rages

risk-based approaches to good environmental status

WP3 APPLICATION OF RISK-BASED APPROACH TO NON-INDIGENOUS SPECIES (DESCRIPTOR 2)

Deliverable 3.3 – Report on risk criteria and significance levels

Version 2

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Contents

Introduction

This document constitutes the Deliverable 3.3 - Report on risk criteria and significance levels. Task 3.3 – "Establish risk criteria and significance levels" defines risk criteria, aggregation methods and elaborates risk scales (ratings) for D2 risk evaluation, incorporating information from EASIN (European Alien Species Information Network) and AquaNIS (Information system on aquatic non-indigenous and cryptogenic species) databases, as well as from the regulation on Alien Invasive Species List of Union concern [Regulation (EU) 1143/2014]. Deliverable 3.1 (Bartilotti et al. 2020a) reported the available information on non-indigenous, cryptogenic and data-deficient species (definitions according to Tsiamis et al. 2019), hereinafter referred as non-indigenous species (NIS), occurring in two sub-regions of the North-East Atlantic Ocean region defined under the Marine Strategy Framework Directive (MSFD) and considered in the RAGES project: the Bay of Biscay and the Iberian Coast (ABI), and the Macaronesia (AMA). Deliverable 3.2 defined the risk context, including the management objectives, assessment scales and risk parameters and categories. In addition, as NIS are one of the key pressures affecting the marine environment considered for the MSFD implementation, a preliminary list of established NIS with known adverse effects was delivered, as one of the relevant criteria elements for the assessment of Good Environmental Status (GES). This list also considered the distribution of NIS in the two sub-regions, and highlighted those NIS considered of high impact in EASIN, the network that provides technical and scientific support to the MSFD. The definition of these criteria elements provides support for the next steps of the risk approach: risk analysis and risk evaluation.

Figure 1 summarises the steps required for the application of a Risk-Based Approach (RBA) to NIS developed under the RAGES project.

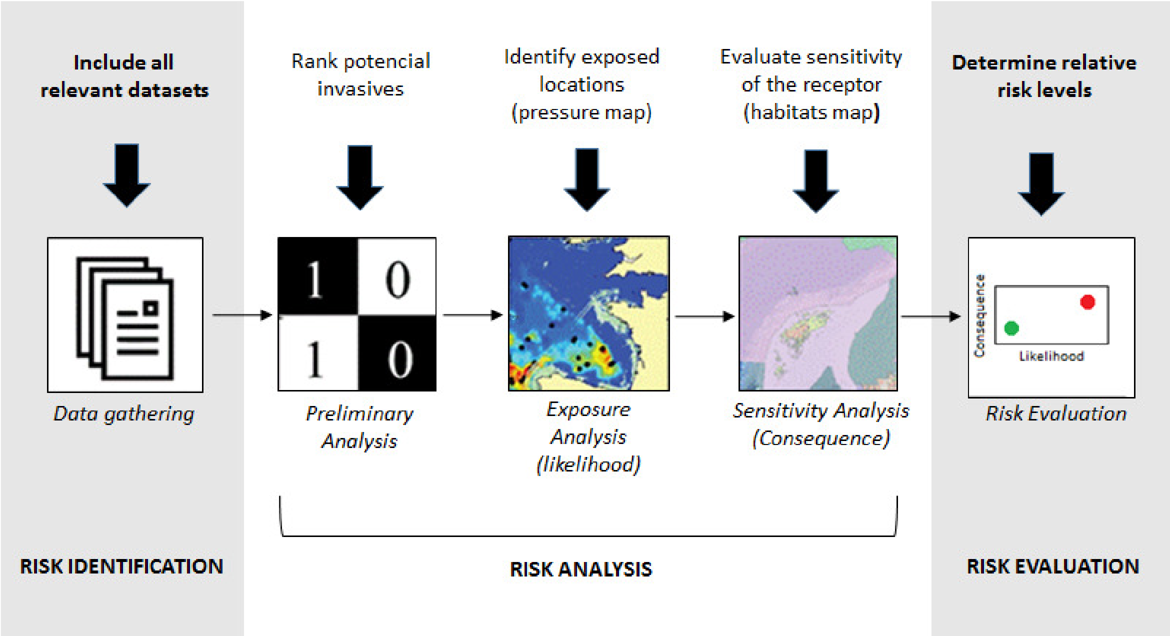

Figure 1. Diagrammatic representation of the work required under step 2 (Risk Identification), step 3 (Risk Analysis) and step 4 (Risk Evaluation) of the RAGES Risk-Based Approach, with a link to the three main steps of the ISO 31000 (2009).

Risk Analysis

The aim of this risk analysis is to provide a methodology to assess the risk levels associated with NIS and their introduction pathways.

In this framework, the proposed risk analysis consists of two main steps:

1) *Preliminary analysis*
   - The development of a ranking system aiming to identify NIS that should be of high priority for risk assessment. This system combines species biological traits and information on adverse environmental and socioeconomic impacts.

2) *Exposure analysis*
   - Identification of pathway activity hotspots (e.g. marinas, ports, terminals and aquaculture facilities). The location of areas at higher risk of introduction will be mapped based on the data gathered from shipping density and the distribution of aquaculture facilities.
   - Analysis of areas susceptible to NIS introductions – identification of the most susceptible areas based on the spatial distribution of established NIS across the two sub-regions.

Preliminary analysis

Horizon-Scanning approach

The purpose of the preliminary analysis is to rank high-risk NIS present at the sub-regional scale using a Horizon-Scanning (HS) method. HS approaches have been recognized as an essential tool to prioritize potential threats posed by new and emerging NIS to a target area (Shine et al. 2010). Over the past decade, a number of HS exercises have been performed to provide a ranked list of NIS likely to arrive, establish, spread, and having a potentially adverse impact on native ecosystems (see Roy et al. 2015 for a review). The following methodology to rank NIS is built upon the approaches derived from Roy et al. (2014) (e.g., Roy et al. 2015, 2019; Tsiamis et al. 2020). The method combines a structured approach, including information relevant for the invasion process, coupled with expert judgement to validate the results.

<u>List of species for HS</u>

In this exercise, the information compiled in Deliverable 3.1 (Bartilotti et al. 2020a) will provide a reference base to prioritize species for applying the Risk-Based Approach (RBA). The NIS data comprise information from online databases (e.g., EASIN, AquaNIS), as well as from peer-reviewed scientific papers, technical-scientific reports, MSc and PhD thesis, and other initiatives, such as the reports of the Working Group on Introductions and Transfers of Marine Organisms (WGITMO) of the International Council for the Exploration of the Sea (ICES).

