide. It lives in subtidal habitat, because it is not adapted to the intertidal conditions. It can be found at 100 m deep, it prefers sandy, sand-muddy and stony bottoms. Whelks are carnivores; they feed on worms, crustaceans, mussels and mollusc. The sexual maturity is around 5 or 7 years, and the spawning season can vary from one place to other. They live in moderate or cold sea temperatures, 29º C is lethal for them (FAO, 2007).*

There is a fishery activity on common whelks in UK (Ager, 2007).

In its native range the population declined during the 90's, North Sea and Wadden sea, this was related with the presence of TBT (tributyltin) pollution from antifouling paints (FAO, 2007).

Impacts: *B. undatum can be a great predator; it could affect bivalves farms and has negative socio-economic impacts. It is not considered an invasive or alien species, due to this there is not information about its impacts.*

Spread vector in RF: *Accidental introduction, the spread vector is probably food trade.*

B. Undatum data records in Europe. MarBEF (2004). European Marine Biodiversity Research Sites. Available online at http://www.marbef.org/data/sites.php. Consulted on 2008-02-11.

Situation in RF: *It has been seen last 3 year in Tavira area. (Afonso, pers. comm.). Another Buccinium sp. appear in the work of Calvario (1995) about the macrobenthic* *communities in Ria Formosa. However, it is not specie specific.*

During the interview to shellfish collectors, Mr. Manjua affirmed that 2 species of whelks have appeared recently in RF; one coming from Angola and present since 5 years ago, which is abundant., the other one appears since 20 years ago, and is a great predator. However, this species were identified at university as native species from this coast, Hexaplex trunculus and Stramonita haemastoma, and they are abundant (Afonso, pers. Comm.).

Impact assessment and potential risk in RF: *Unknown impact. The potential risk is low; it is not considered an alien species, its traits are not from an invasive species; and the water temperature would be a spread and survival barrier in RF. However, the current situation in RF is unknown, and it could be a great predator.*

Management in RF: *There is not current management action for this specie. The presence and abundance of B. undatum and similar species should be studies in order to clarify the situation, and study its establishment and possible introduction vectors.*

Information sources: *FAO Species Sheet WebPages, The Marine Life Information Network for Britany and Ireland WebPages (Ager,2007), MarBEF European Network WebPages; it do not appear in alien species information.*

Image: www.arkive.org

Gambusia affinis (Baird and Girard, 1853)

It is freshwater fish, native from east and south USA (Global Invasive Species Database, 2005). Nowadays, it is present world-wide. It is thought that G. affinis is the most widely introduced freshwater fish (Global Invasive Species Database, 2005). It is called mosquito fish in English and Gambúsia in Portuguese. It has up to 13 synonyms that are not valid.

***Introduction history:** Gambusia affinis was introduced world wide as mosquitos control measure, because it feed on mosquito eggs. However, it is highly predatory on fish and invertebrate eggs, which reproduction success decrease. Due to this, the intentional introductions as mosquito control stop. In Global Invasive Species Database (2005) it appears as introduced in a long list of countries included Portugal. However, this records are not show in the distribution map of DAISIE (2008) or other databases as OBIS (2007).*

G. affinis was introduced in Portugal between 1900 and 1921 for mosquito control. It was distributed by the health security service in all rivers, ponds and lakes; it was freely given to its spread. Nowadays, it is forbidden its introduction, but it is present in all freshwater bodies (Grade, pers. Comm.).

***Ecology/ Description:** Gambusia affinis is a small fish; males grow to 40 mm in length, while females reach 70 mm long. It lives in freshwater habitats, rivers, wetlands, lakes, ponds and estuarine habitats. It can survive in wide range of conditions; it resists brackish waters with pH between 6 to 8, temperatures between 12 to 29, and even 42 for short periods, and also survive in low oxygenated water and with high salinity (Global Invasive Species Database, 2005).*

G. affinis is very similar to G. holbrooki, now they are considered sub-species rather than distinct species (Global Invasive Species Database, 2005). Both species can appear as the same one in some documents and WebPages.

