Information on measures and related costs in relation to species considered for inclusion on the Union list – *Rugulopteryx okamurae*

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Date of completion: 21/08/2020

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Species (scientific name)	*Rugulopteryx okamurae* (E.Y. Dawson) I.K. Hwang, W.J. Lee & H.S. Kim 2009
Species (common name)	-
Author(s)	Anastasia Tsirika, PhD Biologist
Date Completed	21/08/2020
Reviewer	José Carlos García-Gómez, Faculty of Biology of the University of Seville John Alonso, GEF-UNDP-IMO GloFouling Partnerships

Summary of the most effective measures

Summarise the most effective measures discussed below for each category highlighting cost-effectiveness where known. There is no need to summarise the species invasion status within the EU, or its taxonomy etc., which are dealt with in the species Risk Assessment.

Rugulopteryx okamurae (E.Y. Dawson) I.K. Hwang, W.J. Lee & H.S. Kim, 2009, (Dictyotales, Ochrophyta), previously known as *Dilophus okamurae*, constitutes a common brown algal species, native to the temperate areas of the North-western Pacific (e.g. Korea, Japan, China, Taiwan and Philippines) (Huang, 1994).

In the European territory, *R. okamurae* is an introduced taxon, recorded in two Member States: France (Verlaque et al., 2009) and Spain (Altamirano et al., 2016). The introduction of this species in both European Countries is considered an un-intentional introduction. *R. okamurae* was firstly recorded in the EU, in the Thau Lagoon of the French coast during 2002, as a result of seed importation for the culturing of Japanese oyster (*Crassostrea gigas* [Thunberg]) (Verlaque et al., 2009). The introduction of *R. okamurae* in Spain, from its native areas in the Pacific, is considered to have taken place via maritime transportation. Introduction of alien species through maritime transportation (hull fouling and ballast waters) in the Strait of Gibraltar is suggested as common and expected, due the intense maritime activities in the area (Ruíz et al., 1997; Ribera Siguan, 2003), although this has not been proven for all the invasive macroalgae species established in this geographical area.

Based on scientific works, published since the detection of the species in the Strait of Gibraltar (Altamirano et al., 2016, 2019; El Aamri et al., 2018; Navarro-Barranco et al., 2019; García-Gómez et al., 2018, 2020a, b), the expansion of *R. okamurae* in the Atlantic and Mediterranean coasts of Spain is characterized as invasive, causing numerous problematic situations in native biocommunities (García-Gómez et al., 2018, 2020b; MTERD, 2020). The secondary spread of *R. okamurae* is one of the most significant marine threats from invasive species facing the European territory. Taking into consideration: a. the EU non–native organism risk assessment scheme implemented by the Spanish Ministry for Ecological Transition and Demographic Challenge (MTERD) (2020), b. the relevant published data on the invasive characteristics of *R. okamurae* in the area of Spain and Northern Africa, as well as the existing models as for the suitable areas for the establishment of the species populations (Altamirano *et al.* 2016, 2019; Ocaña et al., 2016; García-Gómez et al., 2018, 2020b), and c. the relatively easy dispersion of the organism in the marine environment combined with the difficulties of preventing it, it is obvious that *R. okamurae* could proliferate within the ecological environment of the Atlantic coast of Andalusia, the Bay of Biscay and Portugal, the Mediterranean area and the Black Sea (Altamirano et al. 2019; MTERD, 2020). All the available data strongly suggest that the high propagation capacity of *R. okamurae*, in combination with its extraordinary competitive and colonization capacity, enhances its possible establishment once entered in an area that presents favorable biotic and abiotic factors (Altamirano et al., 2019; García-Gómez et al., 2020b).

There have been successful, if expensive, campaigns to completely eradicate alien invasive seaweeds (though not *R. okamurae)*, however, in every case this has relied on very early detection, and there are limited options to control invasive seaweeds once the opportunity for eradication has passed (Anderson, 2007). For instance, no effective eradication or even containment measures exist for other macroalgal species established in the Mediterranean Sea: *Lophocladia lallemandii, Stypopodium schimperi, Womersleyella setacea*, etc. Taking into consideration that *R. okamurae* has demonstrated an enormous spreading capacity, far beyond of that of any other invasive macroalgae along the Spanish coasts up to now (MTERD, 2020), it is clear that eradication or control campaigns of established populations are likely to fail.

The prevention of additional un-intentional introductions of *R. okamurae* into the EU territory, the prevention of secondary spread of the species to other areas in the European Union, and the achievement of early detection of the algae populations are therefore of great importance and considered as the most effective of measures that can be implemented for dealing with this species. Moreover, actions towards the rapid eradication and management of established populations should be further researched and considered, despite their current low effectiveness (due to the species special characteristics of reproduction and expansion).

Prevent intentional introduction into the territory: There are no intentional pathways of introduction for *R. okamurae*. All introductions are considered unintentional.

Prevent un-intentional introduction into the territory: Additional un-intentional introductions of *R. okamurae* into the EU could be prevented through effective ballast water management, biofouling management and measures for the prevention of introduction (and secondary spread) of *R. okamurae* through shellfish imports and transfers.

Prevent secondary spread: Apart from the natural dispersal of *R. okamurae* via marine currents (unfortunately not possible to prevent), and the secondary spread through ballast water, hull biofouling and spread through marine aquaculture (addressed in the unintentional introductions section), the algae's dispersion to new nearby areas is taking place via numerous human activities including: fishing (both commercial and recreational), marine tourism activities (recreational boats, SCUBA diving), marine litter, etc. From these activities, fishing could be the most important in relation to the species secondary spread, as gear accidentally collects fixed and suspended algae material and then transfer it to new areas, where *R. okamurae* establishes easily. The most effective way to address these pathways of secondary spread is through public awareness-raising activities focusing in fishermen, divers, tourists, etc.

Achieve early detection: *R. okamurae* is characterized as a very competitive species with a high colonization ability, and therefore the achievement of early detection is critical. Early detection is achieved mainly via the implementation of scientific monitoring programs focusing on susceptible areas (harbours, ports, marinas, etc.), in combination with citizen science, where stakeholders, volunteers and relevant professional target groups participate actively in the species' early detections (e.g. SCUBA-divers – appropriate briefing before diving for the identification of possible alien species, fishermen – training for the early detection of *R. okamurae* thalli found on gears, port institutions etc.).

Rapid eradication: There are no rapid eradication measures known to have been applied to *R. okamurae.* The species thalli are characterized by an extreme propagation capacity through vegetative and asexual structures that can easily escape from management strategies such as eradication campaigns. In addition, thalli can grow directly over the hard substrata but also on other seaweeds as epiphyte or even on benthic fauna. Therefore, any rapid eradication campaign would highly likely be ineffective. In addition, there are no known predatory organisms, parasites or pathogens that may affect it in the invaded area (MTERD, 2020).

Diverse techniques have been applied to eradicate or control other marine macroalgae, including chemical treatments (i.e., bleach, salt), thermal treatments (i.e., cold shock, heating), osmotic shock (i.e., freshwater and salinity treatments) (Anderson, 2007), mechanical or manual removal by hand and/or aided by vacuum or dredge pumps (Conklin, 2007; Marks et al., 2017), light attenuation, containment barriers, and water-removal with *in situ* desiccation (Anderson, 2007). However, none of these currently available techniques would be effective against *R. okamurae,* due to the species biology and invasive potential. Manual removal is the only measure that is realistically available to be applied to the species following early detection, though even this measure is likely to be ineffective. Manual removal of thalli is therefore the only measure discussed below, maintaining all reservations.

Management (e.g. control, eradication, containment): As with rapid eradication there are no known management measures for *R. okamurae*. In fact, there are no effective measures for the management (control, eradication or even containment) of invasive macroalgae species in the Mediterranean Sea. Few experimental management studies or programs took place for *Caulerpa racemosa, Caulerpa taxifolia* and a few other taxa, with no promising results. Those programs included manual removal, physical control with dry ice, hot water jets, chemicals and underwater welding devices to boil the plants in situ, etc. (Otero et al., 2013). The situation is even more complicated regarding *R. okamurae*'s invasive populations due to its high propagation capacity, due to vegetative and asexual structures that can easily escape from management strategies and due to its ability to grow in various substrates (both on reefs, as epiphyte on other macroalgae, on benthic fauna taxa, etc). Therefore, even if the previously mentioned management measures were effective against the other macroalgae species, it is unlikely they would be successful for controlling invasive established populations of *R. okamurae* given the characteristics of the species. As with rapid eradication, manual removal is discussed as the only measure realistically available to be applied to the species, maintaining all reservations.

Prevention of <u>intentional</u> introductions:– measures for preventing the species being introduced intentionally into the territory of a Member State. **This table is for a single measure, and the table is repeated for each separate prevention measure identified.**	
Measure name	There are no intentional pathways of introduction for *R. okamurae*. All introductions are considered un-intentional.
Measure description Provide a description of the measure and its objective, noting the pathway of introduction being addressed If relevant, include a summary of the methodology to apply the measure, with references to sources of information where detail can be found.	
Scale of application At what geographic scale is the measure applied? What is the largest scale at which it has been successfully used? Please provide examples reporting areas (km^2 or ha) if possible.	
Effectiveness of the measure Is it effective in relation to its objective? Based on cases where the measure has been applied (ideally correctly and comprehensively), please select one of the categories of effectiveness (with an 'X'), and provide a rationale, with supporting evidence and examples of effectiveness, if possible. Please identify factors that are critical in determining its effectiveness.	***Effectiveness of measures*** · *Effective* ☐ · *Neutral* ☐ · *Ineffective* ☐ · *Unknown or not yet applied* ☐ *Rationale*:

<table>
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e.g. Number of times, and/or period of time over which measure needs to be applied to have results achieve its objective
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e.g. cost, staff, equipment etc.
Please note the resources (and their costs if available) that are required to implement the measure to meet its objective.</td><td></td></tr>
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- implementation cost for Member States
- the cost of inaction
- the cost-effectiveness
- the socio-economic aspects

Include quantitative &/or qualitative data, and case studies (incl. from countries outside the EU).</td><td></td></tr>
<tr><td>Side effects (incl. potential) – both positive and negative
i.e. positive or negative side effects of the implementation of the measure (not the IAS itself) on public health, environment including non-targeted species, etc. For example, native species non-target impacts from trapping.</td><td>
<table>
<tr><td><i>Environmental effects</i></td><td><i>Positive</i></td><td></td><td><i>Mixed</i></td><td></td><td><i>Negative</i></td><td></td><td><i>None</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
<tr><td><i>Social effects</i></td><td><i>Positive</i></td><td></td><td><i>Mixed</i></td><td></td><td><i>Negative</i></td><td></td><td><i>None</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
<tr><td><i>Economic effects</i></td><td><i>Positive</i></td><td></td><td><i>Mixed</i></td><td></td><td><i>Negative</i></td><td></td><td><i>None</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
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<i>Rationale</i>:</td></tr>
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<td>For each of the side effect types please select one of the categories (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.

NOTE – this does not refer to direct intended effects of the measure (e.g. a reduction of the IAS population, or an increase in native species)</td>
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<td>Acceptability to stakeholders
e.g. impacted economic activities, animal welfare considerations, public perception, etc.

Please select one of the categories of acceptability (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.</td>
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<tr><td><i>Acceptability to stakeholders</i></td><td><i>Acceptable</i></td><td></td><td><i>Mixed</i></td><td></td><td><i>Unacceptable</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
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<i>Rationale</i>:
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<td>Level of confidence on the information provided [2]

Please select one of the confidence categories along with a statement to support the category chosen. See <i>Notes</i> section at the bottom of this document.
NOTE – this is not related to the effectiveness of the measure</td>
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<tr><td><i>Inconclusive</i></td><td></td><td><i>Unresolved</i></td><td></td><td><i>Established but incomplete</i></td><td></td><td><i>Well established</i></td><td></td></tr>
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<i>Rationale</i>:
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<table>
<tr><td colspan="2">Prevention of un-intentional introductions – measures for preventing the species being introduced un-intentionally into the territory of a Member State (cf. Article 13 of the IAS Regulation). This table is repeated for each of the prevention measures identified.</td></tr>
<tr><td>Measure name</td><td>Ballast Water Management</td></tr>
<tr><td>Measure description
Provide a description of the measure and its objective, noting the pathway of introduction being addressed
If relevant, include a summary of the methodology to apply the measure, with references to sources of information where detail can be found.</td><td>Macroalgal introductions through ballast water have been considered relatively unimportant, since macroalgae are rarely recorded in ballast water samples (Boudouresque & Verlaque, 2002). In addition, an extensive international study of the species composition in ballast water tanks found only fragments of four macroalgal taxa, within a total of 990 taxa (bacteria, fungi, protozoans, algae, invertebrates and fishes) and thus it is considered that ballast water is a less important pathway for macroalgal introductions (Gollasch et al., 2002). However, Flagella et al. (2007) mention that this is due to the difficulties with the identification of algal germlings and fragments. Their study showed that many macroalgae can in fact survive and be successfully transported in microscopic forms through ballast water, but this has been scarcely reported, probably because of the need to culture samples to identify the macroalgae present.

<i>R. okamurae</i> can be introduced from its native communities in the western Pacific to new areas of the European territory (other than the ones already established in Spain), via maritime transportation and in particular via ballast water. Ballast water can also lead to the species secondary spread from the established populations in the European territory, to other harbours in the Mediterranean, Atlantic or Black Sea. Ballast Water Management as a measure for preventing un-intentional introduction and secondary spread of non-native taxa is not species-specific and thus not referring to <i>R. okamurae</i> specifically. The information given below concerns all the aquatic organisms introduced into areas via ballast water.