To perform the HS exercise, species will be divided by phyla: Annelida, Arthropoda, Bryozoa, Cercozoa, Chlorophyta, Chordata, Cnidaria, Ctenophora, Mollusca, Myzozoa, Nematoda, Nemertea, Ochrophyta, Platyhelminthes, Porifera, Rodophyta and Tracheophyta. Each group will be assigned at least to three assessors for scoring and validation.

<u>Ranking system - parameters and categories</u>

The ranking system is developed based on the following parameters: likelihood of introduction, establishment, spread, and potential adverse impacts. Each parameter is associated with risk categories, which reflect criteria that are considered relevant to the invasion process. In total, eight risk categories are defined to contribute to score calculation: number of introduction pathways, life cycle duration, reproductive rate, environmental tolerance to salinity and temperature, dispersal ability and potential environment and socioeconomic adverse impacts. The risk categories and associated definitions are shown in Table 2. Definitions given for life cycle, reproductive rate and dispersal ability provide basic information to guide the evaluation, and other aspects may be incorporated into the decision-making process by the experts as pertinent.

The assessment of the number of introduction pathways through which NIS may arrive can be used to estimate the likelihood of introduction. The major pathways which act as vectors for NIS introduction within the scope of this report are presented in Table 1. The system to categorise the introduction pathways follows the terminology proposed by the Convention on Biological Diversity (CBD, 2014), with modifications suggested by Harrower et al. (2018).

Table 1. Possible pathways of NIS introduction within the scope of the RAGES project. Categorisation pathways are adapted from CBD (2014). Descriptions are provided in Harrower et al. (2018).

Pathway Category	Pathway Subcategory	Description
Release	Fishery in the wild	*Fish and other aquatic animals released into the (semi)natural environment to provide additional or alternative subsistence and/or commercial or recreational fishing opportunities*
Escape	Aquaculture / mariculture	*Species that have escaped from confinement or controlled situations in either freshwater or marine environments to produce food or other agricultural type products including bioenergy products*
	Pet/aquarium/terrarium species (including live food for such species)	*Species that have escaped confinement or controlled environments where they were kept by private collectors or hobbyists for recreation, enjoyment, companionship and/or trading*
	Live food and live bait	*Species that have escaped from confinement or controlled environments where they were kept and/or transported as live food or live bait (excluding live foods given to pet species)*

Contaminant	Contaminant bait	*Species introduced unintentional as a contaminants in/of bait (e.g. crustacean, cephalopods, molluscs)*
	Contaminant on animals (excluding parasites and species transported by host and vector)	*Species introduced unintentionally as contaminants on animals transported through human related activities*
	Parasites on animals (including species transported by host and vector)	*Unintentional introduction of parasitic species transported by a host animal or an animal that acts as a vector*
Stowaway	Angling/fishing equipment	*Species introduced unintentionally as stowaways on equipment used by recreational anglers or commercial/professional fishermen*
	Container/bulk	*Species introduced as accidental stowaways on containers, bulk freight, etc. (e.g. shipping containers, other cargo in boxes)*
	Hitchhikers on ship/boat (excluding ballast water and hull fouling)	*Species that have been introduced unintentionally by being a hitchhiker in or on ships, boats or other watercraft (e.g. hovercraft, submarines) but excluding species transported in ballast water or via hull fouling (e.g. species collected within the hull, such as sea chests, bilge water and within the hull itself*)
	Machinery/equipment	*Species that have been introduced unintentionally by being a hitchhiker in or on machinery or equipment being transported between locations*
	Organic packing material (wood packaging)	*Species that have been introduced unintentionally by being a stowaway in or on packing materials such as boxes, pallets, etc.*
	Ship/boat ballast water and sediments	*Species that have been introduced unintentionally via the ballast water and sediments of ships and boats*

	Ship/boat hull fouling	*Species that have been introduced unintentionally as hull-fouling organisms on ships and boats*

The life cycle duration and reproductive rate can represent good predictors of NIS introductions. For example, species characterized by short life cycle and high reproductive rate, introduced by ballast water, may expand in abundance (number of individuals) during transportation, increasing the probability of their release at the site of introduction, which may also lead to a successful introduction and establishment. The environmental tolerance of NIS to different salinity and temperature ranges is also a reliable indicator for predicting the risk of introduction and establishment (Minchin et al. 2014). The likelihood of spread of NIS after their introduction, will depend on the dispersal ability of the species, determined by their life-history characteristics (e.g., NIS with complex life cycles, having pelagic and benthic life stages have a wide range of dispersal opportunities when compared to those with only the pelagic or benthic life) (Minchin et al. 2014). The information from the adverse environmental and socioeconomic impacts of NIS may represent a valuable guide for predicting the consequences of NIS introduction into a new environment (Ricciardi, 2003, Blackburn et al. 2014), despite the uncertainty associated with this category, i.e., predict how species will respond when placed into a different ecological context (Roy et al. 2014).

Risk scoring

Risk scores are assigned by each assessor following the overall basis for scoring the likelihood of introduction, establishment, spread and potential adverse effects presented in Table 2. The risk scores were standardized for comparisons between two possible scenarios provided under the risk score guidance: lower risk scenarios receive a score of 1, while higher risk scenarios receive a score of 3. To guide the assessors in performing the exercise, a spreadsheet template is provided including four sections: (1) Read me, (2) Risk-scoring table, (3) Risk-scoring example, (4) Glossary and Acronyms. The risk-scoring table included in the spreadsheet template contains the following parameters: likelihood of introduction, establishment, spread, and potential adverse impacts. Each parameter is associated with risk categories, which reflect criteria that are considered relevant to the invasion process. In total, eight risk categories were defined to contribute to score calculation: number of introduction pathways, life cycle duration, reproductive rate, environmental tolerance to salinity and temperature, dispersal ability and potential and socioeconomic negative impacts. The spreadsheet template is provided in Annex 1.

Table 2. The overall basis for scoring the likelihood of introduction, establishment, spread and potential impact using Horizon Scanning exercise in the ABI and AMA sub-regions.

