# Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention

## Contract No 07.0202/2016/740982/ETU/ENV.D2

*Final Report*

**Annex 9: Risk Assessment for *Plotosus lineatus* (Thunberg, 1787)**

**Risk assessment template developed under the "Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention" Contract No 07.0202/2016/740982/ETU/ENV.D2**

**Based on the Risk Assessment Scheme developed by the GB Non-Native Species Secretariat (GB Non-Native Risk Assessment - GBNNRA)**

**Name of organism:** *Plotosus lineatus* (Thunberg, 1787)

Common name: striped eel catfish

**Author(s) of the assessment:**
Marika Galanidi: Dr, Dokuz Eylul University, Institute of Marine Sciences and Technology, Izmir, Turkey
Argyro Zenetos Dr, Research Director, Hellenic Centre for Marine Research, Greece

**Risk Assessment Area:** European Union (excluding the outermost regions)

**Peer review 1:** Jack Sewell, The Marine Biological Association, Plymouth, United Kingdom
**Peer review 2:** Rabitsch Wolfgang Environment Agency Austria, Department of Biodiversity and Nature Conservation, Vienna, Austria

**Peer review 3:** Rob Tanner, Scientific Officer Invasive Alien Plants, European and Mediterranean Plant Protection Organization (EPPO/OEPP)
**Peer review 4:** Elena Tricarico, Università degli Studi di Firenze, Firenze, Italy

**Peer review 5:** Paul Stebbing, Aquatic non-native species specialist, Cefas, The Nothe, Barrack Road, Weymouth, DT4 8UB

This risk assessment has been peer-reviewed by five independent experts and discussed during a joint expert workshop. Details on the review a how comments were addressed are available in the final report of the study.

**Completed:** 17/11/2017

Approved by IAS Scientific Forum on 26/10/2018

| **RISK SUMMARIES** | | | |
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| | **RESPONSE** | **CONFIDENCE** | **COMMENT** |
| **Summarise Entry** | very likely | very high | Originally a Lessepsian immigrant, *Plotosus lineatus* is not yet proliferating within marine subregions of the EU, but has established populations in neighbouring countries (Tunisia, Turkey and the Middle East) and will very likely enter the EU region by natural dispersal. Considering its limited demand in the aquarium trade and its presence in a relatively small number of~~popularity in~~ large public aquaria in the potential establishment area, the likelihood of entry through aquaria related pathways is not very high~~also high~~. |
| **Summarise Establishment** | very likely | very high | *P. lineatus* can tolerate a wide range of salinities, occupies many different marine habitats and has thermal requirements that are met throughout the Mediterranean Sea, the Black Sea and a limited area in the Bay of Biscay (where establishment can occur only after an aquarium-related introduction event). It is already established in the Levantine Sea and expanding its distribution towards the north and west; its establishment in the risk assessment area is thus considered very likely. Establishment is not expected to be prevented by competition or predation and will likely be facilitated by existing management practices in Europe, particularly the Mediterranean-wide trawling ban at depths<50m and other national fisheries restrictions, which will favour both the spawning and the early life stages of the species with a preference for shallow waters.. |
| **Summarise Spread** | moderately rapidly | high | The short duration and demersal nature of the larvae and the population explosion of *P. lineatus* in Israel point to larval retention in this region. It appears that |

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| | | | post-larval dispersal of the juveniles and adults has driven the spread of this species in the Mediterranean Sea so far at rates of 100-200 km per year; however it is probably only the adults that can cross large distances isolated by deeper waters. The juveniles move incessantly over sand while feeding so it is unlikely that they will venture (or survive well) into deep waters where food is more scarce.  Its climatic requirements are not anticipated to pose significant barriers for spread, with only a few areas in the Mediterranean and the Black Sea displaying temperatures close to its thermal limit for spawning. In the rest of the EU Seas, establishment is expected to be limited to the Bay of Biscay and the south coast of Portugal. At a more localized scale, some spread could be achieved through fisheries discards, which may also facilitate the species in overcoming depth limitations to its dispersal, while capture and transportation of specimens for the aquarium trade may effect a larger scale spread albeit of lesser importance. |
| **Summarise Impact** | major | low | The ecological role of the species in the invaded range has not been adequately studied and, at the abundances reached in a population explosion, it is likely to be important. *P. lineatus* has the potential to exert significant predation pressure on native prey species, compete for resources with similar predators and effect changes in native community structure. The organism has been implicated in the competitive exclusion of the native species *Mullus barbatus* and *M. surmuletus* from coastal sandy habitats. Moreover, feeding swarms of juveniles may increase turbidity, affecting suspension feeders, and change properties of the sediment with implications for nutrient cycling, mobilization of demersal eggs or dormant cysts. |