The integrated approach towards the prevention of un-intentional introduction of non-native taxa from one region to another, came via the Ballast Water Management Convention (BWMC) which was adopted in 2004 by the International Maritime Organization (IMO) and entered into force in 2017. BWMC aims to prevent the spread of harmful aquatic organisms from one region to another, by establishing standards and procedures for the management and control of ships' ballast water and sediments. Under the Convention, all ships in international traffic[1] are required to manage their ballast water and sediments to a certain standard, based on a ship-specific ballast water management plan. In</td></tr>
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[1] Applies to ships registered under a flag State (country) that has ratified the BWMC. Ships registered under a flag State that hasn't ratified the BWMC may not be issued with the relevant certificates. However, port States which are Parties will expect non-Party ships to comply with the requirements of the Convention, so as to ensure no favourable treatment is given to them. Note that ships travelling between EU Member States are treated as 'international traffic'. Only ships that operate in the local (domestic) waters of a single authority (party) can be excepted from the Convention's regulations.

addition, all ships will have to carry a ballast water record book and an international ballast water management certificate. The ballast water management standards will be implemented during an appropriate time period. Until the implementation of all standards mentioned in the Convention, ships should exchange ballast water mid-ocean. However, eventually most ships will need to install an on-board ballast water treatment system[2].

In detail, the BWMC introduces two different management standards:

- Ballast Water Exchange Standard (D1 standard for an interim period until D2 is fully implemented), requiring ships to exchange a minimum of 95% ballast water volume, whenever possible at least 200 nautical miles (nm) from the nearest land and in water depths of at least 200 metres (if not possible, the BWE shall be conducted at least 50 nm from the nearest land and in waters at least 200 metres in depth;
- Ballast Water Performance Standard (D2 standard according to the ship specific application schedule), which requires that ballast water discharged has a number of viable organisms, such as *R. okamurae*, below specified limits. Specifically, ships conducting ballast water management shall discharge less than 10 viable organisms per cubic metre greater than or equal to 50 micrometres in minimum dimension and less than 10 viable organisms per millilitre less than 50 micrometres in minimum dimension and greater than or equal to 10 micrometres in minimum dimension. D2 generally requires the installation of a certified ballast water treatment device, through mechanical (filtration, separation), physical (heat treatment, ozone, UV light, deoxygenation treatment) and chemical methods (biocides), which enables sterilisation to avoid transfer of ballast water mediated species.

Since 2017, the BWMC applies to signatory countries (currently 85 representing 91.11% of world total tonnage), and ballast waters should be exchanged in open seas (BWE) or treated (BWT) with mechanical, physical, chemical or biological processes. Details and the list of approved and certified ballast water management systems can be found online[3] . In addition, the European Marine Safety Agency has produced a number of guidance and best practices documents to support EU Member States to implement the convention[4]. Full implementation of D2 is expected by September 2024, when the risk of further introductions and spread of this (and other invasive) species through ballast water is expected to be greatly reduced.

Efficiencies of various technologies utilised for ballast water treatment are reviewed by many scientists (Tsolaki & Diamadopoulos, 2010; Vorkapić et al., 2018; Hayes et al., 2019), and can vary with treatment method, but the application of many combined methods appears to be most effective.

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[2] http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Control-and-Management-of-Ships%27-Ballast-Water-and-Sediments-(BWM).aspx

[3] IMO http://www.imo.org

[4] EMSA Ballast water http://www.emsa.europa.eu/implementation-tasks/environment/ballast-water.html

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<td>Scale of application
At what geographic scale is the measure applied? What is the largest scale at which it has been successfully used?
Please provide examples reporting areas (km^2 or ha) if possible.</td>
<td>The measure is applied globally. Moreover, regarding the secondary spread of <i>R. okamurae</i> from the established areas in Spain to other places in the Mediterranean, Black Sea or even Atlantic coasts, measures to implement BWMC should be applied at a national level, and ultimately at EU level. Unfortunately, there are some limitations in BWMC’s application: Ballast Water Exchange shall take place at least 50 nautical miles from the nearest land and deeper than 200 metres, conditions which are not always met for European shipping, or domestic shipping of many countries. In such cases, Ballast Water Treatment systems are at least necessary.</td>
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<tr>
<td>Effectiveness of the measure
Is it effective in relation to its objective?

Based on cases where the measure has been applied (ideally correctly and comprehensively), please select one of the categories of effectiveness (with an ‘X’), and provide a rationale, with supporting evidence and examples of effectiveness, if possible.

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<p>BWM effectiveness is strongly related to the implementation of the D2 standard, which is expected to be fully operative in 2024.</p>
<p>Undoubtedly, D1 standard (BWE) can reduce the concentration of alien organisms in ballast discharged in coastal waters but its effectiveness is not 100%, depending on several parameters such as life stages of transported species, shipping routes, distances and water depth, especially in EU and domestic transportation (Ruiz & Reid, 2007). Shipboard studies of ballast water exchange show that the efficiency of volumetric exchange can vary from 66% to more than 99%, depending on ship type and method of exchange (Ruiz & Reid, 2007).</p>
<p>Regarding Ballast Water Treatment (BWT) (D2 standard), the various BWT systems have different effectiveness. Combination of methods increases effectiveness. The exact result of BWE and BWT is not yet well known regarding macroalgae transportation and introduction in new areas. Microscopic stages of macroalgae can withstand long periods of darkness and subsequently develop when conditions improve (Leukart & Lüning, 1994; Worm et al., 2001; Santelices et al., 2002). The effectiveness of the BWMC, and the different combinations of BWT, in relation to macroalgae needs to be assessed (Rosas-Guerrero et al., 2018). In relation to <i>R. okamurae,</i> it is important to note its high capacity to produce vegetative propagules and asexual monospores, and that portions of adult thallus of the species have survival rates between 80-100% after being grown in dark conditions for three weeks and that these thalli even increased their biomass during this time (MTERD, 2020). Despite these unknowns, BWT (D2 standard) applied under the BWMC is assessed as ‘effective’ to prevent the species intentional introductions via ballast water. However, this assumes that the correct BWT combinations are identified and the measures are applied fully.</p>
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e.g. Number of times, and/or period of time over which measure needs to be applied to have results achieve its objective
(please indicate the units)</td>
<td>BWM measure should be applied indefinitely.</td>
</tr>
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Resources required[1] e.g. cost, staff, equipment etc. Please note the resources (and their costs if available) that are required to implement the measure to meet its objective.	BWM and in particular BWT is costly. However, it is important to stress that this measure would address all marine non-native taxa, and not just macroalgae, or *R. okamurae* specifically. Equally, the associated costs of implementation is not specific to *R. okamurae.* Costs vary according to the different adopted systems, and include different ballast water treatment design, supply and installation of the equipment, training of the staff, operating and maintenance costs and consumed fuel oil. The cost of installing Ballast Water Management Systems will be borne by the shipping companies. In addition to shipping costs, port costs must also be mentioned. Ports and terminals need to have adequate reception facilities (ballast water reception facilities and sediment reception facilities), especially until the full implementation of D2 standards (Satir & Dogan-Saglamtimur, 2014). Hayes et al. (2019) mention that ballast water exchange involves two types of costs: (i) the cost of operating the pumps, including fuel, energy and maintenance; and, (ii) the opportunity costs associated with slowing ship speed or diversion to areas that meet the D1 Standard of the Ballast Water Management Convention. The pumping costs depend on the type and size of the vessel, the ballast tank configuration and the method of exchange. King et al. (2012) reviewed information provided by vendors for a range of system types and ship types. Purchase prices of the units ranged between USD $640,000 and $947,000 (ca. €591,000 – 875,000). Estimated costs of installation varied from USD $22,000 to $70,000 (ca. €20,000 – 65,000) for new builds, depending on vessel type, and from USD $48,000 to $173,000 (ca. €44,000 – 160,000) for retrofits. For most systems, the annual operating costs for maintenance were typically between USD $9,000 (ca. €8,300) (Deoxygenation/Cavitation) and $17,000 (ca. €15,700) (Electrolysis/Electrochlorination), depending on vessel type and size, but technologies that used active substances had a much wider range (USD $31,000–$296,000, ca. €28,600 – 273,000 (Filtration/Chemical)) because the use of chemicals varied widely between different ship types and sizes. Regarding the operational costs, Vorkapić et al. (2018) estimated the average annual cost (USD/year) of 3 types of BWM: Sequential flow (in accordance to D1) = $4,368 (c. €3,686) UV radiation (in accordance to D2) = $2,885 (c. €2,435) Electrochlorination (in accordance to D2) = $623 (c. €525)
Additional cost information[1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States	Possible costs of implementing the BWM Convention are grouped in three main categories, according to the time of their occurrence and their distribution: (1) preparatory phase costs (capacity building, coordination and communication, legislative, policy and institutional reform costs; Port Biological Baseline Surveys (PBBS) and Risk assessments), (2) compliance-related costs (costs incurred to ensure adherence to the BWM Convention and encompass processes such as certification, monitoring and inspection) and (3) other indirect costs from issues not covered by the Convention (Interwies & Khuchua, 2017). Those costs can be grouped into one-time costs (e.g.

<table>
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<td>- the cost of inaction
- the cost-effectiveness
- the socio-economic aspects

Include quantitative &/or qualitative data, and case studies (incl. from countries outside the EU).</td>
<td>development of compliance measures) and ongoing costs (e.g. regular surveys of BWM systems on board of ships, inspection of ships etc.) and vary by State and number of ports (Interwies & Khuchua, 2017). Examples of estimated costs for specific actions related to the implementation of BWMC are given in the Economic Assessment of Ballast Water Management Report (Interwies & Khuchua, 2017). As an example we mention that, indicative costs for conducting Port Biological Baseline Surveys in one of Ghana’s main ports are ≈ USD $100K (ca. €92K) (Interwies & Khuchua, 2017).

Another survey from Australia (Hayes et al., 2019), mentions that the sample sizes and hence costs of sampling specific ports to a standard with high statistical power proved to be too high (reportedly between AUD $175K - $355K - ca. €104K – 210K), to repeat on a regular basis. The previously mentioned costs can be covered either by public bodies or private entities, according to national legislation.

In some cases, particularly for short shipping routes within and between EU Seas, regulations A4 and A3 of the BMWC enable the granting of exemptions from the requirement for BWM (provisions made in the BWMC for regular routes and other cases – Olenin et al., 2016). Such requests must fulfil certain criteria and require a risk assessment, according to BWMC guidelines (Stuer-Lauridsen et al., 2018).

The cost of inaction: Several countries have concluded that the economic value of the resources at risk, even if these resources are only moderately impacted, far exceeds the costs of implementation of the BWMC (Interwies & Khuchua, 2017). Regarding <i>R. okamurae</i>, and its invasive populations in Spain, the economic impact is associated to fishing activities (economic losses in captures by fisheries), beach management in Southern Spain (removal of drifted material on the beaches) and the tourism sector related to them. It has been estimated that economic impacts from the species in Spain reached €1.3M in nine months (Altamirano et al., 2019 in MTERD, 2020).

Cost-effectiveness: Considering that prevention is always preferable and more cost-effective than post-border management, especially for long-term measures, ballast water management that deals with all ballast related invasive species simultaneously, is one of the most cost-effective measures available.

Socio-economic aspects: Potential risks from the usage of chemical, physical and biological processes under the frame of BWT, should be studied in the future.</td>
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i.e. positive or negative side effects of the implementation of the measure (not the IAS itself) on public health, environment including non-targeted species, etc. For example,</td>
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<tr><td><i>Economic effects</i></td><td><i>Positive</i></td><td></td><td><i>Mixed</i></td><td><i>X</i></td><td><i>Negative</i></td><td></td><td><i>None</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
</table>

<i>Rationale</i>:

BWTs environmental effects are mainly positive, due to the prevention of un-intentional introduction or spread of non-native species across different taxa. However, we must mention that according to specific publications, some</td>
</tr>
</table>

<table>
<tr>
<td>native species non-target impacts from trapping.

For each of the side effect types please select one of the categories (with an 'X'), and provide a rationale, with supporting evidence and examples if possible.

NOTE – this does not refer to direct intended effects of the measure (e.g. a reduction of the IAS population, or an increase in native species)</td>
<td>BWTs can cause environmental pollution, i.e. introduction of contaminants into the natural environment that could cause adverse change (Werschkun et al., 2014), especially if they use active substances. Different BWT systems and combinations of them are being certified and approved after a testing process. GESAMP – "Ballast Water Working Group on Active Substances" (GESAMP – BWWG) undertakes technical evaluations in accordance with the Procedure for approval of ballast water management systems that make use of Active Substances (G9), based on a specified methodology [5]. GESAMP-BWWG, taking into account lessons learned and experience gained, updates the methodology, as it is recognized as a living document and Member Governments are invited to bring the revised Methodology to the attention of all parties concerned and, in particular, manufacturers of ballast water management systems that make use of active substances. To date, more than 60 BWMS that make use of active substances and/or preparations have received Basic Approval from IMO, representing various technologies such as electrolysis, chemical addition (biocides) and ozonation. In addition, more than 40 BWMS have also received Final Approval. Through the work of the GESAMP-BWWG, a number of IMO-approved BWMS are available on the market to allow shipowners to comply with the requirements of the BWM Convention[6]. Another initiative towards the testing of BWMS is the Global TestNet, which was developed to address the need for standardization and comparability in the testing of ballast water management systems (BWMS) and aims to the promotion of comparable and accurate test results on the performance evaluation of technologies and methodologies, through an open exchange of information, transparency in methodologies and advancing the science of testing.

Regarding the social effects, they are positive for fishermen and other stakeholders involved. Management of <i>R. okamurae</i> excess biomass constitutes a big problem for local administrations, and has a big public impact, including on tourism. In addition, BWM can also have positive effects on public health, through the prevention of spread of pathogenic micro-organisms and harmful algal blooms.