	Risk Category	Risk Category definition	Risk score guidance	Score
Likelihood of introduction	Number of introduction pathways	Number of introduction pathways likely to be responsible for species introduction outside their native range (considering CBD subcategory pathways, see Table 1).	Species linked to more than one pathway receive a higher ranking than species linked to one only.	one pathway = 1 more than one = 3
	Life cycle duration	Duration of the phases from the egg to the adult, i.e. the developmental stages of an organism until reaching the adult phase. The life cycles of different species may also vary in the type of reproduction, sexually or asexually (Ebenman & Persson, 1988). Life cycle period may consider duration of developmental stages (e.g. abbreviated larval development in terms of number of stages and duration of development) and in general, are dependent on habitat features (e.g. temperature) and the size of the organism.	Species with a short life cycle receive a higher ranking than species with a long life cycle.	long = 1 short = 3
	Reproductive rate	The growth rate of a population per generation; equivalent to the number of female offspring that each female produces over its lifetime (Freeman et al. 2014).	Species with a high reproductive rate receive a higher ranking than species with a low reproductive rate.	low = 1 high = 3

Likelihood of establishment	Environmental tolerance to salinity	Euryhaline organisms are able to tolerate and thrive in a wide salinity range (i.e. freshwater, brackish water and marine waters); stenohalyne species can only survive within a narrow salinity range (in marine waters).	Euryhaline species receive a higher ranking than stenohalyne species.	stenohalyne = 1 euryhaline = 3
	Environmental tolerance to temperature	Eurythermal organisms are able to tolerate and thrive in a wide temperature range of temperature; stenothermal species can only survive within a narrow temperature range.	Eurythermal species receive a higher ranking than stenothermal species.	stenothermal = 1 eurythermal = 3
Likelihood of spread	Dispersal ability	Dispersal as the ecological process that involves the movement of an individual or multiple individuals away from the population in which they were born to another location, or population, where they will settle and reproduce (Croteau, 2010).	Species with high dispersal ability receive a higher ranking than species with low dispersal ability.	low = 1 high = 3
Potential negative impact	Environmental	Environmental impact categories leading to deleterious effects are: 1) Ecological impacts (competition, predation, razing/herbivory/browsing, biofouling, hybridization); 2) Sanitary impacts (poisoning/toxicity); 3) Abiotic impacts (chemical, physical or structural impact on the ecosystem. (see Bartilotti et al. 2020a for detailed definitions).	Species assigned to more than one of the three impact categories receive a higher ranking than species assigned to only one or none.	none or one impact category = 1 more than one of the 3 impact categories = 3

	Socioeconomic	Socioeconomic impact categories leading to adverse effects are: 1) Economic: production losses (e.g., in agriculture, fisheries, aquaculture, recreational values), changes in economic values, management costs increase and generation of direct, indirect, option and existence values (e.g.: commercial exploitation, aquarium trade); 2) Social: harm to human health and social life. (see Bartilotti et al. 2020a for detailed definitions).	Species assigned to both impact categories receive a higher ranking than species assigned to only one or none.	none or one of the two categories = 1 both = 3

Uncertainty

HS assessments typically deal with knowledge gaps and high levels of uncertainty (Roy et al. 2018). Uncertainty may arise from the quality of the information used or its interpretation, i.e., judgment subjectivity (Regan et al. 2002). One possible approach to include uncertainty analysis is to develop confidence levels (low, medium, high) that can be associated with each risk category to produce the combined final score (Mastrandrea et al. 2010). For every risk category, an assessor is asked to provide a level of confidence with his/her answer. The confidence level should reflect the robustness of pieces of evidence (the type, amount, quality and consistency of the data) and/or the expert opinion (Mastrandrea et al. 2010). It is important to underline that confidence levels should be supported by well documented information sources, with references to the scientific literature (peer-reviewed publications). If this is lacking, then it may also include other sources, such as grey literature and expert opinion (Roy et al. 2018). In this approach, confidence level scores are assigned for each risk category, where scores of 1, 2 and 3 correspond, respectively, to low, medium and high evaluation. The basis for providing the confidence levels for each scoring (Table 3) is presented below.

Table 3. The basis for providing the appropriate confidence level for each NIS scoring (adapted from Tsiamis et al. 2020 and Harrower et al. 2018).

High	*Evidence is supported by peer reviewed publications and/or grey literature by respected sources (e.g. technical-scientific reports); the available evidence is not controversial.*
Medium	*Evidence is supported by grey literature (e.g. MSc and PhD thesis) or evidence is indirect (based on other species of the same genus or higher taxonomic group)*; *and/or the statement is supported by expert opinion with good confidence level (degree of confidence in being correct 50-100%).*
Low	*Evidence is supported by grey literature from unknown/non-expert authors, publications from unspecified sources; and/or the statement is not supported by expert opinion.*

The mean confidence level score is calculated for each risk category per species to provide an overall confidence level (high, medium or low).

Data deficiencies

Information about characteristics and adverse effects remains unknown for a large number of NIS, which may lead to the incorrect categorization of the species as harmless, following the assumption of ‘no impact - no harm’ (Ojaveer, 2015). In light of this, the scoring of data-deficient NIS (i.e., NIS with unknown or insufficient information) represents a significant challenge and should be considered carefully as management efforts will rely on the results. In this context, unknown information will be treated with a distinct score value, as it is not subject to a confidence assignment. In this case, if true precaution is applied, the worst-case scenario (highest score) should be considered whenever the information on NIS is absent (score 3, see Table 2). However, this could lead to the prioritization of a number of NIS, for which a large proportion of data is unknown (Matthews et al. 2017; Strubbe et al. 2019). On the other hand, the lowest scores could lead to underestimation of potential risks. In light of this, an intermediate score value of 2 is proposed in an attempt to cautiously manage the lack of information.

Overall score calculation and preliminary rank of NIS

The overall score value is based on the score assignments of each risk category for each species (score 1 = lower risk scenario, score 2 = unknown, score 3 = higher risk scenario) and are calculated as: [Number of introduction pathways x (life cycle + reproductive rate + likelihood establishment + likelihood of spread) x (potential adverse environmental impacts + potential adverse socioeconomic impacts)]. Overall scores range from 10 to 270 points. The preliminary rank is defined as:

1) Top Priority - Species that rank above the mean of the maximum risk score, with high confidence.

2) Alert - Species that rank above the mean of the maximum risk score, with low to medium confidence or species that rank below the mean risk with low to medium confidence.

3) Less Concern - Species that rank below the mean of the maximum risk score, with high confidence.

Validation by experts and final evaluation with recommended actions

The preliminary ranked list of NIS provides a starting point for discussion and validation of the list by all experts.

1) Species that rank above the mean of the maximum risk score, with high confidence – need for specific measures.

2) Species that rank above the mean of the maximum risk score, with low to medium confidence or species that rank below the mean risk with low to medium confidence – need for monitoring/ research actions.

3) Species that do not fall into the top priority category but are considered of high risk – monitoring/research actions recommended.

4) Species that rank below the mean of the maximum risk score, with high confidence – less concern; however, surveillance monitoring recommended.

An exercise was performed to illustrate the output of the proposed ranking system (Appendix A).

Finally, the proposed ranking system is applicable for the likelihood of introduction, which allows the assessment of criterion D2C1 (newly introduced species), as well as for the likelihood of invasion, once it takes into account the likelihood of establishment, spread and potential adverse impacts (D2C2).

Application of an alternative decision-support system for ranking NIS

In order to assess the potential influence of the prioritization method on the HS results an alternative method, ELECTRE III, will be applied to rank species in function of the risk they represent as NIS, for the two regions, ABI and AMA separately.