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| | | | The recorded social impacts on the health and safety of fishermen and beachgoers stung by *P. lineatus* are currently moderate but widespread in the affected areas. The possibility of more severe injuries affecting larger areas, as this venomous species spreads in the Mediterranean Sea cannot be ignored.<br>Economic impacts in the invaded range are largely associated with the substantial presence of *P. lineatus* in trawl catches as discards and the loss of income to fishermen because of the increased time needed to sort the catch and the loss of working hours due to injuries. Fisheries regulations in the EU means that lower bycatch rates and less severe impacts may be expected in the risk assessment area.<br>Applying the precautionary principle, we conclude that this species can have major impacts both on the environment and human well-being. |
| **Conclusion of the risk assessment** | high | medium | With a high likelihood of entry through natural dispersal from neighbouring countries and the possibility of “facilitated” or accidental escapes from domestic or public/private aquaria, high likelihood for establishment and subsequent population explosion and the potential for major environmental and health impacts, *P. lineatus* is considered a high risk invasive species for the EU. |

**Distribution Summary (for explanations see EU chapeau and Annex 2):**

Member States

| | Recorded | Established (currently) | Established (future) | Invasive (currently) |
|---|---|---|---|---|
| Belgium | - | - | - | - |
| Bulgaria | - | - | Yes | - |
| Croatia | - | - | Yes | - |
| Cyprus | - | - | Yes | - |

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| Denmark | - | - | - | - |
| Estonia | - | - | - | - |
| Finland | - | - | - | - |
| France | - | - | Yes | - |
| Germany | - | - | - | - |
| Greece | - | - | Yes | - |
| Ireland | - | - | - | - |
| Italy | - | - | Yes | - |
| Latvia | - | - | - | - |
| Lithuania | - | - | - | - |
| Malta | - | - | Yes | - |
| Netherlands | - | - | - | - |
| Poland | - | - | ? | - |
| Portugal | - | - | Yes | - |
| Romania | - | - | Yes | - |
| Slovenia | - | - | Yes | - |
| Spain | - | - | Yes | - |
| Sweden | - | - | - | - |
| United Kingdom | - | - | - | - |

EU marine regions and subregions

| | Recorded | Established (currently) | Established (future) |
|---|---|---|---|
| Baltic Sea | - | - | ? |
| Black Sea | - | - | Yes |
| North-east Atlantic Ocean | - | - | - |
| Bay of Biscay and the Iberian Coast | - | - | ? |
| Celtic Sea | - | - | - |
| Greater North Sea | - | - | - |
| Mediterranean Sea | - | - | - |
| Adriatic Sea | - | - | Yes |
| Aegean-Levantine Sea | Yes | Yes | Yes |

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| Ionian Sea and the Central Mediterranean Sea | - | - | Yes |
| Western Mediterranean Sea | Yes | Yes | Yes |

| **EU CHAPEAU** | | |
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| **QUESTION** | **RESPONSE** | **COMMENT** |
| 1. In which EU biogeographical region(s) or marine subregion(s) has the species been recorded and where is it established? | Recorded: Aegean-Levantine Sea (Egypt, Israel, Lebanon, Syria, Turkey) and Western Mediterranean Sea (Tunisia).<br>Established: Mediterranean – Aegean-Levantine Sea (Egypt, Israel, Lebanon, Syria, Turkey) and Western Mediterranean Sea (Tunisia) | |
| 2. In which EU biogeographical region(s) or marine subregion(s) could the species establish in the future under current climate and under foreseeable climate change? | **Current climate:**<br>Mediterranean - Aegean-Levantine Sea, Western Mediterranean Sea, Ionian Sea and the Central Mediterranean, Adriatic Sea<br>Black Sea<br>Bay of Biscay and the Iberian Coast (low likelihood)<br><br>**Foreseeable climate change:**<br>Mediterranean – Aegean-Levantine Sea, Western Mediterranean Sea, Ionian Sea and the Central Mediterranean, Adriatic Sea<br>Black Sea<br>Bay of Biscay and the Iberian Coast (low likelihood)<br><br>For relevant distribution maps, see the Annexes 1, 2 | Spawning of *P.lineatus* occurs in June-July (Heo et al., 2007) for Japan, Edelist et al., 2012 combined with life-cycle characteristics for Israel- see Q1.23) and at temperatures between 21 and 27 °C (Moriuchi & Dotsu, 1973). Suitable temperature conditions are currently met in the Mediterranean, Black Sea and the Iberian coast and the Bay of Biscay marine regions. With particular reference to the Iberian coast and the Bay of Biscay, sea surface temperatures (SST) of 21 °C in July are currently observed in the south coast of Portugal and in the Bay of Biscay (2012-2016 SST average, datasets retrieved from Copernicus Marine Services-see URL http://marine.copernicus.eu/services-portfolio/access-to-products/?option=com_csw&view=details&product_id=GLOBAL_REP_PHY_001_021. Regarding salinity requirements, *P. lineatus* is considered an amphidromous marine catfish species that is known to enter estuaries and withstand brackish water conditions (Froese & Pauly, 2017). Job (1959) found that *P. lineatus* held in experimental conditions at 29 °C could tolerate salinities |