Finally, as reported above, BWM is costly, so it can have negative economic effects on shipping companies. The costs differ according to the BWT systems used and can be reduced over the ship's lifetime, but the initial investment is seen as being costly. On the other hand, the cost to broader society of inaction as analysed previously is even higher.</td>
</tr>
<tr>
<td>Acceptability to stakeholders
e.g. impacted economic activities, animal welfare considerations, public perception, etc.</td>
<td>
<table>
<tr><td><i>Acceptability to stakeholders</i></td><td><i>Acceptable</i></td><td></td><td><i>Mixed</i></td><td><i>X</i></td><td><i>Unacceptable</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
</table>
<i>Rationale:</i>
</td>
</tr>
</table>

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[5] http://www.imo.org/en/OurWork/Environment/BallastWaterManagement/Documents/BWM.2-Circ.13-Rev-4.pdf

[6] http://www.gesamp.org/site/assets/files/2041/rs101e.pdf

Please select one of the categories of acceptability (with an 'X'), and provide a rationale, with supporting evidence and examples if possible.	There could be some resistance from ship owners or companies, due to the cost and type of systems to be applied on the ship (e.g. chemical methods, even if more effective, could elicit some health issue concern for people working on the ship). In addition, the use of chemicals to treat ballast water may not be well-accepted by the public.
Level of confidence on the information provided [2] Please select one of the confidence categories along with a statement to support the category chosen. See *Notes* section at the bottom of this document. **NOTE – this is not related to the effectiveness of the measure**	*Inconclusive* ☐ | *Unresolved* ☐ | *Established but incomplete* *X* | *Well established* ☐ *Rationale*: Different studies and recent reviews agree on the importance of BWM. There are no specific studies on effectiveness of prevention of unintentional introductions for *R. okamurae* by BWM. In addition, many surveys nowadays deal with the effectiveness of ballast water exchange and the efficiency of various physical and chemical methods, regarding the appropriate implementation of the BWMC. However, as the implementation of D2 standard is to be fully operative by 2024, many surveys are going to be published during the next period.

Prevention of <u>un-intentional</u> introductions – measures for preventing the species being introduced un-intentionally into the territory of a Member State (cf. Article 13 of the IAS Regulation). **This table is repeated for each of the prevention measures identified.**	
Measure name	**Biofouling management**
Measure description Provide a description of the measure and its objective, noting the pathway of introduction being addressed If relevant, include a summary of the methodology to apply the measure, with references to sources of information where detail can be found.	Hewitt et al. (2004; in Johnson and Chapman, 2007) suggest there is good evidence that in some areas establishment of alien marine species originating from hull fouling exceeds that attributable to transport in ballast water. Ribera Siguan (2003) also indicate that fouling of ships' hulls is considered to be the most important pathway for the un-intentional introduction of macroalgae. All macroalgae have the potential to colonise ships' hulls and other maritime structures, especially species that occur either within or near port environments. The majority of macroalgal species attached to ship hulls succeed in their establishment in new areas where transferred via maritime transportation either by macroscopic thalli, or by microscopic stages of the life cycle. This could explain the introduction of *R. okamurae* in the Strait of Gibraltar from its native areas in the Pacific, and could lead to the secondary spread of the species in other Mediterranean or Atlantic

	areas of the European Territory, considering the intense maritime traffic in this region. In addition, it is known that this species can adhere easily to surfaces of very diverse nature and composition, such as glass, iron, rubber or ceramic (García-Gómez et al., 2018). Studies have shown that the biofouling process begins within the first few hours of a ship's immersion in water and all ships have some degree of biofouling, even those which may have been recently cleaned or had a new application of an anti-fouling coating system (Frey et al., 2014; Bohn et al., 2016; Galil et al., 2019). The potential for invasive aquatic species transferred through biofouling to cause harm has been recognized by the International Maritime Organization (IMO), the Convention on Biological Diversity (CBD), several UNEP Regional Seas Conventions (e.g., Barcelona Convention), etc. The biofouling that may be found on a ship is influenced by a range of factors, such as design and construction, specific operating profile such as operating speeds, the location when not in use (e.g., open anchorage or estuarine port), places visited and trading routes and maintenance history of hull cleaning practices. The role of recreational vessels as a pathway related to biofouling, should be highlighted. This is even more important for the Mediterranean Sea, which constitutes both a hotspot for recreational boating and for non-indigenous species (NIS). Ulman et al. (2019) surveyed over 600 boat owners and sampled the same boat hulls for NIS in 25 marinas across the Mediterranean and found recreational vessels to travel considerably, averaging 67 travel days and 7.5 visited marinas per annum. This results in a high potential for spreading NIS, especially as 71% of sampled vessels host at least one (and up to 11) NIS. As a result of this survey, the authors demonstrate that recreational boating has a very high capacity for the spread of non-indigenous species (NIS) in the Mediterranean, due to both high NIS richness on boats and extensive travel (Ulman et al., 2019). In July 2011, the IMO Guidelines for the control and management of ships' biofouling to minimise the transfer of invasive aquatic species (Biofouling Guidelines[7]) were adopted by the Marine Environment Protection Committee (MEPC) (resolution MEPC.207(62))[8]. The aim of the action was the contribution towards the un-intentional introduction or secondary spread of invasive non-native species, via an integrated approach to the management of biofouling. It represents the first international action addressing ships' biofouling with the goal to reduce the accumulation of micro- and macro-organisms on the outside of ships by choosing the appropriate coating, by conducting in-water inspections and cleaning, as well as proper removal during dry-docking. Ships are recommended to follow a biofouling management plan and to keep a record book. MEPC.207(62) was complemented by resolution MEPC.1/Circ. 792[9] on "Guidance for Minimizing the Transfer of Invasive Aquatic Species as Biofouling (Hull fouling) for Recreational Craft" for recreational vessels < 24m (IMO, 2012). Both guidance documents include recommendations for the application of anti-fouling systems, with attention to niche areas, the removal of fouling at dry-docking and

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[7] IMO Biofouling guidelines http://www.imo.org/en/OurWork/Environment/Biofouling

[8] http://www.imo.org/en/KnowledgeCentre/IndexofIMOResolutions/Marine-Environment-Protection-Committee-(MEPC)/Documents/MEPC.207(62).pdf

[9] http://www.imo.org/en/OurWork/Environment/Biofouling/Documents/MEPC.1-Circ.792.pdf

<table>
<tr><td></td><td>the safe disposal of the biofouling debris, etc. Lastly, the GEF-UNDP-IMO GloFouling Project launched in 2018 aims to build capacity in developing countries for implementing the IMO Biofouling Guidelines[10].
The guidelines apply to all ships[11] and, if implemented correctly, could prevent the introduction and spread of *R. okamurae.* The main practices for the removal of biofouling from ships' hulls and niche areas are:
1. Dry docking. During this process all fouling is removed and thereafter anti-fouling paint is applied. The frequency of this procedure is not fixed and can vary a lot (from 6 months to 5 years), a result of many parameters. It has been noticed that in most cases anti-fouling coatings seem to be efficient for almost a year and thereafter, heavy fouling can start occurring (Sylvester et al., 2011; Frey et al., 2014). This situation can be even worse if the ship remains for a long period in a port (Galil et al., 2019).
2. In-water cleaning. It is a procedure implemented in combination with dry docking. It is based on technologies that capture debris and render it non-viable.
3. The treatment of niche areas requires use of either ultrasonic antifouling systems, heat-based or different methods of cleaning (Zabin et al., 2016). For sea-chests in particular, a variety of treatment systems are available that involve the release of toxic chemicals; while such treatments have been shown to reduce the number of sessile and sedentary fouling organisms, they are less effective against mobile organisms (Coutts & Dodgshun, 2007).</td></tr>
<tr><td>**Scale of application**
At what geographic scale is the measure applied? What is the largest scale at which it has been successfully used?
Please provide examples reporting areas (km^2 or ha) if possible.</td><td>The scale of application of this measure should be at a global, regional and national level and, ultimately, at an EU level and it should be applied to all vessels (commercial and recreational), so as to prevent the un-intentional introduction of *R. okamurae* to new areas, as well as the secondary spread of already established populations into other places of the European territory.</td></tr>
<tr><td>**Effectiveness of the measure**
Is it effective in relation to its objective?

Based on cases where the measure has been applied (ideally correctly and comprehensively), please select one of the categories of effectiveness</td><td><table><tr><td>***Effectiveness of measures***</td><td>*Effective*</td><td>*X*</td><td>*Neutral*</td><td></td><td>*Ineffective*</td><td></td><td>*Unknown or not yet applied*</td><td></td></tr></table>
Rationale:
Due to the fact that IMO Biofouling Guidelines are voluntary, the level of implementation by countries is low. Even more, awareness of their existence, as a non-mandatory instrument, is limited. Thus, it is difficult to find concrete evidence on the effectiveness of IMO Biofouling Guidelines to prevent marine alien species introductions and spread.</td></tr>
</table>

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[10] GloFouling Project https://www.glofouling.imo.org/

[11] The definition of ship by the IMO Biofouling Guidelines includes not only ships in the traditional sense, but also any floating platforms and structures – this means also offshore oil and gas, exploration, seabed mining and dredging, large aquaculture structures, etc.

(with an 'X'), and provide a rationale, with supporting evidence and examples of effectiveness, if possible. Please identify factors that are critical in determining its effectiveness. Please note if effectiveness is based on research only (e.g. field trials).	On the other hand, there is plenty of evidence that effective biofouling management does reduce the level of risk of introductions (Amara et al., 2018; Georgiades et al., 2020). Antifouling systems are diverse, and their effectiveness depends on the system applied and the type of vessel. If an appropriate anti-fouling system is not applied, biofouling accumulation increases. Some factors to consider when choosing an anti-fouling system include the following: 1. planned periods between dry-docking; 2. ship speed; 3. ship type and construction, etc. In addition, the selection of the appropriate materials is of a great importance. Non-toxic paints may have a shorter lifespan than organotin paints and, consequently may need to be applied more often and may be less efficient in preventing biofouling. Mechanical grooming is helpful in reducing fouling on submerged surfaces coated with fouling release coatings (Hearin et al., 2016). Low saline treatments can be highly effective at reducing biofouling (even by 100%, although it depends on the situation) and can be used in conjunction with antifouling coating systems (De Castro et al., 2018). However, once the ship is stationary for any length of time, the effectiveness of anti-fouling coatings diminishes, with rapid colonisation of assemblages of aquatic organisms becoming attached to the hull. In these cases, the use of alternative systems, such as those based on ultrasonics, should be considered. The rating of this measure as effective refers to the full and proper implementation of the IMO Biofouling Guidelines. Theoretically, removing biofouling material and ensuring fouling free vessel surfaces reduces the associated risks of *R. okamurae* translocations. Nevertheless, there does not appear to be any comprehensive analysis of the compliance levels or efficacy of the Marine Environment Protection Committee (MEPC) 2011 biofouling guidelines in reducing alien species introductions/spread (Hayes et al., 2019). Antifouling is applied on a voluntary basis. Dry docking at appropriate intervals can be effective but is costly, while emerging in-water cleaning technologies with capture and treatment of the fouling debris that can provide more cost-effective alternatives should be carefully applied in order to avoid the risk of releasing propagules, biocides and other chemicals in the environment.
Effort required e.g. Number of times, and/or period of time over which measure needs to be applied to have results achieve its objective **(please indicate the units)**	Biofouling management should be applied indefinitely.
Resources required [1] e.g. cost, staff, equipment etc. Please note the resources (and their costs if available) that are required to	Costs vary according to the different systems adopted and the type of treated ships, as well as to different operating and maintenance costs. For example, even if high pressure washing in dry-dock is very effective for removing fouling, it is not practical for a ship to be dry-docked frequently, due to costs, and therefore ship owners will likely avoid it.

implement the measure to meet its objective.	However, it is important to underline that the primary cost associated with fouling is the increased fuel consumption attributable to increased frictional drag, while the costs related to hull cleaning and painting are much lower than those (Schultz et al., 2011). Economic effects of biofouling go far beyond the cost of control and eradication efforts. In details, Schultz et al. (2011) analysed the hull fouling economic impacts for a mid-sized naval surface ship (Arleigh Burke-class destroyer DDG-51). For this purpose, a range of costs associated with hull fouling was examined, including expenditures for fuel, hull coatings, hull coating application and removal, and hull cleaning. The mentioned survey, showed that even modest improvements in the fouling condition of a hull, when considered across just the DDG-51 class, could save enough money to cover the costs of development, acquisition, and implementation of even relatively expensive technical or management solutions. A decrease in fouling from FR-30 to FR-20 results in an annual cost savings to the Navy of USD $340K (c. €286K) per DDG-51 (Schultz et al., 2011). The cost of implementation of this measure will be borne by the shipping companies or private vessel owners. Costs associated with hull fouling management measures are again not specific to *R. okamurae* but refer to all marine non-native species. The cost of removing the vessel to dry dock and applying anti-fouling coatings ranges from around USD $100,000 (c. €84,000) per vessel weighing up to 5,000 tonnes to over USD $464,000 (c. €392,000) per vessel (for vessels >200 meters in length) and may take 5–7 days with average opportunity costs per vessel per day[12] of USD $4,400 (c. €3,700) for bulk vessels, USD $9,600 (c. €8,100) for general cargo vessels and USD $11,200 (c. €9,400) for container vessels (Hayes et al., 2019). Emerging In-Water Cleaning systems (e.g. vacuum and filtration systems, coupled with brushes, blades or water jets) are currently available in only a few locations worldwide and are more costly than traditional methods (diver-based and ROV-based cleaning) (Zabin et al., 2016; Zabin et al., 2018). The cost to marina owners of establishing a biosecure treatment facility for the disposal of hull fouling material has been estimated to be at least £45-50K (ca. €50-56K) in the UK (DEFRA, 2012). On the other hand, this also represents a potential source of income for marina owners via either charging fees directly for delivery of services or authorising companies to operate.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	Implementation cost for Member States: The implementation cost for Member States depends on the number of ships to be treated and the adopted systems. The cost of inaction: *R. okamurae* invasive populations' in Spain affect the economy of the relevant areas. The economic impact is associated to fishing activities (economic losses in captures by fisheries) and beach management in Southern Spain (removal of drifted material on the beaches). It has been estimated that economic impacts from the species in Spain reached €1.3M in nine months (Altamirano et al., 2019 in MTERD, 2020). It is obvious that inaction

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[12] Opportunity costs refer to the time lost during the implementation of antifouling procedures

<table>
<tr>
<td>Include quantitative &/or qualitative data, and case studies (incl. from countries outside the EU).</td>
<td>regarding <i>R. okamurae</i> and any other invasive species introduced or spread via biofouling is much more consuming than the anti-fouling systems aiming at the prevention of such situations.