The ELECTRE III approach is based on Bernard Roy's works (Martin & Legret, 2005, Brignon et al. 2018) within the operational research company SEMA-METRA in the 60's and in the university Paris-Dauphine since the 70's.

The ELECTRE III approach provides the comparison of actions scored for different criteria defined by the user based on the construction of a preference hypothesis, named "surpassing relation". This approach could consider ordinal or qualitative criteria. In our case study the actions are NIS, and the criteria used are the same as those used by the HS approach. ELECTRE III uses an aggregation algorithm, separated in two phases:

- Comparison of all actions by pairs (A, B), using evaluations and weighting of criteria, in order to test the hypothesis of "surpassing relation" between two actions; action A is at least as good as action B. The surpassing relation is reflexive but not transitive.
- Ranking actions based on these comparisons.

The general principle of ELECTRE is based on the construction of a preference hypothesis, named "surpassing relation" between actions. The surpassing relation is reflexive but not transitive.

Actions are compared in pairs and all pairs are characterized by a surpassing relation. This relation is not fully accepted or rejected, but the degree of credibility of the relation is assessed following two indices: the compliance index and the discordance index.

- The compliance index indicates the importance of the affirmation of the surpassing relation between two actions. The higher the index, the clearer the affirmation of surpassing is, i.e., the higher the index, the clearer the affirmation that A is at least as good as action B.

- The discordance index: the higher the index, the more discordant actions A and B are.

Relations between actions are defined by thresholds of indifference, preference and veto that need to be set up for each criterion.

- Indifference (i): this threshold defines the estimated non-significant difference between two evaluations.
- Preference (p): this threshold defines the difference between two evaluations, which indicates that one option is preferred over the other.
- Veto (v): this threshold defines the difference between two evaluations, which indicates that the action with the lower evaluation cannot be ranked better at the end than the other action, whatever the relations for the other criteria are.

<u>Compliance index</u>

The test of compliance (Figure 2) consists in calculating an index for each criteria of each surpassing relation. The index of compliance is:

- 1, when the assessment of A for the criteria j (gj(A)) is better than the one of B (gj(B)), up to the indifference threshold i.
- 0, when the evaluation of A for a criterion is worse than that of B, with a difference higher than the preference threshold p.
- A value between 0 and 1, proportional to the difference between the indifference and the preference thresholds.

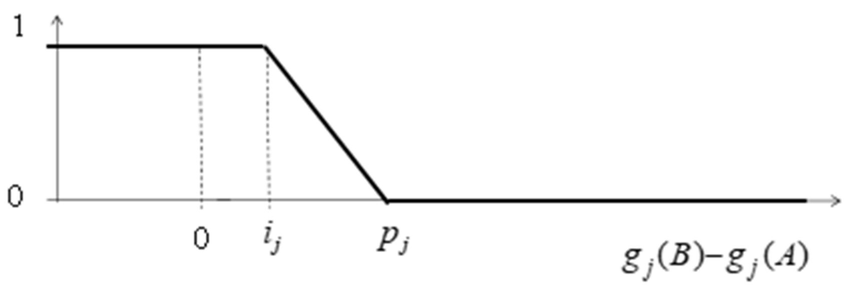

Figure 2. Estimation of the compliance index for one criterion.

<u>General compliance index</u>

At the end all compliance indices of all criteria for a pair (A, B) are aggregated in a general compliance index by multiplying each index by the weight of the criteria set up at the beginning for each criterion (weighted average).

Discordance index

The discordance test (Figure 3) consists in calculating an index for each pair of actions (A,B) and for each criteria g_j. The index of discordance is:

- 0, when the evaluation score of A for the criterion j (gj(A)) is lower than the evaluation score of B for the same criterion j (gj(B)), and the difference between the two scores is lower than the preference threshold p.
- 1, when the evaluation score of A for the criterion j (gj(A)) is better than the evaluation score of B (gj(B)), and the difference between the two scores is lower than the veto threshold v.
- A value between 0 and 1, proportional to the difference between the preference and veto thresholds.

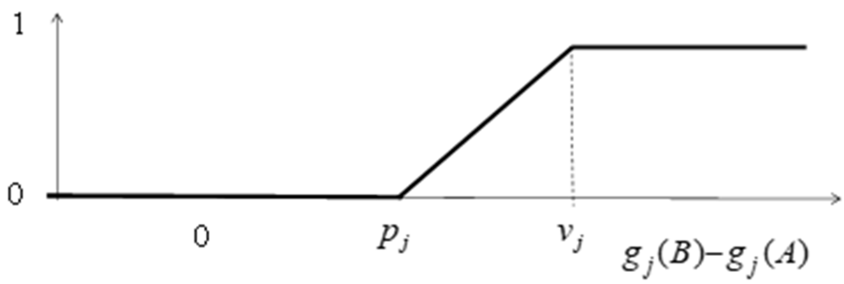

Figure 3. Estimation of the discordance index by criterion.

Finally, compliance and discordance for each criterion complement each other.

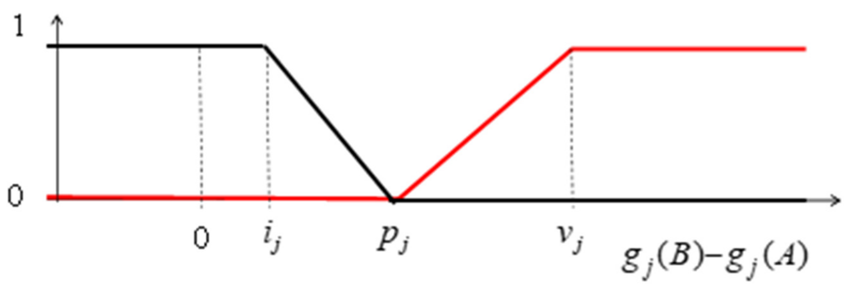

Figure 4. Complementarity of the indices of compliance (black line) and discordance (red line) by criterion.

The degree of credibility of the relation between actions A and B is based on the compliance and the discordance indices, indicating if the surpassing relation of A on B is credible or not.

- If the compliance index is higher or equal to the discordance index, then the degree of credibility is equal to the value of the compliance index.
- If the compliance index is strictly lower than the discordance index, then the degree of credibility is equal to the value of the compliance index subtracted from the discordance indices.

Finally, ELECTRE III establishes a partial pre-ranking based on degrees of credibility and a discrimination threshold. It is called partial pre-ranking because it accepts ex-aequo rankings of actions, considering the possibility of not comparing actions. The discrimination threshold set up by the user allows to separate valid surpassing relation and non-valid surpassing relation according to their degrees of credibility. Two complete partial pre-rankings are generated through two antagonistic "distillation" procedures ("ascending" and "descending"). Partial pre-ranking works by iteration, each iteration selects one action or several actions, which surpass the most clearly the other actions and which are the least surpassed by other actions. Actions selected are removed and another iteration is carried out, and so on. A final ranking is obtained by crossing the two pre-rankings. Finally, a sensitivity analysis is carried out to estimate the stability of the results.