***Impacts:** G. affinis has impacts over other species and over the community. It is an aggressive species and highly predator on mosquito, fish and invertebrate eggs. It is responsible of destroy mosquito and native fish populations. Also alter zooplackton and invertebrate communities. This species is also a vector of parasites for other fishes (Global Invasive Species Database, 2005). It is considered a potential pest (Froese and Pauly, 2008)*

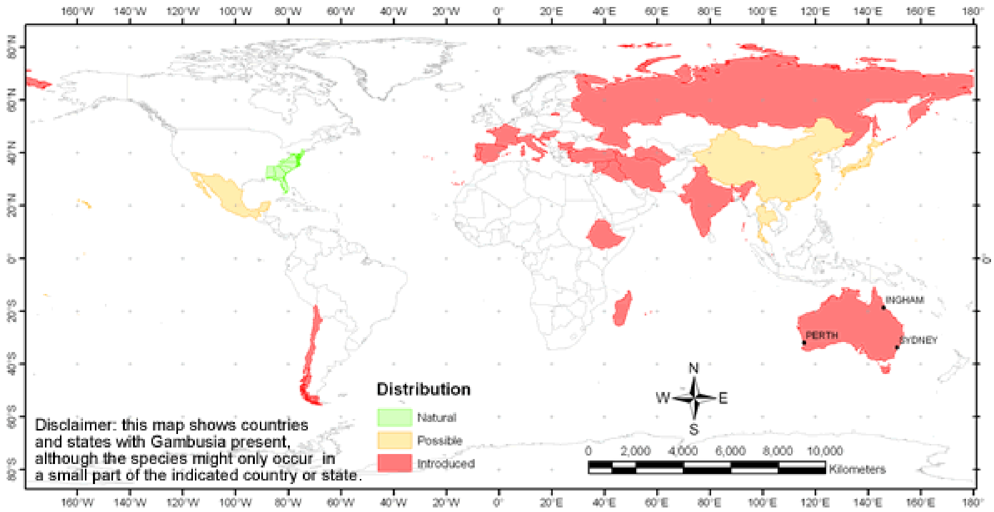
***Spread vector in RF:** It was introduced for mosquito control, more than 50 years ago (Grade, pers. Comm.).*

***Situation in RF:** Establish and naturalized in the freshwater bodies of RF (Grade, pers. comm.).*

***Impact assessment and potential risk in RF:** Low impact. G. affinis is a high risk specie, considered by Global Invasive Species Database (2005) one of the 100 worst invasive species. However, in Ria Formosa it is not considered that has any risk.*

Management in RF: *There is not any current management activity in Ria Formosa. It is not priority species.*

Information sources: *The WebPages of fishbase.org (Froese and Pauly, 2008) and Global Invasive Species Database, (2005), as well DAISIE database WebPages(2008).*



Distribution map. (Pest fish in North East Queensland. Australian Centre for Tropical Freshwater Research. Available at: http://www.actfr.jcu.edu.au/Projects/Pestfish/Profiles/ProfileGambusia.htm. Consulted in 2008).

Image: Slaboch, R. 2004. Available at: www.fishbase.org

Trachemys scripta (Schoepff, 1792)

It is a popular reptile that can be found in all pets shops. It is native of Mississippi valley in USA. It has been recorded in a wide range of countries, Europe, Asia and South Africa as examples (Global Invasive Species Database, 2005).

Introduction history: *Since 70' it have been produced and exported for international pet trade (Global Invasive Species Database, 2005). Once introduced is release from its owner in natural ecosystems.*

No record of this specie in the wild in the Natural Park was found. However, its presence was confirmed by the Natural Park by personal communication (Grade, pers. Comm.). However, probably it is present since several years ago. This specie appears in the Portuguese law of alien species, Annex III, which includes the species that have ecological impact, it is forbidden to introduce them or its trade (Decreto-lei n.º 565/99).

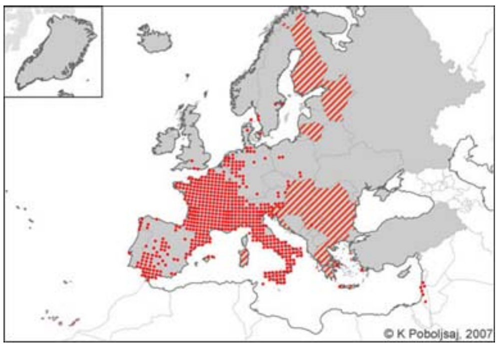
Ecology/ Description: *It lives in is lakes, freshwater courses and wetlands. They can live for about 40 years. The nesting occurs from April to July in the temperate zones, usually they excavate on the shore of the freshwater body, but it can occur in beaches as well. They are omnivorous and opportunistic predators. They can be a prey as well for rodents and corvids mainly (DAISIE, 2008).*