Cost-effectiveness: Considering that prevention is always preferable and more cost-effective than post-border management, especially for long-term measures, antifouling systems constitute one of the most cost-effective measures available. Biofouling management constitutes a measure, already implemented by the ship owners and companies, as a solution for problems, other than the introduction of invasive species. It is considered that build-up of biofouling on marine vessels can damage the hull structure and the propulsion systems. The accumulation of biofouling organisms on hulls can increase both the hydrodynamic volume of a vessel and the hydrodynamic friction, leading to increased drag which decrease speeds and increase the needed fuel.

Socio-economic aspects: Potential risks from the usage of chemicals under the frame of biofouling management, should be studied in the future.0</td>
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<tr>
<td>Side effects (incl. potential) – both positive and negative
i.e. positive or negative side effects of the implementation of the measure (not the IAS itself) on public health, environment including non-targeted species, etc. For example, native species non-target impacts from trapping.

For each of the side effect types please select one of the categories (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.

NOTE – this does not refer to direct intended effects of the measure (e.g. a reduction of the IAS population, or an increase in native species)</td>
<td>
<table>
<tr><td><i>Environmental effects</i></td><td><i>Positive</i></td><td></td><td><i>Mixed</i></td><td><i>X</i></td><td><i>Negative</i></td><td></td><td><i>None</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
<tr><td><i>Social effects</i></td><td><i>Positive</i></td><td><i>X</i></td><td><i>Mixed</i></td><td></td><td><i>Negative</i></td><td></td><td><i>None</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
<tr><td><i>Economic effects</i></td><td><i>Positive</i></td><td></td><td><i>Mixed</i></td><td><i>X</i></td><td><i>Negative</i></td><td></td><td><i>None</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
</table>

<i>Rationale</i>:

Some antifouling systems can cause environmental problems: for example, one of the most effective anti-fouling paints, developed in the 1960s, contains the organotin tributylin (TBT), which has been proven to cause deformations in oysters and sex changes in whelks[13] (Barreiro et al., 2004; Nicolaus y Barry, 2015; Laranjeiro et al., 2018), and has been banned globally by IMO since 2008 (Charry et al., 2019). Other biocides are also used in antifouling systems, despite their potential impacts on the marine ecosystems (Almeida et al., 2007; De Castro et al., 2018). For this reason, the development of new non-toxic antifouling solutions has been promoted (Basu et al., 2020; Kyei et al., 2020; Xie et al., 2020). Although chemical treatments, ultrasonic systems, the use of heat or of UV light all work as anti-fouling, they can be costly or pose health and safety risks, and some may increase corrosion of hulls (De Castro et al., 2018).

The application of anti-fouling technologies increases fuel efficiency in vessels, resulting in lower fuel costs and lower greenhouse gas emissions (IMO, 2011).

Regarding the social effects, they are positive for both fishermen and stakeholders involved. Management of <i>R. okamurae</i> excess biomass constitutes a big problem for local administrations, and a big public impact, including on tourism. In addition, anti-fouling systems can also have positive effects on public health, through the prevention of spread of pathogenic micro-organisms and harmful algal blooms.</td>
</tr>
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[13] IMO page on anti-fouling systems http://www.imo.org/en/OurWork/Environment/Anti-foulingSystems/Pages/Default.aspx [Accessed 01/06/2020]

<table>
<tr><td></td><td>Finally, as reported above, anti-fouling systems can be costly for ship owners or companies, so it can have some negative economic effects, which can be compensated by the reduction of the fuel consumption. The costs differ according to the anti-fouling systems used, but the cost of inaction is in any situation even bigger.</td></tr>
<tr><td>Acceptability to stakeholders
e.g. impacted economic activities, animal welfare considerations, public perception, etc.

Please select one of the categories of acceptability (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.</td><td><table><tr><td><i>Acceptability to stakeholders</i></td><td><i>Acceptable</i></td><td></td><td><i>Mixed</i></td><td><i>X</i></td><td><i>Unacceptable</i></td><td></td><td><i>Unknown</i></td><td></td></tr></table>
<i>Rationale</i>:

There could be some resistance to some biofouling measures by ship owners or companies due to the cost and type of systems to be applied on the ship. However, as mentioned above, effective anti-fouling systems can save money by reducing fuel consumption and this can favour the acceptability of the measure.

Commercial ship-owners have a strong interest in having their vessels cleaned in order to decrease fuel consumption and applying anti-fouling coatings is a common industry practice, as is dry-docking for regular maintenance and compliance with shipping regulations.</td></tr>
<tr><td>Level of confidence on the information provided [2]

Please select one of the confidence categories along with a statement to support the category chosen. See <i>Notes</i> section at the bottom of this document.
NOTE – this is not related to the effectiveness of the measure</td><td><table><tr><td><i>Inconclusive</i></td><td></td><td><i>Unresolved</i></td><td></td><td><i>Established but incomplete</i></td><td><i>X</i></td><td><i>Well established</i></td><td></td></tr></table>
<i>Rationale</i>:

Different studies and recent reviews agree on the importance of biofouling management, even if they recognise that any measures should be better implemented. There are no specific studies on the effectiveness of prevention of unintentional introductions for <i>R. okamurae</i> by biofouling management.</td></tr>
</table>

<table>
<tr><th colspan="2">Prevention of <u>un-intentional</u> introductions – measures for preventing the species being introduced un-intentionally into the territory of a Member State (cf. Article 13 of the IAS Regulation). This table is repeated for each of the prevention measures identified.</th></tr>
<tr><td>Measure name</td><td>Measures for the prevention of introduction and secondary spread of <i>R. okamurae</i> through shellfish transfers</td></tr>
<tr><td>Measure description
Provide a description of the measure and its objective, noting the pathway of introduction being addressed</td><td>Among the marine organisms involved in aquaculture transfers, shellfish (especially oysters) have long been a posteriori associated with the introduction of marine organisms (Mineur et al., 2007; Mineur et al., 2008; Wolf et al., 2018). As part of the EU Program ALIENS ‘Algal Introductions to European Shores’ and the Programme National surl’</td></tr>
</table>

If relevant, include a summary of the methodology to apply the measure, with references to sources of information where detail can be found.	Environnement Côtier (PNEC) “Lagunes Méditerranéennes”, an assessment of the efficiency of oyster transfers as vector of unintentional species introduction in France was carried out, focused on the marine macrophytes (Verlaque et al., 2007). At this point, it should be mentioned that the introduction of invasive species does not only occur with the movement of farmed species, but also with farm structures and equipment. As the aquaculture facilities are located in sheltered coastal areas and provide many artificial hard substrates (mariculture tools, ropes, nets, etc), they constitute an optimal habitat for non-indigenous species (Katsanevakis & Crocetta, 2014; Leonard et al., 2017 in Rech et al., 2018). The introduction of *R. okamurae* in Thau Lagoon, France is associated with oyster imports (*Crassostrea gigas*) carried out later than 1977, probably in 1994, from Korea (Verlaque et al., 2009) and it is considered an accidental entry (Boudouresque et al., 2011). Due to the commercial success of oyster farming, the Thau lagoon acts as a donor of oyster populations for cultivation in many parts of the Mediterranean and Atlantic (Mineur et al., 2007; Verlaque et al., 2007). Taking into consideration that transfers of shellfish livestock occur regularly between the Thau Lagoon and the other European Mediterranean and Atlantic aquaculture sites (Mineur et al., 2007; Verlaque et al., 2007), the risk of secondary dispersal of *R. okamurae* in Europe appears high. At this point, it should be clarified, that although *R. okamurae* is not invasive in the Thau lagoon, it cannot be ruled out that it will be invasive in other areas. Towards the prevention of new introductions of invasive species through aquacultures, the European Council Regulation (EC) No 708/2007[14] concerning use of alien and locally absent species in aquaculture defines the procedures to be followed to minimise the risk of introducing non-target alien species, accompanying commercial shellfish spat and stocks. According to the Regulation, all aquaculture operators who intend to introduce an alien species, or translocate a locally absent species, must first apply for a permit from the competent authority of the Member State where the transfer will take place. The Regulation specifies the information to be provided by the applicant and the type of assessment that the competent authority must perform before granting the permit. The bivalves *Crassostrea gigas* and *Ruditapes philippinarum*, listed in Annex IV of Council Regulation 708/2007, constitute an exception and can be moved without any risk assessment or quarantine. In addition, the regulation does not apply to movements of locally absent species within the Member States “except for cases where, on the basis of scientific advice, there are grounds for foreseeing environmental threats due to the translocation, Art. 2 para. 2.”. As oyster beds of *Crassostrea gigas* are responsible for the introduction of *R. okamurae* in the Mediterranean Sea (Verlaque et al., 2009), their translocation could be considered as a risk for further introductions and spread of *R. okamurae*. It is important to note that additional local, national or European (e.g. Natura 2000 related) regulations may apply that limit the translocation possibilities of species like *Crassostrea gigas* and *Ruditapes philippinarum* throughout Europe.

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[14] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32007R0708

	Comprehensive guidelines on the introductions and transfers of marine organisms aiming among others to preventing introductions of exotic species are available through IUCN (Shine et al., 2000)[15] and ICES (2005)[16] (in Verlaque et al., 2007). These guidelines include, among others: strategy for implementation, recommended procedure for all species prior to reaching a decision regarding new introductions, guidelines (If the decision is taken) to proceed with the introduction, recommended procedure for introduced or transferred species which are part of current commercial practice, general considerations regarding the release. Indicatively, they are summarised here: • Awareness of farmers concerning the risks associated with uncontrolled importation must be increased • Awareness of farmers about cleaning tools and hardware before moving from one area to another • Aquaculture should be based on native, local stock whenever possible. Imports and transfers of stock should be minimized, thoroughly inspected and quarantined for an appropriate observation period • Spatial attention would have to be paid during aquaculture trials with new exotic species (even with livestock from hatcheries) • Non –native livestock for introduction must be produced in hatcheries • Live products destined for consumption, processing and aquarium or display should not be placed into the natural environment • In the case of livestock transfers (including interregional ones), decontamination processes and/or quarantine • Efficient treatment (e.g. hot water for oysters) to avoid introduction or secondary dispersal of exotic or native species would have to be carried out prior to each transfer that is to say after the period of re-immersion preceding the transfer and would have been repeated on arrival. As a general conclusion it is recommended that stricter control measures (see above), than the ones already implemented, are required. Unfortunately, even the implementation of the above mentioned measures seem to have not led to significant results concerning macroalgal species, as oysters visually cleaned of epibionts can still bear a high diversity of viable macrophyte propagules (Verlaque et al., 2007).
Scale of application At what geographic scale is the measure applied? What is the largest scale at which it has been successfully used?	Such measures on the transfer of mussel consignments would need to be adopted at the European Union level to reduce the risk of the spread of marine invasive alien species in general, including *R. okamurae.* Regarding the introduction or movement of the bivalve *Crassostrea gigas* (being responsible for *R. okamurae* introduction in Thau lagoon), which is an exception under Council Regulation (EC) No 708/2007, additional local or national regulations must apply.

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[15] https://portals.iucn.org/library/sites/library/files/documents/EPLP-040-En.pdf

[16] https://www.nobanis.org/globalassets/ices-code-of-practice.pdf

<table>
<tr><td>Please provide examples reporting areas (km^2 or ha) if possible.</td><td></td></tr>
<tr><td>Effectiveness of the measure
Is it effective in relation to its objective?

Based on cases where the measure has been applied (ideally correctly and comprehensively), please select one of the categories of effectiveness (with an ‘X’), and provide a rationale, with supporting evidence and examples of effectiveness, if possible.

Please identify factors that are critical in determining its effectiveness.

Please note if effectiveness is based on research only (e.g. field trials).</td><td><table><tr><td><i>Effectiveness of measures</i></td><td><i>Effective</i></td><td><i>X</i></td><td><i>Neutral</i></td><td></td><td><i>Ineffective</i></td><td></td><td><i>Unknown or not yet applied</i></td><td></td></tr></table>
<i>Rationale</i>:

Shellfish imports from countries outside the EU are strictly managed and very limited in the past decade or two (Haydar & Wolff, 2011; Robert et al., 2013; Muehlbauer et al., 2014), however the risk for new introductions of <i>R. okamurae</i> from native populations cannot be excluded. Katsanevakis et al. (2013) notice the decrease of the trend in aquaculture-related new introductions of marine alien species in the last two decades presumably as a result of compulsory regulations as well as voluntary measures (Zenetos, 2019). This pathway, however, is still very relevant for spread within the EU, unless national/regional regulations provide a stricter regulatory framework than Council Regulation (EC) No 708/2007, concerning use of alien and locally absent species in aquaculture, especially with respect to the oyster <i>Crassostrea gigas</i> transfers. Therefore, the risk still exists, especially for transfers conducted within countries or between EU Member States where there is a lack in legislation and any actions are upon the awareness and the willingness of the cultivators. Unfortunately, illegal or unreported transfer also takes place, besides the known threats (Haydar & Wolff, 2011; Theodorou et al., 2011).

When properly implemented, simple changes to the shellfish transfer practice can reduce the risk of species introductions (Verlaque et al., 2007). Heat treatment is an efficient way to kill macrophyte propagules (Mineur et al., 2007). Certain French oyster farmers already commonly use such a treatment to remove small oyster spat and other fouling organisms from medium-sized oysters. Immersion in saturated brine for a short period is another effective method of control of various invasive organisms such as <i>Crepidula fornicata</i> and <i>Sargassum muticum</i> (Mineur et al., 2007).