Ranking results obtained with ELECTRE III and those obtained by the HS approach can point to species for which further expert analysis could be warranted.

Exposure Analysis

Identification of pathway activity hotspots

For the exposure assessment, attributes like frequency, extent or intensity of the activity may be considered. In this perspective, the identification of areas where new introductions (i.e., new records) are more likely to occur, such as marinas, ports, terminals and aquaculture facilities will allow for targeting of high-risk locations for monitoring new NIS incursions (assessment of D2C1). The location of the main ports, marinas, recreational ports and the distribution of aquaculture facilities (for production of microalgae, macroalgae, finfish and shellfish) can be obtained using EMOdnet services (data available for Portugal, Spain and France) and through interactive maps developed by the Government of Portugal and Spain (interactive maps not available for France). Data on shipping density and aquaculture for both sub-regions are also available through

EMOdnet (Table 5). The number of ports, marinas, recreational ports and aquaculture facilities were compiled for each marine reporting unit (MRU) and are presented in Table 6.

Table 5. Data sources to assess areas of introduction and intensity of pathway activity for ABI and AMA sub-regions.

Pathway	Shipping density	Location of ports, marinas and aquaculture facilities
Commercial shipping	EMODnet (https://www.emodnet-humanactivities.eu/view-data.php)	EMODnet (https://www.emodnet-humanactivities.eu/view-data.php)
Recreational boating	EMODnet https://www.emodnet-humanactivities.eu/view-data.php	EMODnet https://www.emodnet-humanactivities.eu/view-data.php Portugal: https://www.psoem.pt/geoportal_psoem/ https://www.dgrm.mm.gov.pt/marinas-e-portos-de-recreio
Aquaculture		EMODnet https://www.emodnet-humanactivities.eu/view-data.php Portugal: https://www.psoem.pt/geoportal_psoem/ Spain: https://servicio.pesca.mapama.es/acuivisor/

Table 6. Numbers of ports, marinas, recreational ports and aquaculture facilities across ABI and AMA sub-regions. FR/Bob: France/Bay of Biscay MRU. ES/NA: Spain/North Atlantic MRU. ES/SA: Spain/South Atlantic MRU. PT/A-NW: mainland Portugal Northwest MRU. PT/B-SW: mainland Portugal Southwest MRU. PT/C-S: mainland Portugal/South MRU.

MSFD Sub-region	MS/MRU	Main ports [a]	Marinas and other commercial and recreational ports	Aquaculture facilities
ABI	FR/BoB	4	59[b]	129[a]

ABI	ES/NA	11	60[b]	4829[e]
ABI	ES/SA	2	10[b]	57[e]
ABI	PT/A-NW	4	7[c]	93[c]
ABI	PT/B-SW	3	16[c]	87[c]
ABI	PT/C-S	2	11[c]	1090[c]
AMA	ES/Canary	2	36[d]	14[e]
AMA	PT/Azores	9	12[c]	2[c]
AMA	PT/Madeira	3	5[c]	2[c]

[a] *Retrieved from https://www.emodnet-humanactivities.eu/view-data.php*
[b] *Keller et al. (2011)*
[c] *Retrieved from https://www.dgrm.mm.gov.pt/*
[d] *Retrieved from https://puertoscanarios.es*
[e] *Retrieved from https://servicio.pesca.mapama.es/acuivisor/*

To illustrate part of the information available, vessel density and finfish and shellfish production sites maps retrieved from EMODnet for the ABI and AMA sub-regions are shown in Figure 5 and Figure 6.

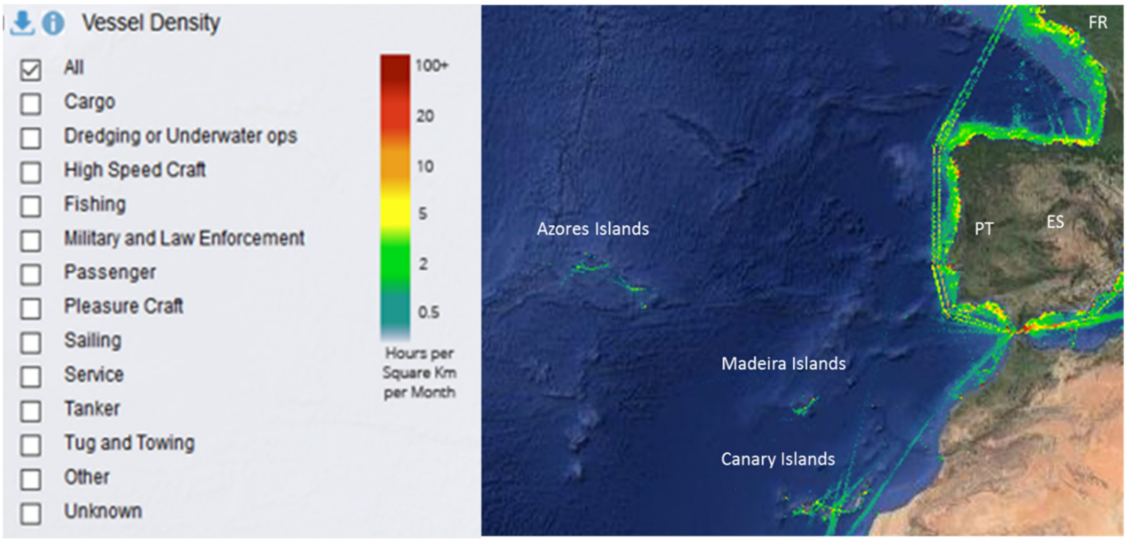

Figure 5. Map illustrating the vessel density across ABI and AMA sub-regions (adapted from EMODnet).

Figure 6. Map displaying finfish and shellfish production sites across ABI and AMA sub-regions (adapted from EMODnet). Numbers indicate the aquaculture facilities in the area.

To identify the areas at increased risk of new introductions, the location of pathway activity hotspots will be mapped based on the data gathered from shipping density and the distribution of aquaculture facilities.

Analysis of areas susceptible to NIS introductions

Several studies have shown that habitat anthropogenic changes (i.e. nutrient enrichment, loss of top consumers, water pollution, eutrophication), may promote the successful establishment of marine NIS (e.g. Crooks et al. 2010; Clark and Johnston, 2011; Früh et al. 2012, Briggs, 2012). Thus, the distribution of established NIS can give some insight into areas more prone to new introductions. The distribution of NIS in each MRU across the sub-regions targeted in this study is shown in Figure 7.