Impacts: *T. scripta can transmit diseases in South America. It affects the communities; it outcompete the native turtle in France. In addition, can affect the population of invertebrates, like dragon fly, and birds by predation and destroy the nest (Global Invasive Species Database, 2005). There is no record of impacts in RF, it shows a not aggressive behaviour (Grade, pers. Comm.)*

Spread vector in RF: *Intentional introduced for pet trade. It escapes or is release by its owners, and then disperses naturally.*

Situation in RF: *It is common specie, present in at least one freshwater system. One population is present in St. Lurenço River. It is possible that there is more introduce turtle specie. The population status is unknown (Grade, pers. Comm.).*

Impact assessment and potential risk in RF: *Unknown impacts. It is high risk specie, which is considered one of the 100 world's worst invader by Global Invasive Species Database, 2005. However, in Ria Formosa have not been study its impacts.*



DAISIE European Invasive Alien Species Gateway, 2008. Trachemys scripta *http://www.daisie.ceh.ac.uk/speciesFactsheet.do?speciesId=961 [Accessed 2nd April 2008].*

Management in RF: *It is considered harmful specie and it is forbidden in Portugal. In Ria Formosa there is a proposal for its control and eradication, its program have not been approved yet. (Grade, Pers. Comm.). The situation and impacts of this species should be study.*

Information sources: *Global Invasive Species Database WebPages (2005) and DAISIE database WebPages (2008).*

Annex II

Terrestrial Non-Indigenous Species in Ria Formosa

Birds

Estrilda astrilda

It is a bird introduced intentionally from Africa. It is common specie, established and present everywhere. It was introduced for pet trade and then escape or released. Currently it can be breed and sold illegally. No data of the impacts of its introduction. Sources of information: ICN, 2004; Grade, pers. Comm.

Nandayus nenday

This bird native from South America was intentional introduced for pet trade. It has been observed in Loule. It is protected under the CITES convection against illegal trade of animals. There is no record of effect of impacts. Sources of Information: SEO, 2008

Ploceus melanocephalus

Native from Africa was intentional introduction as pet trade. Probably introduced by 1995 to 2000, it is a common species but it is just present in localized areas. It has been seen in Quinta do Lago, Ria Formosa. Source of information: Forum aves Portugal, 2008, Diaz Pastor, pers. Comm.

Mammals

Genetta genetta

This mammal was probable introduced in roman's times or before. Nowadays, it is part of the natural biota and do not represent any risk (Grade, pers. Comm.). Source of information: ICN, 2004; Grade, pers Comm.

Herpestes ichneumon

This mammal was probable introduced in roman's times or before. Nowadays, it is part of the natural biota and do not represent any risk. Source of information: ICN, 2004; Grade, pers. Comm.

Plants:

Alianthus altissima

It was introduced for ornamental purpose (Plantas invasoras do Portugal, 2007). It is invasive species and appears in the Portuguese list of invasive plants (Decreto-lei n.º 565/99). Source of information: ICN, 2004; Plantas invasoras do Portugal, 2007

Carpobrotus edulis

It was introduced for garden trade and for erosion control in dunes. It is native of South of Africa. It is invasive species. Impacts: high density, high competition and soil acidification (Plantas invasoras do Portugal, 2007). It appears in Portuguese alien species law (Decreto-lei n.º 565/99). Sources of information: Plantas invasoras do Portugal, 2007; Furtado, 1989; Viegas, 2007; ICN, 2004.

Acacia longifolia

It is native of Australia, introduced for ornamental use. Impacts: it is a high competitor and create dense populations (Plantas invasoras do Portugal, 2007). Appear in Portuguese alien species law (Decreto-lei n.º 565/99; ICN,2004). Sources of information: ICN, 2004; Plantas invasoras do Portugal, 2007.

Acacia Saligna

It is native of Australia, introduced for ornamental purpose and for erosion control. Impacts: competition (Plantas invasoras do Portugal, 2007). Sources of information: Panagopoulos, pers. Comm.; Plantas invasoras do Portugal, 2007.

Acacia retinoides

It is native of Australia, introduced for ornamental use. Impacts: high density population; alters soil conditions (Plantas invasoras do Portugal, 2007). It is invasive species, appears in the Portuguese alien species law (Decreto-lei n.º 565/99). Sources of information: Plantas invasoras do Portugal, 2007; ICN, 2004.