Regarding stricter control measures, such as thorough inspections, the cryptic form of <i>R. okamurae</i>, could possibly not be detected, and moreover it is very hard to ‘clean’ the material from the algae’s propagules and monospores. Therefore, a quarantine is recommended as well, in order to decrease the risk.</td></tr>
<tr><td>Effort required
e.g. Number of times, and/or period of time over which measure needs to be applied to have results achieve its objective
(please indicate the units)</td><td>People working at the cultivation industry will have to implement the proposed control and treatment measures. Awareness, information and training play a key role towards this direction. The actions must be carried out mainly by the oyster farmers, while other bodies (public administration, scientific community, etc.) also play an important key role, mainly in the field of awareness.</td></tr>
</table>

Resources required [1] e.g. cost, staff, equipment etc. Please note the resources (and their costs if available) that are required to implement the measure to meet its objective.	All the resources required for the implementation of the measure are not species specific and refer to all the accidentally introduced alien taxa through aquacultures and not to *R. okamurae.* The implementation costs could be significant for the producers, especially those with a limited production. Shellfish hatcheries which enable the industry to produce seed consistently and decrease the risk for introduction of non-native species, are characterized by an increased cost, compared with fished seed and seed collected with ropes, in the case of mussels (Kamermans, 2008). Another cost is for the implementation of awareness campaigns.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects Include quantitative &/or qualitative data, and case studies (incl. from countries outside the EU).	Implementation cost for Member States: The most significant cost for Member States relate to the systematic enforcement of compliance with the law, as well as the participation or full organization of awareness and information activities. Cost of inaction: Failure to implement preventative measures in the shellfish culture industry can result in the secondary spread of *R. okamurae* in new areas of the EU, where it could become as invasive as in Spain. This has potentially significant economic impacts, as previously mentioned, deriving from lack of action to tackle the unintentional introduction of this taxon. Cost-effectiveness: For measures that are already in place (i.e. legislation and codes of best practice), cost-effectiveness is high. As the measures implemented are not specific for *R. okamurae*, other alien species can be also prevented from expanding.

<table>
<tr>
<td>Side effects (incl. potential) – both positive and negative
i.e. positive or negative side effects of the implementation of the measure (not the IAS itself) on public health, environment including non-targeted species, etc. For example, native species non-target impacts from trapping.

For each of the side effect types please select one of the categories (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.

NOTE – this does not refer to direct intended effects of the measure (e.g. a reduction of the IAS population, or an increase in native species)</td>
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<table>
<tr><td><i>Environmental effects</i></td><td><i>Positive</i></td><td><i>X</i></td><td><i>Mixed</i></td><td></td><td><i>Negative</i></td><td></td><td><i>None</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
<tr><td><i>Social effects</i></td><td><i>Positive</i></td><td></td><td><i>Mixed</i></td><td></td><td><i>Negative</i></td><td><i>X</i></td><td><i>None</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
<tr><td><i>Economic effects</i></td><td><i>Positive</i></td><td></td><td><i>Mixed</i></td><td></td><td><i>Negative</i></td><td><i>X</i></td><td><i>None</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
</table>
<i>Rationale</i>:

Environmental effects are mainly positive, due to the prevention of un-intentional introduction or spread of other marine invasive alien species that are moved within this pathway.

The measures implemented can increase production costs for shellfish growers. Moreover, the use of hatchery produced seed, although leading to regular and predictable production free of other organisms, is more expensive as well.

Economic effects may also result in social impacts if some shellfish aquaculture enterprises go out of business.
</td>
</tr>
<tr>
<td>Acceptability to stakeholders
e.g. impacted economic activities, animal welfare considerations, public perception, etc.

Please select one of the categories of acceptability (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.</td>
<td>
<table>
<tr><td><i>Acceptability to stakeholders</i></td><td><i>Acceptable</i></td><td></td><td><i>Mixed</i></td><td><i>X</i></td><td><i>Unacceptable</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
</table>
<i>Rationale</i>:

The implementation of the measure is generally accepted by most stakeholder groups, due to the protection of the environment, the economy and society from the import of foreign species. However, because of the fact that the operating costs of shellfish farms would increase significantly, there is likely to be negative reactions. These are reinforced by the fact that <i>R. okamurae</i> is a species that does not cause any problems to the cultivation itself and therefore the measures can be considered as unnecessary expenses.
</td>
</tr>
<tr>
<td>Level of confidence on the information provided [2]

Please select one of the confidence categories along with a statement to support the category chosen. See</td>
<td>
<table>
<tr><td><i>Inconclusive</i></td><td></td><td><i>Unresolved</i></td><td></td><td><i>Established but incomplete</i></td><td><i>X</i></td><td><i>Well established</i></td><td></td></tr>
</table>
<i>Rationale</i>:

These are well established and widely approved practices, some of them already translated into legislation with demonstrated effectiveness. Some uncertainty remains however in relation to the detectability of <i>R. okamurae,</i> as it
</td>
</tr>
</table>

Notes section at the bottom of this document. **NOTE – this is not related to the effectiveness of the measure**	can be transferred as propagules and monospores, which cannot be found during routine inspection of the transferred material.

Prevention of <u>secondary spread</u> of the species – measures for preventing the species spreading within a Member State once they have been introduced (cf. Article 13 of the IAS Regulation). **This table is repeated for each of the prevention measures identified.**	
Measure name	All measures which refer to the prevention of *R. okamurae*'s un-intentional introduction in the European Territory are necessary and applicable for the prevention of secondary spread of the species. So, Ballast Water Management, Biofouling Management, and measures for the prevention of *R. okamurae*'s introduction through shellfish transfers are effective and proposed for the secondary spread of the species from areas where already established (either as an invasive algae species – Spain, or not – France) to other areas in the European Territory.
Measure description Provide a description of the measure and its objective, noting the pathway of spread being addressed If relevant, include a summary of the methodology to apply the measure, with references to sources of information where detail can be found.	
Scale of application At what geographic scale is the measure applied? What is the largest scale at which it has been successfully used? Please provide examples reporting areas (km^2 or ha) if possible.	
Effectiveness of the measure Is it effective in relation to its objective?	

Based on cases where the measure has been applied (ideally correctly and comprehensively), please select one of the categories of effectiveness (with an 'X'), and provide a rationale, with supporting evidence and examples of effectiveness, if possible. Please identify factors that are critical in determining its effectiveness. Please note if effectiveness is based on research only (e.g. field trials).	
Effort required e.g. Number of times, and/or period of time over which measure needs to be applied to have results achieve its objective **(please indicate the units)**	
Resources required [1] e.g. cost, staff, equipment etc. Please note the resources (and their costs if available) that are required to implement the measure to meet its objective.	
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	

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<tr><td>Include quantitative &/or qualitative data, and case studies (incl. from countries outside the EU).</td><td></td></tr>
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For each of the side effect types please select one of the categories (with an 'X'), and provide a rationale, with supporting evidence and examples if possible.

NOTE – this does not refer to direct intended effects of the measure (e.g. a reduction of the IAS population, or an increase in native species)</td><td><table>
<tr><td>***Environmental effects***</td><td>*Positive*</td><td></td><td>*Mixed*</td><td></td><td>*Negative*</td><td></td><td>*None*</td><td></td><td>*Unknown*</td><td></td></tr>
<tr><td>***Social effects***</td><td>*Positive*</td><td></td><td>*Mixed*</td><td></td><td>*Negative*</td><td></td><td>*None*</td><td></td><td>*Unknown*</td><td></td></tr>
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</table>
Rationale:</td></tr>
<tr><td>**Acceptability to stakeholders**
e.g. impacted economic activities, animal welfare considerations, public perception, etc.

Please select one of the categories of acceptability (with an 'X'), and provide a rationale, with supporting evidence and examples if possible.</td><td><table>
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Please select one of the confidence categories along with a statement to</td><td><table>
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</table>
Rationale:</td></tr>
</table>

support the category chosen. See *Notes* section at the bottom of this document. **NOTE – this is not related to the effectiveness of the measure**	

Prevention of secondary spread of the species – measures for preventing the species spreading within a Member State once they have been introduced (cf. Article 13 of the IAS Regulation). **This table is repeated for each of the prevention measures identified.**	
Measure name	**Awareness and education-training campaigns for professionals and amateurs**
Measure description Provide a description of the measure and its objective, noting the pathway of spread being addressed If relevant, include a summary of the methodology to apply the measure, with references to sources of information where detail can be found.	*R. okamurae* is a species already established in the European Territory, currently known in at least two Member States, but there is a high risk of it spreading to new areas of the European Territory (MTERD, 2020). In addition to ballast water, ship biofouling and aquaculture transfers, other potential vectors, responsible for the dispersion of *R. okamurae* are fishing activity (both professional and amateur), recreational activities (boat renting, SCUBA – diving, snorkelling) and marine litter (West et al. 2009; Katsanevakis et al.; 2013, Kelly et al., 2012). In all of the above mentioned cases, thalli or even monospores and propagules attach to the equipment used (gears, anchorage systems, diving equipment, etc.) and in the case that the equipment is not managed properly (cleaned out of water, washed with fresh water, dried, etc.) it is very highly possible to spread the species from one area to another. Even if the gear and equipment are being cleaned away from the coast and in deep waters, it is very likely for *R. okamurae* to spread because, even though floating material can sink to depths out of the photic zone, due to its survival capacity to darkness (Rosas-Guerrero et al. 2018), sea currents can move those thalli again the photic zone (MTERD, 2020). The most effective measure towards the prevention of secondary spread un-intentionally through human activities is the implementation of awareness and education-training campaigns for key stakeholders. The campaigns must be organized and carried out at a national and local scale, with the active participation and assistance of specialized scientific staff. The moto should reflect the widely used 'check, clean and dry' message, targeting equipment and clothing especially when moving between areas. It is also recommended to encourage responsible recreational boating through targeted

<table>
<tr>
<td></td>
<td>information, education and training. Informative materials should be placed at susceptible sites (e.g. harbours), but it should be stressed that “measures should be implemented by everyone, everywhere, every time”.

To prevent the introduction and spread of the species due to fishing (professional and amateur), recreational boating and diving equipment, the information – training campaign, should focus on:
i. cleaning gears and all the fishing equipment out of the water (do not throw thalli in the sea),
ii. inspection of equipment (boat, motor, anchor, trailer, equipment etc) for the presence of aquatic organisms,
iii. cleaning all equipment used in marine environments with freshwater,
iv. when finding fouling fauna and flora species remove them and dispose of them far from the water,
v. let equipment dry completely before entering another water body when possible,
vi. use anti-fouling paint or products on boat hulls,
vii. when doing diving and/or other water sports, make sure to clean, drain and dry your equipment after every use.</td>
</tr>
<tr>
<td>Scale of application
At what geographic scale is the measure applied? What is the largest scale at which it has been successfully used?
Please provide examples reporting areas (km^2 or ha) if possible.</td>
<td>The measure will need to be applied across the EU by individual Member States where the species has a risk of being introduced. However, as this is an important measure to prevent the spread of most aquatic (marine and freshwater) invasive alien species it is recommended that it is applied by all EU Member States. Informative materials should be placed at susceptible areas, including those with fishing (professional and leisure), recreational boating, diving and other water sports’ activities. Awareness campaigns can be run at national, sub-national or even local level.</td>
</tr>
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<td>Effectiveness of the measure
Is it effective in relation to its objective?

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</table>
<i>Rationale</i>:

The effectiveness of the measure depends on the development and implementation of appropriate information and training tools that are targeted at each stakeholder. The coordinated action of all stakeholders (public bodies, NGOs, fishermen's associations, yacht rental companies, sailing clubs, diving centers, etc.) also plays an important role.

The effectiveness of awareness campaigns is accepted globally and is considered as a significant tool for management of invasive aquatic species (as prevention is more effective than cure). Giakoumi et al. (2019), using expert knowledge, prioritized 11 management actions for controlling 12 model species (macrophytes, fish, invertebrates), distinguished by differences in dispersion capacity, distribution in the area to be managed, and taxonomic identity. Raising public awareness was highly prioritized.</td>
</tr>
</table>

Please identify factors that are critical in determining its effectiveness. Please note if effectiveness is based on research only (e.g. field trials).	Awareness programs might be more effective if targeted at those most active in water-based recreation, especially boat users and others who constitute an unwitting vector in the spread of aquatic invasive species (Eisworth et al., 2011). While no data exists on the effectiveness of this measure at prevention of *R. okamurae* secondary spread, it is generally accepted that public awareness and training is the most important weapon towards this direction.
Effort required e.g. Number of times, and/or period of time over which measure needs to be applied to have results achieve its objective **(please indicate the units)**	This measure should be applied indefinitely.
Resources required [1] e.g. cost, staff, equipment etc. Please note the resources (and their costs if available) that are required to implement the measure to meet its objective.	Awareness and education-training campaigns include the involvement of many different stakeholders. Public bodies (ministry, regional units, municipalities, port authorities), NGOs and other environmental protection companies, scientific staff for the correct description of the problem and for the popularization of knowledge, etc. The resources required for the proper implementation of the measure include: 1. the cost of designing and reproducing the information material (printed, digital, etc.) for tourism operators, shops which sell or rent fishing and diving equipment, diving centers, etc., and 2. the costs for organizing information and training workshops for marine professionals to highlight the problem and demonstrate the proper management practices of the equipment of various activities in order to prevent the dispersal of *R. okamurae*.
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects Include quantitative &/or qualitative data, and case studies (incl. from countries outside the EU).	Implementation cost for Member States: The cost varies greatly between Member States as there is a large difference in both number and type of professional as well as leisure activities on the coastal areas. The cost of inaction: See tables above. Cost-effectiveness: Considering that prevention is always preferable especially for organisms like *R. okamurae*, which are easily widespread and almost not able to be controlled after established, public awareness seems to be a very cost-effective measure.

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</table>

<i>Rationale</i>:

The major environmental side effect of this measure is that it will prevent the spread of many aquatic invasive alien species, not just <i>R. okamurae</i>.

As far as the social side effects of the measure, the expansive action of the species has caused very significant problems for fishermen in the affected areas leading to reduced fishing capacity. Coastal areas are also facing significant problems due to the accumulation of huge biomass for decomposition. The problem is aesthetic, it affects tourism and affects the local population (with all the negative consequences that the decomposition of a large biomass can have).

The economic benefits are mixed as there is a significant cost to organizing and implementing awareness and education activities, but the negative economic consequences of the spread of the species in other areas are even more pronounced.
</td>
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</table>

<i>Rationale</i>:

The awareness campaign itself should be acceptable to most stakeholders. Some professionals may resist implementing the best practices regarding the spread of invasive alien species, either because its time consuming or costs money to inspect their equipment, to clean it in a proper place and to dry it appropriately or because they think that they are not going to be affected by the species spread. Fortunately, those stakeholders seem to be a minority, as examples from invasive alien fishes, indicate that potentially affected stakeholders, such as professional and recreational fishers, are highly motivated to contribute to recording efforts of invasive species (Giovos et al., 2018).
</td>
</tr>
<tr>
<td>Level of confidence on the information provided [2]

Please select one of the confidence categories along with a statement to</td>
<td>
<table>
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</table>

<i>Rationale</i>:
</td>
</tr>
</table>

support the category chosen. See *Notes* section at the bottom of this document. **NOTE – this is not related to the effectiveness of the measure**	Awareness and educational-training campaigns are increasing in numbers, as they are one of the easiest and possibly most effective means to prevent the spread of aquatic invasive alien species. However, up to now, there are no specific studies on the effectiveness of prevention of secondary spread of *R. okamurae,* using these measures.