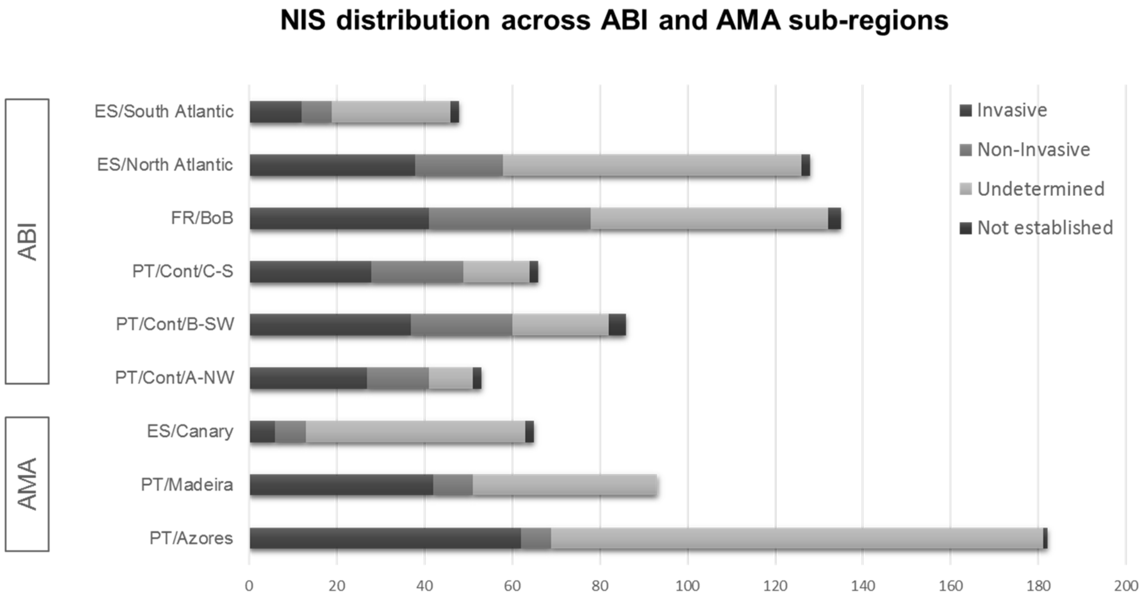

Figure 7. Distribution of NIS across ABI and AMA sub-regions. Established NIS correspond to the sum of invasive and non-invasive species. FR/Bob: France/Bay of Biscay MRU. ES/NA: Spain/North Atlantic MRU. ES/SA: Spain/South Atlantic MRU. PT/A-NW: mainland Portugal Northwest MRU. PT/B-SW: mainland Portugal Southwest MRU. PT/C-S: mainland Portugal/South MRU.

Risk Evaluation

The aim of this risk evaluation is to estimate the levels of risk (high, medium, low) associated with NIS and their introduction pathways. The risk of new introductions can be assessed by estimating: (i) which species are more likely to be introduced based on their biological traits and introduction pathways and (ii) the number of MRUs where NIS are established. This can be displayed by plotting the likelihood of introduction (based on the score obtained for the parameter ´likelihood of introduction’, see Appendix A) against the number of established NIS per MRU (Figure 8). Similarly, the evaluation of the risk of invasion can be assessed based on which species are more likely to become invasive (based on the overall score obtained for the NIS) and assessing the number of MRUs where NIS are established (Figure 9).

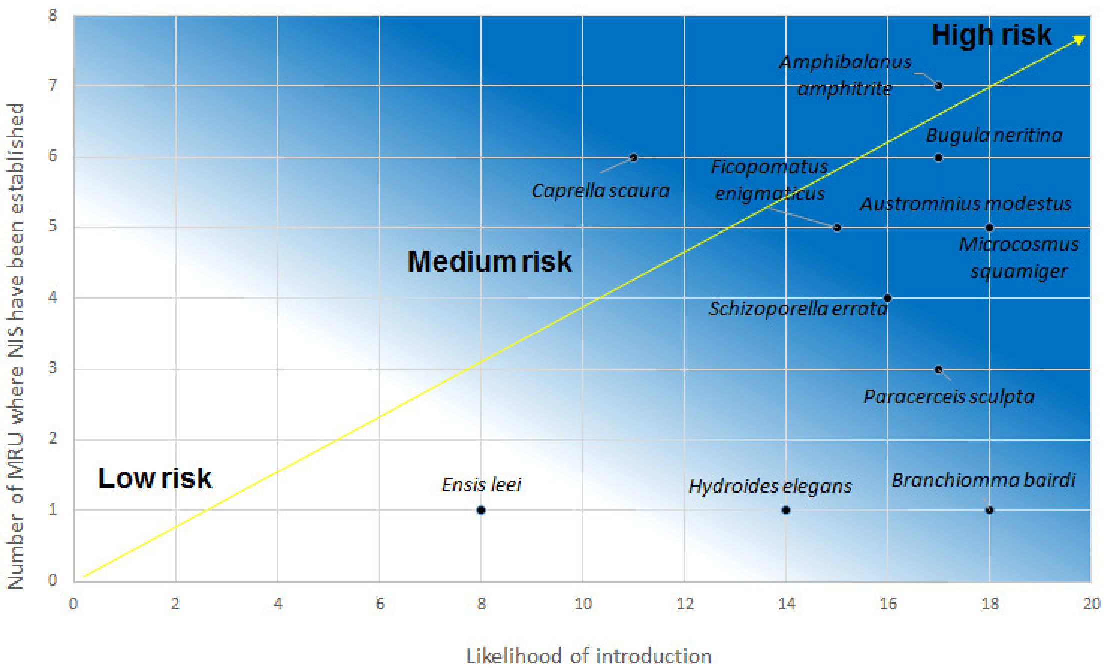

Figure 8. Exercise illustrating how the results of the ranking system and the spatial distribution of established NIS across the MRUs can be graphed to assist risk evaluation.