Acacia Pycnantha

It is native of Australia; it was introduced for ornamental use. Impacts: High density population; compete and eliminate the native sp; alters soil conditions (Plantas invasoras do Portugal, 2007). It is invasive species, appears in Portuguese alien species law (Decreto-lei n.º 565/99). Sources of information: Plantas invasoras do Portugal, 2007; ICN,2004.

Cortadeira selloana

This specie comes from South America. It was introduced for ornamental use. Impacts: Competition for space and resources. It has high risk because of its traits: fast grow; high reproduction rate; can grow in different environments (Plantas invasoras do Portugal, 2007). Sources of information: Panagopoulos, pers. comm.; Capdevila Argüelles et al, 2006; Plantas invasoras do Portugal, 2007; Panagopoulos, pers. Comm.

Oxalis pes-capraea

It is native of South Africa. It was introduced for ornamental use. Nowadays, it is a invasive species (Plantas invasoras do Portugal, 2007). It appears in Portuguese alien species law (Decreto-lei n.º 565/99). Sources of information: Plantas invasoras do Portugal, 2007; ICN, 2004.

Hakea serícea

It is native of Australia, was introduced for ornamental use. Impacts: High competence, less water available in the soil (Plantas invasoras do Portugal, 2007). It is invasive species; appears in Portuguese alien species law (Decreto-lei n.º 565/99). Sources of information: Plantas invasoras do Portugal, 2007; ICN, 2004.

Datura stramonium

It is native from the tropical region of America. It was introduced accidentally (Plantas invasoras do Portugal, 2007). It is invasive species, appears in Portuguese alien species law (Decreto-lei n.º 565/99). Sources of information: Plantas invasoras do Portugal, 2007; ICN, 2004.

Conyza bonariensis

Native of South America, it was introduced accidentally (Plantas invasoras do Portugal, 2007). It isconsider invasive, appears in Portuguese alien species law (Decreto-lei n.º 565/99). Sources of information: Plantas invasoras do Portugal, 2007; ICN, 2004.

Arctotheca caléndula

It is native from South of Africa, was introduced intentionally. Impacts: high density population, outcompete and eliminate native populations (Plantas invasoras do Portugal, 2007). It is invasive species, appears in Portuguese alien species law (Decreto-lei n.º 565/99). Sources of information: Plantas invasoras do Portugal, 2007; ICN, 2004.

Eucalyptus

Native of Australia was introduced intentionally for forestry use in the Iberian Peninsula. It is considered a dangerous species in Spain (black list) (Capdevilla Argüelles et al, 2006). Sources of information: ICN, 2004; Capdevilla Argüelles et al, 2006.

Arundo donax

It is native from east Europe and Asia. Impacts: Competition and change the water flow. It has high risk, can be invader is some environments (Plantas invasoras do Portugal, 2007). Sources of information: Panagopoulos, pers. Comm.; Plantas invasoras do Porugal, 2007