<table>
<tr><td colspan="2">Surveillance measures to support early detection - Measures to run an effective surveillance system for achieving an early detection of a new occurrence (cf. Article 16). This section assumes that the species is not currently present in a Member State, or part of a Member State’s territory. This table is repeated for each of the early detection measures identified.</td></tr>
<tr><td>Measure name</td><td><i>Establishment of monitoring networks</i></td></tr>
<tr><td>Measure description
Provide a description of the measure and its objective
If relevant, include a summary of the methodology to apply the measure, with references to sources of information where detail can be found.</td><td>The integrated application of International, European Community (Marine Strategy Framework Directive (MSFD), Water Framework Directive (WFD), etc.) and National legislation on water ecosystems in general, but also on marine, is based on the development and implementation of appropriate monitoring programs. The frequency, parameters, monitoring locations, and other features of these programs vary, as the purpose of their application is different in each case. However, the implementation of these programs enhances the possibility of early detection of the introduction of invasive alien species. Early detection of alien species in an area, is therefore possible not only through specialized monitoring programs, but through scientific monitoring for other purposes (e.g. in protected areas, in a Marine Park, in the assessment of habitats conservation status, in the assessment of water quality and many other parallel actions, that occur in Member States).
Monitoring should be implemented according to a monitoring program at a network of sites, where priority should be given to susceptible areas such as harbours (commercial and touristic). It can be undertaken in specific biocommunities (<i>Cystoseira</i> communities, meadows of marine phanerogams, etc.) or through the monitoring of representative taxa as substitutive of the whole community (Puente & Juanes, 2008). A monitoring protocol regarding <i>R. okamurae</i> can vary a lot and may include on a case-by-case basis: occurrence or absence of the species, data about the community where the species was found, and in what condition (attached to the substrate or detached), bathymetric expansion, coverage, etc.). García-Gómez (2020b) followed transects and for each transect, five 50 x 50 cm quadrats were placed randomly and photographed at six depths (0, 5, 10, 20, 30, and 40 m) over horizontal rocky surfaces (Dumas et al., 2009).
In addition, García-Gómez (2015, 2020a) proposed a specific methodology, which was implemented in submarine sentinel stations. The methodology named SBPQ (Sessile Bioindicators Permanent Quadrats) is a based on photographic monitoring of bioindicator species in fixed quadrats. This approach can be an important tool for the early detection of benthic alien invasive taxa and thus García-Gómez et al. (2020b) validated the method for monitoring <i>R. okamurae</i> on poorly lit, vertical and shady substrate in the El Estrecho Natural Park, on the north side of the Strait of Gibraltar (Tarifa). Monitoring was implemented at a submarine sentinel sessile bioindicators permanent quadrats (SBPQ) station installed in 2013. The monitoring detected the presence of <i>R. okamurae</i> in 2016 and recorded the subsequent increase in coverage (García-Gómez et al., 2020b). These authors support the effectiveness of the previously mentioned methodology in the early detection of sessile exotic species with invasive potential in specific habitats.</td></tr>
</table>

<table>
<tr><td></td><td>Galanidi & Eylul (2019) mention that surveillance monitoring for compliance with ballast water management regulations (and anti-fouling practices) is likely to be the most promising option for early detection of target species (in that case of <i>Hemigrapsus sanguineus</i>) in introduction hotspots, including ballast water tanks, although protocols are yet to be established for such procedures.
In addition, the early detection and the spread of the species is also being monitored through citizen science/stakeholder engagement programmes (described as the following measure). However, early warning and monitoring measures can be applied only on adult thalli of <i>R. okamurae</i> and cannot cover propagules and monospores present.</td></tr>
<tr><td>Scale of application
At what geographic scale is the measure applied? What is the largest scale at which it has been successfully used?
Please provide examples reporting areas (km^2 or ha) if possible.</td><td>The scale depends on the area to monitor. High risk and high priority areas should be addressed first, designated based on the proximity to areas where established populations of <i>R. okamurae</i> exist and on the areas where fishing or recreational boats, visiting the affected areas, are ported.</td></tr>
<tr><td>Effectiveness of the measure
Is it effective in relation to its objective?
Based on cases where the measure has been applied (ideally correctly and comprehensively), please select one of the categories of effectiveness (with an ‘X’), and provide a rationale, with supporting evidence and examples of effectiveness, if possible.
Please identify factors that are critical in determining its effectiveness.
Please note if effectiveness is based on research only (e.g. field trials).</td><td><table><tr><td><i>Effectiveness of measures</i></td><td><i>Effective</i></td><td><i>X</i></td><td><i>Neutral</i></td><td></td><td><i>Ineffective</i></td><td></td><td><i>Unknown or not yet applied</i></td><td></td></tr></table>
<i>Rationale</i>:
The work undertaken by García-Gómez et al. (2020a, b) has shown that monitoring networks, using the SBPQ method can effectively detect <i>R. okamurae</i> and monitor changes in its coverage. They also explicitly support the effectiveness of the methodology in the early detection of sessile exotic species with invasive potential in specific habitats.
The effectiveness of the measure is increased in cases where the scientific monitoring programs are implemented for the purpose of inventory, estimation and record of non- indigenous invasive species. Key elements include the programs focus on hotspots (harbours, marinas, etc.) and the inclusion of taxonomists in the scientific team. Tempesti et al. (2020) studied macrozoobenthic fouling assemblages in the port area of Livorno, focusing on the occurrence of non-indigenous species (NIS) and among the 262 species identified, twenty-six were alien or cryptogenic, seventeen of which were new records for the study area.
On the other hand, when monitoring is not specifically targeting alien species, then it is less effective, as it may not be carried out frequently enough for early detection. In addition, it is also possible that nonindigenous species are not identified, when the scientific team focuses on other biological or abiotic parameters.</td></tr>
</table>

<table>
<tr><td></td><td>Finally, due the morphological similarity with native <i>Dictyota</i> species, <i>R. okamura</i>e may be producing cryptic invasion (MTERD, 2020).</td></tr>
<tr><td>Effort required
e.g. Number of times, and/or period of time over which measure needs to be applied to have results achieve its objective
(please indicate the units)</td><td><i>R. okamurae</i> expansion along the Andalusian coast since its detection in Spain, in 2016, has been exponential. Monitoring effort should be high (in both frequency and extent), in order to have a high certainty of locating recently introduced or established, populations. Monitoring throughout the invaded areas is also recommended in order to follow the development of the species populations.</td></tr>
<tr><td>Resources required [1]
e.g. cost, staff, equipment etc.
Please note the resources (and their costs if available) that are required to implement the measure to meet its objective.</td><td>There are no available data on the costs regarding scientific monitoring of <i>R. okamurae</i>.
There are numerous scientific monitoring programs for the marine environment that are already applied in Member States. Funding sources vary depending on the objectives of the programs and can be from European Union Funds or even from national funding, either central (ministries, etc.) or local (municipalities, etc.). Personnel involved in the scientific monitoring projects are usually professional scientists. The regional administration in Andalusia is allocating some economic and human resources for monitoring <i>R. okamurae</i> (MTERD, 2020).</td></tr>
<tr><td>Additional cost information [1]
When not already included above, or in the species Risk Assessment.
- implementation cost for Member States
- the cost of inaction
- the cost-effectiveness
- the socio-economic aspects

Include quantitative &/or qualitative data, and case studies (incl. from countries outside the EU).</td><td>Costs of implementation for Member States vary according to whether they already have established populations of <i>R. okamurae</i> in their territory, to the number of hotspot areas and to the human activities in each Member State.
Cost of inaction: See tables above.
Cost-effectiveness: Early detection with targeted monitoring, especially if species-specific tools are developed is considered very cost-effective.</td></tr>
<tr><td>Side effects (incl. potential) – both positive and negative
i.e. positive or negative side effects of the implementation of the measure (not the IAS itself) on public health, environment including non-targeted species, etc. For example, native</td><td><table>
<tr><td><i>Environmental effects</i></td><td><i>Positive</i></td><td><i>X</i></td><td><i>Mixed</i></td><td></td><td><i>Negative</i></td><td></td><td><i>None</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
<tr><td><i>Social effects</i></td><td><i>Positive</i></td><td><i>X</i></td><td><i>Mixed</i></td><td></td><td><i>Negative</i></td><td></td><td><i>None</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
<tr><td><i>Economic effects</i></td><td><i>Positive</i></td><td></td><td><i>Mixed</i></td><td></td><td><i>Negative</i></td><td></td><td><i>None</i></td><td><i>X</i></td><td><i>Unknown</i></td><td></td></tr>
</table>
<i>Rationale</i>:</td></tr>
</table>

<table>
<tr>
<td>species non-target impacts from trapping.

For each of the side effect types please select one of the categories (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.

NOTE – this does not refer to direct intended effects of the measure (e.g. a reduction of the IAS population, or an increase in native species)</td>
<td>No negative side effects are expected from this measure. On the contrary, as a positive environmental side effect it can help the detection of many additional environmental threats including other invasive alien aquatic species.

The social effects of the implementation of scientific monitoring are positive, due to the increased possibility for management actions (where early detection and thus restricted expansion are necessary for the effectiveness).

Economic effects can be characterized as None.</td>
</tr>
<tr>
<td>Acceptability to stakeholders
e.g. impacted economic activities, animal welfare considerations, public perception, etc.

Please select one of the categories of acceptability (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.</td>
<td><table>
<tr><td><i>Acceptability to stakeholders</i></td><td><i>Acceptable</i></td><td><i>X</i></td><td><i>Mixed</i></td><td></td><td><i>Unacceptable</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
</table>
<i>Rationale</i>:

The measure should not encounter any resistance as the general public is not affected by monitoring.</td>
</tr>
<tr>
<td>Level of confidence on the information provided [2]

Please select one of the confidence categories along with a statement to support the category chosen. See <i>Notes</i> section at the bottom of this document.
NOTE – this is not related to the effectiveness of the measure</td>
<td><table>
<tr><td><i>Inconclusive</i></td><td></td><td><i>Unresolved</i></td><td></td><td><i>Established but incomplete</i></td><td><i>X</i></td><td><i>Well established</i></td><td></td></tr>
</table>
<i>Rationale</i>:

This measure is recognised to be effective for detecting new occurrence of species (Tempesti et al., 2020), although the majority of monitoring projects that refer to <i>R. okamurae</i> include populations data (occurrence, densities, depth, habitats, etc.) (García-Gómez, 2015; García-Gómez et al., 2020b) and not early detection. The effectiveness of this measure for the early detection of new <i>R. okamurae</i> populations should be tested. The species’ increased propagation capacity by propagules and monospores, even after a long survival to darkness in combination to its similarity with native species, hardens its early detection.</td>
</tr>
</table>

Surveillance measures to support early detection - Measures to run an effective surveillance system for achieving an early detection of a new occurrence (cf. Article 16). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the early detection measures identified.**	
Measure name	***Development of citizen science programs***
Measure description Provide a description of the measure and its objective If relevant, include a summary of the methodology to apply the measure, with references to sources of information where detail can be found.	Citizen science projects in the marine environment encounter challenges not faced in terrestrial systems. The primary challenges are logistical, stemming from the fact that humans, at best, spend only part of their life on the water. In many contexts, access for citizen scientists is more challenging than on land, often requiring expensive boats, diving gear, or transportation to the coast (Cigliano et al., 2015; Roy et al., 2012). The development of a citizen science program varies significantly and it can include a web page addressing all aspects of alien species in the target area (the analysis of the problem, photos and description of the target organisms, visual distribution maps of the alien species, etc.), where the volunteers can report on the occurrence of species (providing evidence such as photos or samples when needed (after the information is approved by experts, it can be published in the website) (Zenetos et al., 2013). The recent adoption of information and communications technology (ICT) in this field (e.g. web- or mobile application-based interfaces for citizen training and data generation) has led to a massive surge in popularity, mainly due to reduced geographic barriers to citizen participation. Several challenges exist, however, to effectively utilize citizen-generated data for monitoring invasive alien species (or other species of interest) at the global scale (Johnson et al., 2020; Earp & Liconti, 2020). Citizen science has recently been flourishing in the Mediterranean Sea. Several projects, initiatives and campaigns contributed to the early detection and monitoring of marine alien species, with social media and smartphone technology playing a critical role, as they enhance participation and ease community building, while at the same time boost data collection (Zenetos et al., 2017; Giovos et al., 2018). Present efforts include social media initiatives like Facebook groups/pages and web pages managed by scientists, web-based platforms, campaigns and/or projects (Giovos et al., 2019). The Joint Research Centre of the European Commission has developed a dedicated smartphone app for recording species of Union concern; thus, data provided by citizens is sent directly to the competent authority, which can help to detect species at an early stage of invasion. BioBlitz events, where citizen science multi-taxa surveys are undertaken over a short period of time, offer another possibility for enhancing monitoring effort for the detection of marine alien species, and therefor *R. okamurae*.

<table>
<tr><td></td><td>Another tool for effective knowledge exchange is the network of networks (INVASIVESNET) which aims to facilitate greater understanding and improved management of invasive alien species and biological invasions globally (Lucy et al., 2016) and the re-activation of the MAMIAS (Marine Mediterranean Invasive Alien Species) platform to promote regional co-ordination and dissemination of data and important information.

Many European Countries have developed Citizen Science platforms, e.g. see Italy[17], United Kingdom[18], Sweden[19], France[20], Belgium[21], Spain[22], Cyprus and Greece[23], etc.</td></tr>
<tr><td>Scale of application
At what geographic scale is the measure applied? What is the largest scale at which it has been successfully used?
Please provide examples reporting areas (km^2 or ha) if possible.</td><td>The scale is wide and can cover all the aquatic systems of national territories.</td></tr>
<tr><td>Effectiveness of the measure
Is it effective in relation to its objective?