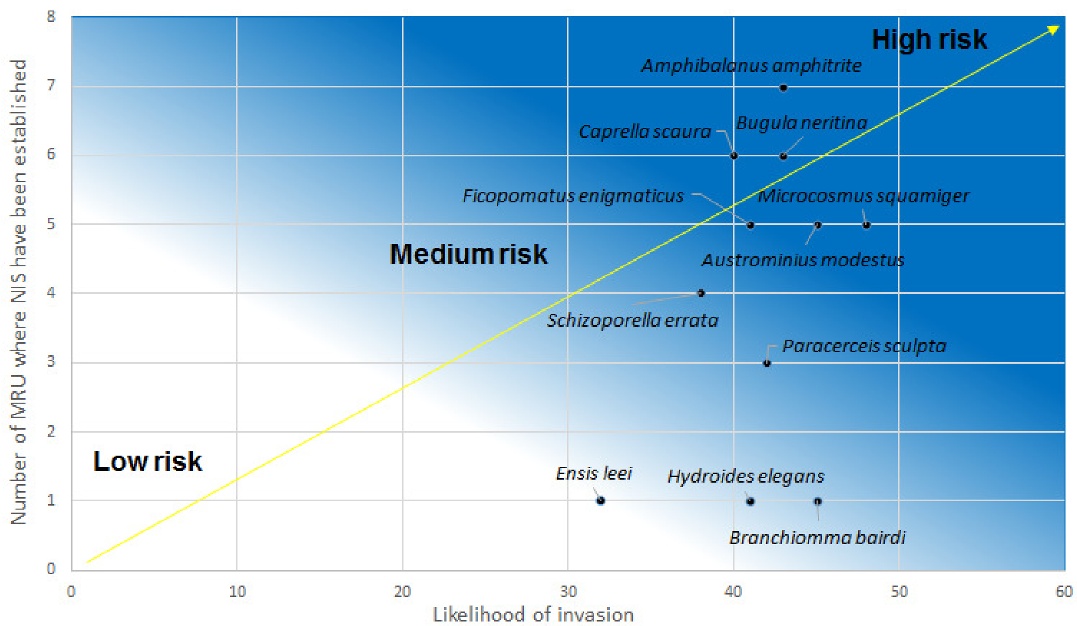

Figure 9. Exercise illustrating how the results of the ranking system and the spatial distribution of established NIS across the MRUs can be graphed to assist risk evaluation.

Additionally, information regarding areas where a higher number of established NIS have been reported combined with the intensity of the results of pathway activity can be used to spot areas at higher risk of new introductions (Figure 10).

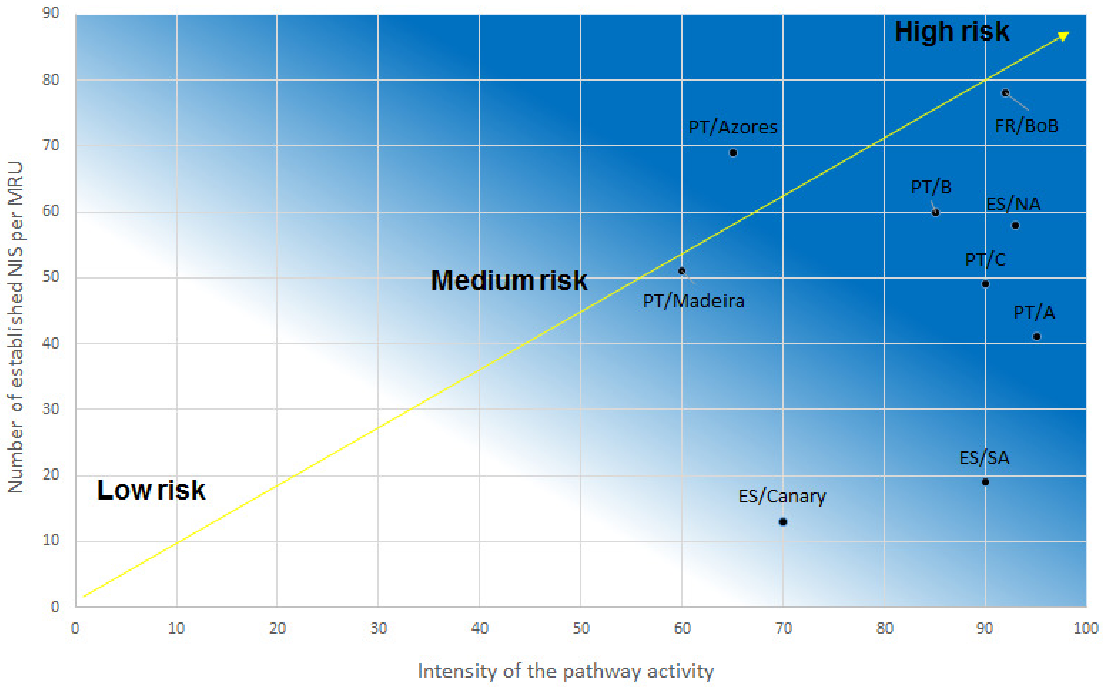

Figure 10. Exercise illustrating how the results of the intensity of the pathway activity versus the number of established NIS per MRU can be graphed to assist the risk evaluation. FR/Bob: France/Bay of Biscay MRU. ES/NA: Spain/North Atlantic MRU. ES/SA: Spain/South Atlantic MRU. PT/A-NW: mainland Portugal Northwest MRU. PT/B-SW: mainland Portugal Southwest MRU. PT/C-S: mainland Portugal/South MRU.

The outcomes of the risk evaluation step include a decision of whether or not a risk should be treated, taking into consideration the understanding of risk obtained during risk analysis, but also ethical, legal, financial and other considerations (see Deliverable 2.3). Table 7 shows an example of how the results of the risk evaluation can facilitate the risk management process.

Table 7. Example of actions resulting from the risk evaluation step.

Risk Evaluation	**Recommendation**
High risk	Control focus or focused surveillance on these species and/or introduction pathways with management actions.
Medium risk	Focused surveillance on these species and/or introduction pathways – not necessarily with management actions.
Low risk	No action needed.

Finally, species for which a large proportion of unknown data could be flagged with recommendations for “research-action”, so that management allows to gather basic knowledge on them.

Final Remarks

Following the RAGES risk-based approach steps set out in Deliverable 3.2, this report aimed to define the risk criteria and significance levels to assess the risk of NIS new introductions in the Bay of Biscay and the Iberian Coast, and in the Macaronesia. The preliminary analysis presents a horizon-scanning methodology to deliver a ranked list of NIS. This tool takes into account information considered relevant to the invasion process coupled with expert judgment while allowing uncertainty to be incorporated. It is worth noting that the results of this preliminary analysis will allow the comparison among the ranked list of NIS and the NIS lists compiled and presented in the Deliverable 3.2 (Bartilotti et al., 2020b), i.e., NIS with known adverse effects and those reported in EASIN as high impact NIS. Moreover, the risk analysis outlines the assessment of pathway activity hotspots to identify areas at increased risk of new NIS introductions.

Further application of the risk-based approach will be undertaken in the following task, T3.4 “Perform risk assessment”, where the methodology set in the previous steps will be used to perform the assessment on D2, in order to determine if there is a risk of not achieving GES.

Following the previous steps Task 3.5: “Risk management common targets and coordinated measures”, will propose coordinated actions for D2 risk management to be implemented at sub-regional/national/local levels (articles 10, 11 and 13) in areas of concern based on the administrative framework established.

Glossary

Ballast water - water with its suspended matter taken on board a ship to control trim, list, draught, stability or stresses of the ship (IMO, 2004).

Biofouling - accumulation of aquatic organisms such as plants, animals and micro-organisms on surfaces and structures submerged or exposed to the aquatic environment (IMO, 2011).