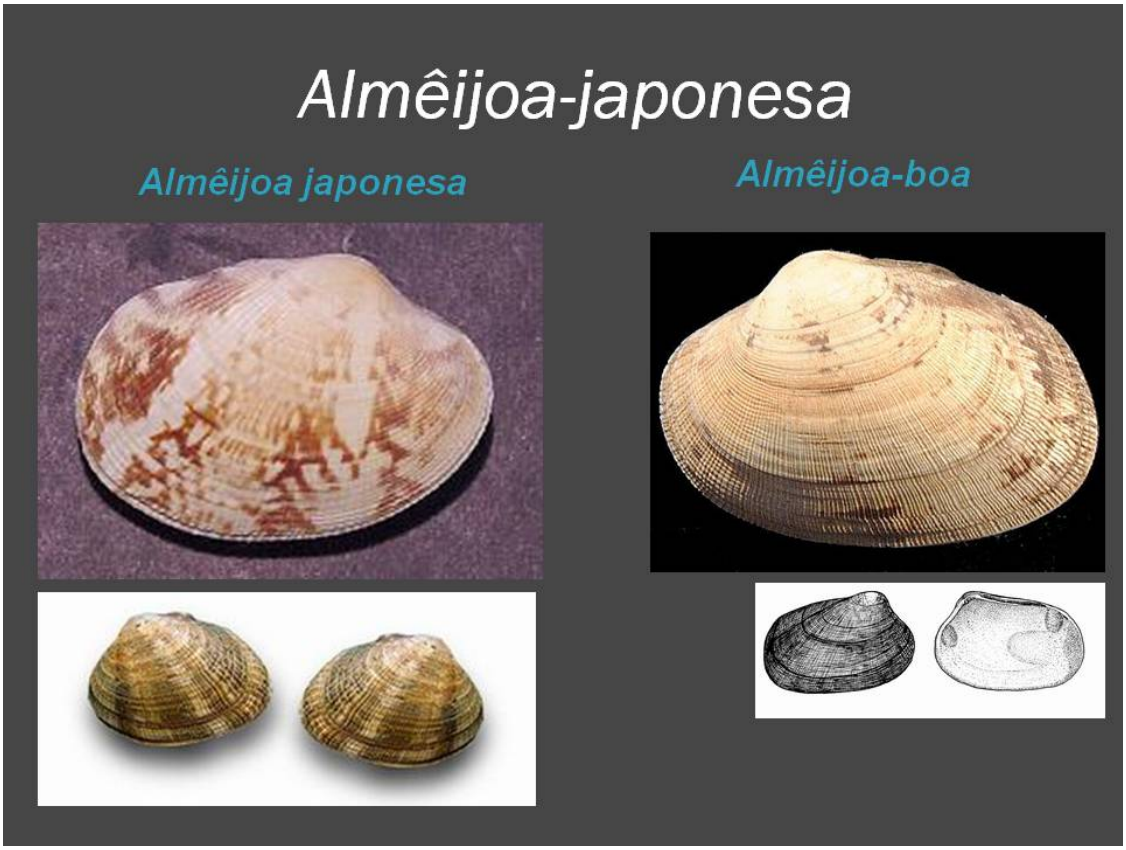
Reptil

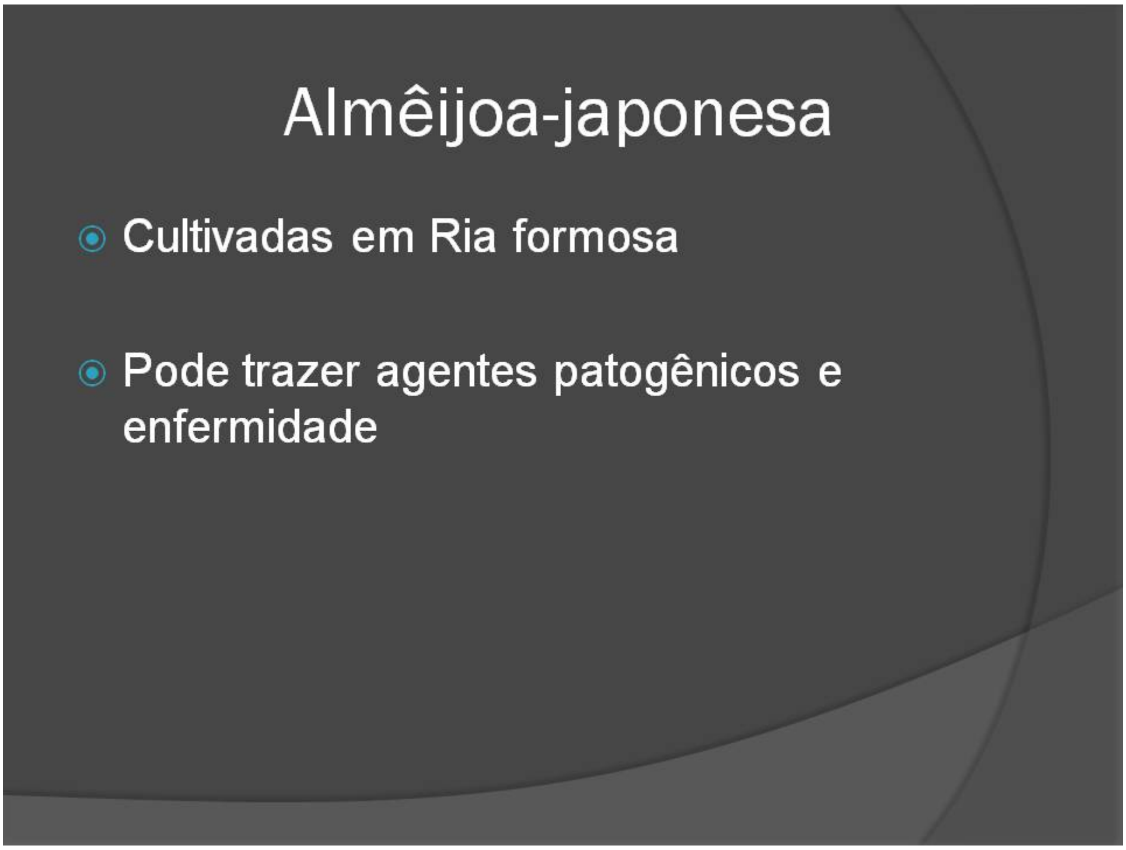
Chamaeleo chamaeleo

It is cryptogenic species; it is believed that was accidental introduced in historical times. Nowadays, it is a threaten specie (ICN, 2004). Sources of information: Grade pers comm.; ICN, 2004.

Annex III

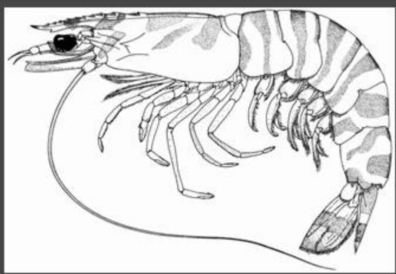
Identification cards of NIS for Shellfish collectors


Almêijoa-japonesa
Almêijoa japonesa
Almêijoa-boa

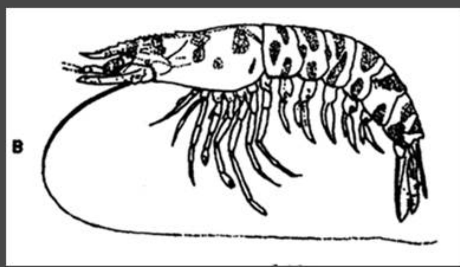

Almêijoa-japonesa
Cultivadas em Ria formosa
Pode trazer agentes patogênicos e enfermidade

Camarão japonês

Camarão japonês



Gamba manchada/ Camarão de quarteria



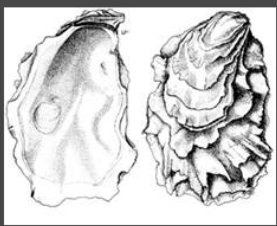
Camarão japonês

- Máximo comprimento total 190 mm (macho), 225 mm (feminino); carapaça comprimento máximo 53 mm (macho) 66 mm (fêmea).
- Cultivadas em RF
- A concorrência com os nativos