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| | | between 2-52 ppt. In fact, the metabolic performance of individuals (both juveniles and adults) acclimated at 12.5 ppt was higher than that of animals kept at 30ppt. Although specific information about salinity thresholds for reproduction and egg/larval survival was not found, there is evidence that *P. lineatus* is common in saline lakes, where salinity can drop to 26ppt (Wallis Lake, Australia – Glasby & van der Broek, 2010; Pitt & Kingsford, 2000) and is also commonly found in river estuaries in Singapore, with recorded salinities as low as 12 ppt (Goh & Goh, 1989; Sin et al., 1991). It is thus considered very likely to be able to penetrate the Strait of Marmara, where both its salinity and temperature requirements are met. Based on the above information, establishment in the Black Sea (salinities of 14-18 ppt) may also be possible but this prediction has a low certainty.<br>It should also be noted that in the Bay of Biscay establishment may occur only after a new introduction event via a human-mediated pathway (unaided dispersal is limited to southern Portugal). This event is not considered very likely (see Risk of Introduction section).<br>Future climate conditions for mapping and distribution assessment purposes were considered as an overall 2 °C sea surface temperature (SST) increase by 2098, projected according to the RCP4.5 scenario of IPCC which corresponds to medium-high anthropogenic radiative forcing RF; an increase in SST of up to 3 °C is predicted under the RCP8.5 scenario corresponding to high anthropogenic RF – IPCC AR5 report, 2013 |

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| 3. In which EU member states has the species been recorded? List them with an indication of the timeline of observations. | None | |
| 4. In which EU member states has this species established populations? List them with an indication of the timeline of establishment and spread. | None | |
| 5. In which EU member states could the species establish in the future under current climate and under foreseeable climate change? | **Current climate:** Cyprus, Greece, Italy, Malta, Croatia, Slovenia, France, Spain, Portugal, Bulgaria, Romania<br><br>**Foreseeable climate change:** Cyprus, Greece, Italy, Malta, Croatia, Slovenia, France, Spain, Portugal, Bulgaria, Romania | See comment in Q.2 about temperature requirements for successful reproduction. In a future scenario of temperature increase by 2 °C, these requirements will be met further north along the west coast of Portugal and for more prolonged periods in the summer |
| 6. In which EU member states has this species shown signs of invasiveness? | None | The species has not entered the risk assessment area. It has shown signs of invasiveness in neighbouring countries of the Levant (see Q.A6). |
| 7. In which EU member states could this species become invasive in the future under current climate and under foreseeable climate change? | **Current climate:** Cyprus, Greece, Italy, Malta, Croatia, Slovenia, Mediterranean France, Spain (Med)<br><br>**Foreseeable climate change:** Cyprus, Greece, Italy, Malta, Croatia, Slovenia, Mediterranean France, Spain (Med) | Under the conditions mentioned above (Q2), the species could establish in the Black Sea and, with a low likelihood, in the Bay of Biscay. It is unlikely that the species will thrive in large numbers at the boundaries of areas of habitat suitability (Townhill et al., 2017). |