Based on cases where the measure has been applied (ideally correctly and comprehensively), please select one of the categories of effectiveness (with an ‘X’), and provide a rationale, with supporting evidence and examples of effectiveness, if possible.

Please identify factors that are critical in determining its effectiveness.</td><td><table><tr><td><i>Effectiveness of measures</i></td><td><i>Effective</i></td><td></td><td><i>Neutral</i></td><td></td><td><i>Ineffective</i></td><td></td><td><i>Unknown or not yet applied</i></td><td><i>X</i></td></tr></table>
<i>Rationale</i>:

Citizen science constitutes an essential and effective tool for the early detection of non-indigenous species. Thousands of volunteers roam the coasts of the world’s oceans during weekends or vacations, providing a wealth of data that can be of scientific value. Those data refer to areas and frequencies that cannot be covered by the existing monitoring programs.

Currently no data exist on the effectiveness of citizen science to <i>R. okamurae</i>’s early detection, even though its value is significant for other macroalgal species. Another issue that is related to the effectiveness of <i>R. okamurae</i> early detection is its similarity to native species and that it is not easy to identify the species, even when being an expert, let alone being an amateur.</td></tr>
</table>

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[17] http://www.unipa.it/dipartimenti/stebicef/Progetto-di-Citizen-Science-Aliens-in-the-sea/
http://innat.it/

[18] http://www.brc.ac.uk/aquainvaders/home

[19] https://www.artportalen.se/

[20] http://doris.ffessm.fr/

[21] http://biodiversite.wallonie.be/fr/invasives.html?IDC=5632

[22] http://iastracker.ic5team.org/

[23] https://isea.com.gr/activities/programs/alien-species/is-it-alien-to-you-share-it/?lang=en

Please note if effectiveness is based on research only (e.g. field trials).	Evidence of the measures effectiveness in the marine environment has been shown by Mannino & Balistreri's (2018), who report on the experience of citizen science in the Egadi Islands MPA with the project '*Caulerpa cylindracea* – Egadi Islands', aimed at monitoring the spread dynamics of the 'sea grape' *Caulerpa cylindracea*. The project registered 156 sightings and also allowed collection of records and information concerning other non-indigenous and cryptogenic species, e.g. the spotted sea hare (*Aplysia dactylomela*), the harpoon weed (*Asparagopsis armata*) and co-generic red sea plume (*A. taxiformis*), the tube-building sabellid (*Branchiomma bairdi*), the blue spotted cornet fish (*Fistularia commersoni*) and the nomad jellyfish (*Rhopilema nomadica*). In addition, Delaney et al. (2007) mention that approximately 1,000 volunteers assessed the presence of invasive (*Carcinus maenas* and *Hemigrapsus sanguineus*) and native crabs within the intertidal zone of seven coastal states of the US, from New Jersey to Maine.
Effort required e.g. Number of times, and/or period of time over which measure needs to be applied to have results achieve its objective **(please indicate the units)**	This measure should be applied indefinitely.
Resources required [1] e.g. cost, staff, equipment etc. Please note the resources (and their costs if available) that are required to implement the measure to meet its objective.	All citizen science projects have a cost, particularly in the initial phases for purposes of designing the project, motivating and training volunteers, producing information and field guide material, setting up a recording platform, etc. The running of citizen science projects commonly involves scientists coordinating activities, verifying observations, collating and analysing data. Most citizens have a smartphone, and the apps are already developed. Adriaens et al. (2015), report that an app developed by the RINSE project cost €20,262. Costs of people screening, validating and managing the collected data should be included: a part-time position could be sufficient, with personnel managing data collected also on other species targeted by the citizen science initiative. Roy et al., (2012) mentions that citizen science projects in the UK, contributing to biodiversity indicators, had annual running costs between £70K and £150K (ca. €78.3K and €167.8K).
Additional cost information [1] When not already included above, or in the species Risk Assessment. - implementation cost for Member States - the cost of inaction - the cost-effectiveness - the socio-economic aspects	This measure is very cost effective, the method engaged the public and is often much appreciated by them, thus the cost of inaction would be high. Cost of inaction: Citizen science campaigns have already made an important contribution to the detection of invasive marine species including macroalgae taxa. As such, the cost of inaction would be missed opportunities for early detection and if possible, eradication of new *R. okamurae* populations with all the potential associated impacts and costs.

<table>
<tr>
<td>Include quantitative &/or qualitative data, and case studies (incl. from countries outside the EU).</td>
<td>Cost-effectiveness: Citizen science projects for purposes of biodiversity monitoring are not cost-free, but can significantly decrease the costs of official monitoring (but not replace them), as well as increase the spatial (and potentially the temporal) scale of observations (Roy et al., 2012).</td>
</tr>
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<td>Side effects (incl. potential) – both positive and negative
i.e. positive or negative side effects of the implementation of the measure (not the IAS itself) on public health, environment including non-targeted species, etc. For example, native species non-target impacts from trapping.

For each of the side effect types please select one of the categories (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.

NOTE – this does not refer to direct intended effects of the measure (e.g. a reduction of the IAS population, or an increase in native species)</td>
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<tr><td><i>Economic effects</i></td><td><i>Positive</i></td><td><i>X</i></td><td><i>Mixed</i></td><td></td><td><i>Negative</i></td><td></td><td><i>None</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
</table>
<i>Rationale</i>:

There are no negative effects of this measure. As positive consequences, citizen science can play a significant role in public engagement, improved education and public awareness, and is recognised as fundamental to the attainment of the objectives of alien species policies (Roy et al., 2018). Moreover, new alien or native species can be detected.

One of the positive side effects of this measure is a greater public and stakeholder awareness of invasive species and their impact on the environment. Moreover, citizen recording schemes usually run for more than one species simultaneously and can contribute to the early detection of other invasive alien species that occupy similar habitats.</td>
</tr>
<tr>
<td>Acceptability to stakeholders
e.g. impacted economic activities, animal welfare considerations, public perception, etc.

Please select one of the categories of acceptability (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.</td>
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</table>
<i>Rationale</i>:

The measure should not encounter any resistance.

Examples from different taxonomic groups, such as invasive alien fishes, indicate that potentially affected stakeholders, such as professional and recreational fishers, are highly motivated to contribute to recording efforts of invasive species (Giovos et al., 2018).</td>
</tr>
<tr>
<td>Level of confidence on the information provided [2]</td>
<td>
<table>
<tr><td><i>Inconclusive</i></td><td></td><td><i>Unresolved</i></td><td></td><td><i>Established but incomplete</i></td><td></td><td><i>Well established</i></td><td><i>X</i></td></tr>
</table>
</td>
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Please select one of the confidence categories along with a statement to support the category chosen. See *Notes* section at the bottom of this document. **NOTE – this is not related to the effectiveness of the measure**	*Rationale*: The importance of citizen science programs for invasive alien species management is widely recognised (Roy et al., 2018). New programs and apps are being developed, showing the popularity of this measure. Stakeholders are often the first to detect alien species in the marine environment. When properly designed, citizen science projects can provide scientifically robust and reliable data (Chase & Levine, 2016; Chandler et al., 2017).

Rapid eradication for new introductions - Measures to achieve eradication <u>at an early stage of invasion</u>, after an early detection of a new occurrence (cf. Article 17). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory. **This table is repeated for each of the eradication measures identified.**	
Measure name	**Manual removal of thalli**
Measure description Provide a description of the measure and its objective If relevant, include a summary of the methodology to apply the measure, with references to sources of information where detail can be found.	There have been successful, if expensive, campaigns to completely eradicate alien invasive seaweeds, but in every case, this has relied on early detection (Anderson, 2007). Manual removal of the invasive individuals is implemented most of the times by volunteers via SCUBA-diving and/or snorkelling. The number of volunteers, the duration of the campaign, its repetition, all depend on the invaded area, the populations' density, the depth variation, etc. *R. okamurae* presents an extraordinary competition and colonization ability, exceeding all earlier seaweed invasions in Spain (invasion of *Asparagopsis armata* (García-Gómez et al., 2020b), *A. taxiformis* (Altamirano et al., 2008; Zanolla et al., 2018 a, b, c), *Lophocladia lallemandii* (Patzner, 1998; Cabanellas-Reboredo et al., 2010; Deudero et al., 2010), *Caulerpa taxifolia* (Verlaque et al., 2015) or *C. cylindracea* that was the most severe invasion regarding macroalgae in the Mediterranean basin (Klein & Verlaque, 2008) (MTERD, 2020). Part of the successful invasion performance of the species is due to its high propagation capacity through vegetative and asexual structures that can easily escape from management strategies such as eradications campaigns. Moreover, *R. okamurae* thalli can grow on various substrate: directly over the hard substrata, as an epiphyte, on fauna taxa, etc. (MTERD, 2020). As no rapid eradication campaigns for *R. okamurae* took place and it is very unlikely to be implemented in the nearest future (due the previously mentioned characteristics of the species invasive attitude, its relatively small thalli and

<table>
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<td>occupation of various substrates, its propagation capacity, etc), the information given in the following paragraphs are based on the campaigns that took place for other invasive macroalgal species, mainly in the Mediterranean Sea.

Experimental eradication studies or programs for <i>Caulerpa racemosa</i> in the Mediterranean have been undertaken. They have been applied with some effectiveness in small sites (400–1,000 cm^2), especially in restricted areas, such as bays and harbours. The standard procedure is repeated manual removal of the seaweed at 3 to 4-week intervals. Nevertheless, <i>Caulerpa racemosa</i> fragments tend to recolonize these areas again after a period of 2 to 18 months (Otero et al., 2013). Regarding <i>Caulerpa taxifolia</i>, various methods have been proposed and tested: manual uprooting, a range of underwater suction devices, physical control with dry ice, hot water jets, chemicals and underwater welding devices to boil the plants in situ. The variable, limited results of these different attempts have precluded the establishment of any permanent control programs (Otero et al., 2013). Another example for eradication and/or population control comes from <i>Codium fragile</i>. Mechanical removal techniques such as trawling, cutting, and suctioning have been tried in different areas. They help to reduce the density of <i>Codium fragile</i> temporarily, but these methods are generally expensive, and the populations quickly rebound to normal densities. Manual removal could be an alternative, but great care is needed as the algae readily reproduce from fragments (Otero et al., 2013).</td>
</tr>
<tr>
<td>Scale of application
At what geographic scale is the measure applied? What is the largest scale at which it has been successfully used?
Please provide examples reporting areas (km^2 or ha) if possible.</td>
<td>Eradication has not been attempted for <i>R. okamurae</i> anywhere in the invaded range. If the species could be detected very early and had a limited distribution, the eradication method of manual removal could be applied at a local scale.</td>
</tr>
<tr>
<td>Effectiveness of the measure
Is it effective in relation to its objective?

Based on cases where the measure has been applied (ideally correctly and comprehensively), please select one of the categories of effectiveness (with an ‘X’), and provide a rationale, with supporting evidence and examples of effectiveness, if possible.

Please identify factors that are critical in determining its effectiveness.</td>
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<table>
<tr><td><i>Effectiveness of measures</i></td><td><i>Effective</i></td><td></td><td><i>Neutral</i></td><td></td><td><i>Ineffective</i></td><td></td><td><i>Unknown or not yet applied</i></td><td><i>X</i></td></tr>
</table>

<i>Rationale</i>:

Eradication of marine invasive alien species has been achieved only in rare cases, when they were detected very early and there was a rapid response in restricted areas. If the species has already managed to establish in large areas, eradication is unlikely (Ojaveer et al., 2015).

The successful rapid eradication of <i>R. okamurae</i> through manual removal seems highly unlikely. Once <i>R. okamurae</i> has become invasive, eradication and even containment are likely to be not possible, due to:

i. the species densities in the affected areas (García-Gómez et al., 2020b, recorded in North Bay of Ceuta, densities from 70 to 100% within a bathymetrical range from 5 to 30 m depth),</td>
</tr>
</table>

Please note if effectiveness is based on research only (e.g. field trials).	ii. reproduction success (more than 100 spores and 25 propagules have been counted in 1 cm^2 of thallus (MTRED, (2020) mentions that in the species Risk Assessment Report as a datum from personal observations of Altamirano *et al.*). Assuming that each one can generate a new clone individual, regardless of whether the thallus is fixed to the substrate or free in the water column, it is more than clear that effective control methods for *R. okamurae* that can be applied in the current stage of invasion are not known, iii. occupation capacity (various depths, biocommunities), iv. relatively small size and similarity with native species v. species' long survival in darkness and following recolonization ability, etc. (MTERD, 2020; Garcia-Gomez et al., 2020b). Furthermore, if the algae are collected, it is important to prevent its dispersion, having in mind the high propagation capacity of *R. okamurae.* Moreover, if it is in the sea bottom and is taken above the photic zone it can survive and colonize new shallow areas (this species can survive up to three weeks in the darkness). Another issue that is related to the limited effectiveness of rapid eradication campaigns is the difficulty for the species early detection, due to its 'cryptic invasion'. 'Cryptic invasions' refer to non-native taxa which intrude and spread within a region, without being noticed early enough, as they are very much alike with other native species (Morais & Reichard, 2017). García-Gómez et al. (2018), mention that *R. okamurae* could have been initially (in 2015) confused with *Dictyota pinnatifida*.
Effort required e.g. Number of times, and/or period of time over which measure needs to be applied to have results achieve its objective **(please indicate the units)**	Intense targeted removals should be organised immediately after early detection, and not stop until there are many days with no visible thalli. Effort should be regularly repeated in the following time period. If individuals are detected again, intense eradication campaigns should be repeated.
Resources required [1] e.g. cost, staff, equipment etc. Please note the resources (and their costs if available) that are required to implement the measure to meet its objective.	If a removal programme is attempted, the most cost-effective option is incorporating volunteers already trained to identify *R. okamurae*, as those campaigns are very time consuming and they last for a long period. Taking into consideration that *R. okamurae* occupies numerous of biocommunities and various substrate and depths, it is estimated that the rapid eradication campaigns, will need a lot of staff and huge effort in a short period of time.
Additional cost information [1] When not already included above, or in the species Risk Assessment.	Cost of inaction: Failure to implement eradication campaigns after early detection would increase the risk of establishment of new populations and of further spread of the species, with all the potential associated impacts and costs, for stakeholders and the public (fisheries, touristic activities).