Ostra-gigante

Ostra-gigante

Ostra portuguesa

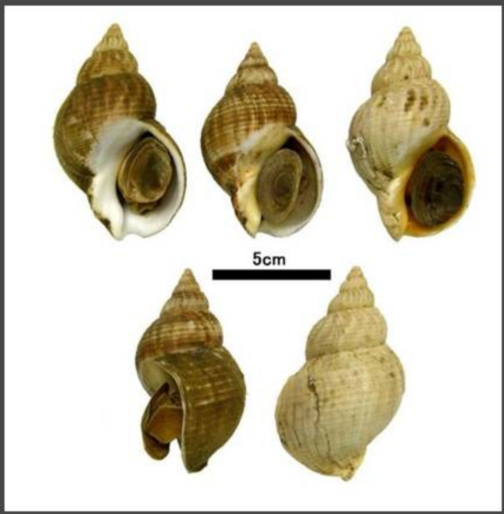


Muito parecidas

Ostra-gigante

- Existe a possibilidade de que ele se tornar um problema de concorrência com a espécie nativa.
  No entanto, é indeciso se a Ostra gigante é a mesma espécie que a ostra portuguesa

Buzo



Buzo

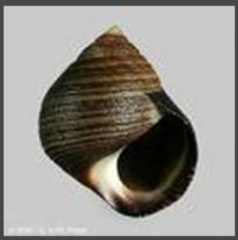
- Muito variável
- É também um grande mollusco, ele pode ser de 10 cm de altura e 6 cm de largura.
- Predador do moluscos

Crepidula fornicata

C. Fornicata

- Pragas para as ostras
- A casca é oval, até 5 cm de comprimento
- C. fornicate cresce normalmente em um formulário de agregados, faz cadeias ou chaminés dos indivíduos uns sobre outros

Borrelho (Lottorina Littorea)



Borrelho

- Cultivadas em Ria formosa
- Littorina littorea é pastoreio gastrópodes
- A cor de casca é geralmente preta ou marrom-escuro cinzento