Contaminant – a species that has an ecological association with, and/or dependence on, a specific organism or product (Harrower et al. 2018).

Cryptogenic species - species with no definite evidence of their native or non-indigenous status due to unknown origin or due to unclear mode of introduction from native range (natural spread *vs* human mediated) (Tsiamis et al. 2019).

Data-deficient species - NIS with insufficient information or new entries not verified by experts or NIS with unresolved taxonomic status (Tsiamis et al. 2019).

Established – NIS growing and reproducing successfully in a given area (Drolet et al. 2016).

Invasive alien species - a subset of established NIS which have spread, are spreading or have demonstrated their potential to spread elsewhere, and have an adverse effect on biological diversity, ecosystem functioning, socio-economic values and/or human health in invaded regions (Olenin et al. 2010).

Non-indigenous species (NIS; synonyms: alien, exotic, non-native, allochthonous) - species, subspecies or lower taxa introduced outside of their natural range (past or present) and outside of their natural dispersal potential. This includes any part, gamete or propagule of such species that might survive and subsequently reproduce (Olenin et al. 2010).

Parasite or pathogen - organisms that live in or on a host and obtain their food from the host at a cost to the host (Harrower et al. 2018).

Pathway - process that results in the introduction of a non-indigenous species from one geographical location to another (Pyšek et al. 2009).

Stowaway - a species that uses vectors to move between locations by chance or unknowingly (Harrower et al. 2018).

Vector - physical means or agent (e.g., ship) in or on which a species moves outside its native range (Genovesi and Shine, 2004).

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Appendix A

An exercise representing a ranked list of NIS addressed for HS and their associated overall scores, overall confidence level and classification. Scores per each risk category associated with each of the four parameters are given: (i) likelihood of introduction, (ii) likelihood of establishment, (iii) likelihood of spread, (iv) potential negative impact. MS/Subdivision/MRU and MSFD sub-region per each species are also provided. Note: Unknown information is not subject to a confidence assignment, therefore confidence levels are not shown, and the corresponding score is 2.

Species	MSFD subregion	MS/Subdivision /MRU	Likelihood of introduction									Likelihood of establishment						Likelihood of spread			Potential negative impact						Overall score	Confidence score (Average)	Overall confidence level	Classification
			Number of introduction pathways			Life cycle duration			Reproductive rate			Environmental tolerance - Salinity			Environmental tolerance - Temperature			Dispersal ability			Environmental			Socioeconomic						
			Score	Confidence level	Confidence score	Score	Confidence level	Confidence score	Score	Confidence level	Confidence score	Score	Confidence level	Confidence score	Score	Confidence level	Confidence score	Score	Confidence level	Confidence score	Score	Confidence level	Confidence score	Score	Confidence level	Confidence score				
Botrylloides violaceus Oka, 1927	ABI	FR/BoB, ES/NA, PT/CONT/B-SW, PT/CONT/C-S	3	High	3	3	Medium	2	3	Medium	2	3	High	3	3	High	3	3	High	3	3	High	3	3	High	3	270	2,750	High	Top Priority
Rhithropanopeus harrisii (Gould, 1841)	ABI	FR/BoB, ES/NA, ES/SA, PT/CONT/B-SW, PT/CONT/C-S	3	High	3	3	High	3	3	High	3	3	High	3	3	High	3	3	High	3	3	High	3	3	High	3	270	3,000	High	Top Priority
Eriocheir sinensis H. Milne Edwards, 1853	ABI	FR/BoB, ES/NA, ES/SA, PT/CONT/A-NW, PT/CONT/B-SW	3	High	3	3	High	3	3	High	3	3	High	3	3	High	3	3	High	3	3	High	3	3	High	3	270	3,000	High	Top Priority
Styela clava Herdman, 1881	ABI	FR/BoB, ES/NA, PT/CONT/A-NW, PT/CONT/B-SW	3	High	3	3	High	3	3	High	3	3	High	3	3	High	3	3	Medium	2	3	High	3	1	High	3	180	2,875	High	Top Priority
Penaeus japonicus Spence Bate, 1888	ABI	FR/BoB, PT/CONT/A-NW, PT/CONT/B-SW	3	High	3	3	High	3	3	High	3	3	High	3	3	High	3	3	High	3	2			2			180	3,000	High	Top Priority
Blackfordia virginica Mayer, 1910	ABI	FR/BoB, ES/NA, ES/SA, PT/CONT/B-SW, PT/CONT/C-S	3	High	3	3	Medium	2	3	high	3	3	Medium	2	3	Medium	2	3	Medium	2	3	High	3	1	Medium	2	180	2,375	High	Top Priority
Asclerocheilus ashworthi Blake, 1981	ABI	ES/NA	2			2			2			3	Medium	2	3	Medium	2	3	Medium	2	2			2			104	2,000	Medium	Alert
Exaiptasia diaphana (Rapp, 1829)	ABI	FR/BoB	2			3	Medium	2	3	Medium	2	3	High	3	3	High	3	1	Medium	2	3	Medium	2	1	Medium	2	104	2,286	Medium	Alert
Hemigrapsus takanoi Asakura & Watanabe, 2005	ABI	FR/BoB, ES/NA	3	High	3	3	Medium	2	3	Medium	2	3	Medium	2	3	Medium	2	3	Medium	2	3	High	3	1	Low	1	180	2,125	Medium	Alert
Boccardia semibranchiata Guérin, 1990	ABI	ES/NA	2			2			2			1	Medium	2	3	Medium	2	3	Medium	2	1	High	3	1	High	3	44	2,400	High	Less Concern
Hydroides dianthus (Verrill, 1873)	ABI	ES/NA, FR/BoB	3	High	3	2			2			1	High	3	3	High	3	3	Medium	2	1	High	3	3	High	3	132	2,833	High	Less Concern
Hemigrapsus takanoi Asakura & Watanabe, 2005	ABI	FR/BoB, ES/NA	2			1	Medium	2	3	Medium	2	3	High	3	3	High	3	3	Medium	2	3	Medium	2	2			130	2,333	High	Less Concern
Ciona intestinalis (Linnaeus, 1767)	ABI	PT/CONT/B-SW	2			3	High	3	3	High	3	3	High	3	3	High	3	3	Medium	2	1	High	3	3	High	3	120	2,857	High	Less Concern
Desdemona ornata Banse, 1957	ABI	FR/BoB, ES/NA, PT/CONT/B-SW, PT/CONT/C-S	3	High	3	2			2			1	High	3	2			3	Medium	2	3	High	3	1	High	3	120	2,800	High	Less Concern
Eurytemora pacifica Sato, 1913	ABI	FR/BoB	2			1	High	3	3	High	3	3	High	3	3	High	3	3	High	3	2			2			104	3,000	High	Less Concern