<table>
<tr>
<td>- implementation cost for Member States
- the cost of inaction
- the cost-effectiveness
- the socio-economic aspects

Include quantitative &/or qualitative data, and case studies (incl. from countries outside the EU).</td>
<td>Cost-effectiveness: very low, given the low likelihood of success. Cost-effectiveness could be high only in cases of highly localised populations, detected very early, and thus with increased chances for eradication.</td>
</tr>
<tr>
<td>Side effects (incl. potential) – both positive and negative
i.e. positive or negative side effects of the implementation of the measure (not the IAS itself) on public health, environment including non-targeted species, etc. For example, native species non-target impacts from trapping.

For each of the side effect types please select one of the categories (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.

NOTE – this does not refer to direct intended effects of the measure (e.g. a reduction of the IAS population, or an increase in native species)</td>
<td>
<table>
<tr><td><i>Environmental effects</i></td><td><i>Positive</i></td><td></td><td><i>Mixed</i></td><td><i>X</i></td><td><i>Negative</i></td><td></td><td><i>None</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
<tr><td><i>Social effects</i></td><td><i>Positive</i></td><td><i>X</i></td><td><i>Mixed</i></td><td></td><td><i>Negative</i></td><td></td><td><i>None</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
<tr><td><i>Economic effects</i></td><td><i>Positive</i></td><td></td><td><i>Mixed</i></td><td><i>X</i></td><td><i>Negative</i></td><td></td><td><i>None</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
</table>

<i>Rationale</i>:

The implementation of this measure could have some negative effects on the native benthic biocommunities, on the one hand due to the disturbance of the native species of fauna and flora from the frequent visits of a large number of volunteers and on the other hand from any removal of other species of macroalgae, due to misidentification.

An implementation of such a campaign from volunteers will increase their overall awareness on biological invasions, which is a positive social effect.
</td>
</tr>
<tr>
<td>Acceptability to stakeholders
e.g. impacted economic activities, animal welfare considerations, public perception, etc.

Please select one of the categories of acceptability (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.</td>
<td>
<table>
<tr><td><i>Acceptability to stakeholders</i></td><td><i>Acceptable</i></td><td><i>X</i></td><td><i>Mixed</i></td><td></td><td><i>Unacceptable</i></td><td></td><td><i>Unknown</i></td><td></td></tr>
</table>

<i>Rationale</i>:

<i>R. okamurae</i> is already a problem for the affected areas of Spain, where invasive populations are well established. As a result of that, eradication campaigns are likely to be welcomed and highly accepted by the stakeholders.
</td>
</tr>
</table>

<table>
<tr>
<td>Level of confidence on the information provided [2]

Please select one of the confidence categories along with a statement to support the category chosen. See <i>Notes</i> section at the bottom of this document.
NOTE – this is not related to the effectiveness of the measure</td>
<td>
<table>
<tr><td><i>Inconclusive</i></td><td><i>X</i></td><td><i>Unresolved</i></td><td></td><td><i>Established but incomplete</i></td><td></td><td><i>Well established</i></td><td></td></tr>
</table>
There is a consensus among scientists that eradications of the majority of species with a large dispersal capacity in the marine environment are highly unlikely to succeed, even when detected very early. Eradication by manual removal has never been attempted for <i>R. okamurae</i>.
</td>
</tr>
</table>

<table>
<tr><td colspan="2">Management - Measures to achieve management of the species once it has become widely spread within a Member State, or part of a Member State's territory. (cf. Article 19), i.e. not at an early stage of invasion (see Rapid eradication table above). These measures can be aimed at eradication, population control or containment of a population of the species. This table is repeated for each of the management measures identified.</td></tr>
<tr><td>Measure name</td><td>Populations' control and/or containment via manual removal of the thalli</td></tr>
<tr><td>Measure description
Provide a description of the measure and its objective.

If relevant, include a summary of the methodology to apply the measure, with references to sources of information where detail can be found.</td><td><table><tr><td><i>What objectives can the measure be applied to:</i></td><td><i>Eradication</i></td><td></td><td><i>Population control</i></td><td><i>X</i></td><td><i>Containment</i></td><td><i>X</i></td><td><i>Not applicable</i></td><td></td></tr></table>
There are limited options to control invasive seaweeds, once the opportunity for eradication has passed (Anderson, 2007). Generalized approaches, transferable across marine regions, for prioritizing actions to control invasive populations are currently lacking (Giakoumi et al., 2019). Giakoumi et al. (2019) using expert knowledge prioritized 11 management actions for controlling 12 model species (macrophytes, fish, invertebrates), distinguished by differences in dispersion capacity, distribution in the area to be managed, and taxonomic identity. The most effective measures for macrophytes were identified to be education and public awareness (with the objective for prevention) and encourage the targeted removal and commercial and/or recreational utilization of dead specimens (the taxonomic family to which <i>R. okamurae</i> belongs, presents a considerable diversity of secondary metabolites with possible commercial interest, with terpenes being one of the best represented groups, but there is no evidence of practical application (De Paula et al., 2011). Physical (mechanical) removal of the species is a measure that is not really applicable for macrophytes, and even less so for species with high dispersal capacity and non-localized established populations (Giakoumi et al., 2019).

For established invasive populations the aim of management is generally to reduce their populations to levels that exert lower impacts considered as acceptable (Usseglio et al., 2017). Neilson et al. (2018) show manual removal in combination with hatchery raised urchin biocontrol to be an effective management approach in controlling invasive macroalgae at reef-wide spatial scales and temporal scales of months to years.

<i>R. okamurae</i> has shown a very explosive development, colonizing most of the hard seabed substrates in those areas where the species is present in Spain. Present coverage of the species has not been estimated, but the value will be over hundreds of hectares including marine protected areas. However, there are no known effective control methods for <i>R. okamurae</i> that can be applied in the current stage of invasion in Spain. Considering that there are no known predatory organisms, parasites or pathogens that may affect it in the invaded area, the only management measure that could be implemented, although with doubtful effectiveness is the populations' control and/or containment via manual removal of the thalli.

For further details regarding this measure, please see the 'Rapid Eradication' table above.</td></tr>
</table>

<table>
<tr>
<td>Scale of application
At what geographic scale is the measure applied? What is the largest scale at which it has been successfully used?
Please provide examples reporting areas (km^2 or ha) if possible.</td>
<td>Populations’ control via manual removal of the thalli has not been attempted for <i>R. okamurae</i> anywhere in the invaded range. This measure could be applied in the areas where <i>R. okamurae</i> is causing the most significant problems (to fishing and touristic sector), in order to reduce its impact.</td>
</tr>
<tr>
<td>Effectiveness of the measure
Is it effective in relation to its objective?

Based on cases where the measure has been applied (ideally correctly and comprehensively), please select one of the categories of effectiveness (with an ‘X’), and provide a rationale, with supporting evidence and examples of effectiveness, if possible.

Please identify factors that are critical in determining its effectiveness.

Please note if effectiveness is based on research only (e.g. field trials).</td>
<td>
<table>
<tr>
<td><i>Effectiveness of measures</i></td>
<td><i>Effective</i></td>
<td></td>
<td><i>Neutral</i></td>
<td></td>
<td><i>Ineffective</i></td>
<td></td>
<td><i>Unknown or not yet applied</i></td>
<td><i>X</i></td>
</tr>
</table>
<i>Rationale</i>:
Effective control methods for <i>R. okamurae</i> that can be applied in the current stage of invasion are not known, although actions towards the management of established populations should be considered, in order to minimize the impact they cause.
Unfortunately, the effectiveness of <i>R. okamurae</i>’s control via manual removal of the thalli is likely to be very low, due to the species dispersal capacity, darkness tolerance, occupation on various biocommunities and substrate.
For further information, please see the ‘Rapid Eradication’ table above.
</td>
</tr>
<tr>
<td>Effort required
e.g. Number of times, and/or period of time over which measure needs to be applied to have results achieve its objective
(please indicate the units)</td>
<td>Intense targeted removals should be organised at the areas where the most significant problems of the invasive expansion of the species is recognized. Effort should be implemented for many days and requires significant number of volunteers, as the affected areas are extended (García-Gómez et al., 2020b). In order to control the populations, the measure should be often repeated. There is no information available of the most appropriate time of the year for the establishment of <i>R. okamurae,</i> and thus for the management measures.</td>
</tr>
<tr>
<td>Resources required [1]
e.g. cost, staff, equipment etc.
Please note the resources (and their costs if available) that are required to implement the measure to meet its objective.</td>
<td>If a removal programme is attempted, the most cost-effective option is incorporating volunteers already trained to identify <i>R. okamurae</i>, as those campaigns are very time consuming and they last for a long period. Taking into consideration that <i>R. okamurae</i> occupies numerous of bio communities and various substrate and depths, it is estimated that the population control campaigns, will need a lot of staff and huge effort.</td>
</tr>
</table>

<table>
<tr>
<td>Additional cost information [1]
When not already included above, or in the species Risk Assessment.
- implementation cost for Member States
- the cost of inaction
- the cost-effectiveness
- the socio-economic aspects

Include quantitative &/or qualitative data, and case studies (incl. from countries outside the EU).</td>
<td>As the established area of the species is currently big and predicted to increase (MTERD, 2020; García-Gómez et al. 2020b), it can be suggested that costs in managing the species may increase exponentially together with its expansion.

Cost of inaction: Failure to implement population control campaigns would maintain and probably increase all the significant impact of R. okamurae invasive populations on native flora and fauna taxa and in addition the economic impacts on the fisheries and touristic sectors.

Cost-effectiveness: very low, given the low likelihood of success.</td>
</tr>
<tr>
<td>Side effects (incl. potential) – both positive and negative
i.e. positive or negative side effects of the implementation of the measure (not the IAS itself) on public health, environment including non-targeted species, etc. For example, native species non-target impacts from trapping.

For each of the side effect types please select one of the categories (with an ‘X’), and provide a rationale, with supporting evidence and examples if possible.

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Rationale:

See Rapid Eradication table above.</td>
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</table>
Rationale:</td>
</tr>
</table>

Please select one of the categories of acceptability (with an 'X'), and provide a rationale, with supporting evidence and examples if possible.	*R. okamurae* constitutes already a problem for the affected areas of Spain, where invasive populations are already well established, causing trouble to fisheries and touristic activities, as well as to native flora and fauna. As a result of that, management actions for controlling the populations are likely to be welcomed and highly accepted by the stakeholders.
Level of confidence on the information provided [2] Please select one of the confidence categories along with a statement to support the category chosen. See *Notes* section at the bottom of this document. **NOTE – this is not related to the effectiveness of the measure**	*Inconclusive* X · *Unresolved* ☐ · *Established but incomplete* ☐ · *Well established* ☐ *Rationale*: There is a consensus among scientists that population control or containment of species with a large dispersal capacity in the marine environment are highly unlikely to succeed. Management measures aiming at the containment or control of the populations has never been attempted for *R. okamurae*.

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See guidance section

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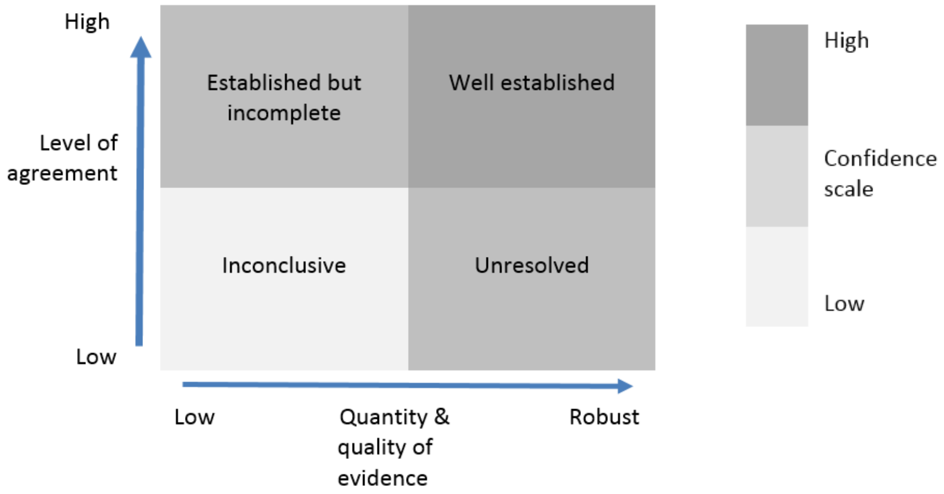
<u>Notes</u>

1. Costs information. The assessment of the potential costs shall describe those costs quantitatively and/or qualitatively depending on what information is available. This can include case studies from across the Union or third countries.

2. Level of confidence[24]: based on the quantity, quality and level of agreement in the evidence.



- **Well established**: comprehensive meta-analysis[25] or other synthesis or multiple independent studies that agree.
- **Established but incomplete**: general agreement although only a limited number of studies exist but no comprehensive synthesis and/or the studies that exist imprecisely address the question.
- **Unresolved**: multiple independent studies exist but conclusions do not agree.
- **Inconclusive**: limited evidence, recognising major knowledge gaps

3. Citations and bibliography. The APA formatting style for citing references in the text and in the bibliography is used.
e.g. Peer review papers will be written as follows:
In text citation: (Author & Author, Year)
In bibliography: Author, A. A., & Author, B. B. (Publication Year). Article title. *Periodical Title*, Volume(Issue), pp.-pp.

(see http://www.waikato.ac.nz/library/study/referencing/styles/apa)

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[24] Assessment of confidence methodology is taken from IPBES. 2016. Guide on the production and integration of assessments from and across all scales (IPBES-4-INF-9), which is adapted from Moss and Schneider (2000).

[25] A statistical method for combining results from different studies which aims to identify patterns among study results, sources of disagreement among those results, or other relationships that may come to light in the context of multiple studies.