| **SECTION A – Organism Information and Screening** | | |
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| **Organism Information** | **RESPONSE** | **COMMENT** |
| 1. Identify the organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank? | Phylum: Chordata, Class: Actinopterygii, Order: Siluriformes (catfish), Family: Plotosidae, Genus/species: *Plotosus lineatus* (Thunberg, 1787)<br><br>**most common synonyms**:*Plotosus anguillaris* (Bloch, 1794)<br>*Plotosus arab* Bleeker, 1862<br><br>**Other synonyms**<br>*Platystacus anguillaris* Bloch, 1794<br>*Plotoseus ikapor* Lesson, 1831<br>*Plotosus brevibarbus* Bessednov, 1967<br>*Plotosus castaneoide*s Bleeker, 1851<br>*Plotosus castaneus* Valenciennes, 1840<br>*Plotosus flavolineatu*s Whitley, 1941<br>*Plotosus lineatus* Valenciennes, 1840<br>*Plotosus marginatus* Anonymous [Bennett], 1830<br>*Plotosus thunbergianus* Lacepède, 1803<br>*Plotosus vittatus* Swainson, 1839<br>*Silurus arab* Forsskål, 1775<br>*Silurus lineatus* Thunberg, 1787 | No varieties, breeds or hybrids are known.<br>Other synonyms listed (FishBase, 2017) are not in use, neither in research or trade/commercial use.<br>Possible species complex: in Bariche et al. (2015) "Distance trees of *P. lineatus* showed that genetic distances within this group were very large and probably indicated the presence of more than one species. This was supported by the presence, within this species complex, of a newly described species, *Plotosus japonicus* that was recently separated from *P. lineatus* (Yoshino & Kishimoto, 2008).<br>Even though only *P. lineatus* is reported from the Red Sea and the study of Bariche et al. (2015) examined only 4 specimens of *P. lineatus* from Lebanon, the information is presented herein for future reference, in case a cryptic invasion is revealed by future molecular studies. Changes in nomenclature/identification resulting from both traditional and molecular studies are common for Mediterranean marine invaders (reviewed by Zenetos et al., 2017). |
| 2. Provide information on the existence of other species that look very similar | *Plotosus lineatus* is the only member of the family Plotosidae reported in the Mediterranean (and the Red Sea).<br>The four pairs of barbels together with the shape and colour of this catfish distinguish it from any other Mediterranean fish species (Otero et al., 2013) | There are no other *Plotosus* species that have been introduced outside of their native range. However, *Plotosus limbatus* (Valenciennes, 1840) and *Paraplotosus albilabirs* (Valenciennes, 1840) are also imported into the USA for ornamental purposes (aquariumtradedata.org, Rhyne et al., 2012). |

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| | See Q.1 above for the possibility of a species complex. | |
| 3. Does a relevant earlier risk assessment exist? (give details of any previous risk assessment and its validity in relation to the EU) | There is no previous full risk assessment, however *P. lineatus* was identified by the latest EU horizon scanning exercise (Roy et al., 2015) as a priority species, with the tenth highest score among species of all taxonomic groups. | |
| 4. Where is the organism native? | Indo-Pacific: Red Sea and East Africa to Samoa, north to southern Japan, southern Korea, and the Ogasawara Islands, south to Australia and Lord Howe Island. Palau and Yap in Micronesia. Sometimes enters freshwaters of East Africa (Lake Malawi) and Madagascar (FishBase, 2017). | This species lives in a variety of coastal benthic habitats, coral reefs, seagrass beds, estuaries and tide pools and open coast (Froese & Pauly, 2017). Juveniles forage in the daytime over sandy and muddy areas, algal beds, on and in coral reef structures and retire at night under reef/rock ledges or artificial structures; *Plotosus lineatus* adults are solitary or occur in small groups of up to 20. Adults are nocturnal and known to hide under ledges or caves during the day (Clark et al., 2011). It is an euryhaline species (Pucke & Umminger, 1979) that tolerates low salinities well (Job, 1959) and prefers warm waters (temperature range 21-29 °C according to OBIS records) (OBIS, 2017). |
| 5. What is the global non-native distribution of the organism (excluding the Union, but including neighbouring European (non-Union) countries)? | Levantine Sea (Egypt, Israel, Lebanon, Syria, Turkey)<br>Western Mediterranean ( Tunisia) | The species has been recorded from neighbouring countries and marine subregions of the EU<br>Israel – first record 2002 (Golani, 2002) - established<br>Egypt – first record 2012 (Temraz & Ben Souissi, 2013) – established<br>Lebanon - 2012 (Bitar, 2013) - established<br>Tunisia – first record 2013 (Ounifi Ben Amor et al., 2016) - established<br>Syria – first record 2014 (Ali et al., 2015) - established (Ali et al., 2017)<br>Turkey – first record 2016 (Doğdu et al., 2016) - established (Cemal Turan, pers.comm.) |

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| 6. Is the organism known to be invasive (i.e. to threaten organisms, habitats or ecosystems) anywhere in the world? | Yes | It is a venomous species and has caused numerous injuries to fishermen and beachgoers in Israel (Gweta et al., 2008; Edelist et al., 2012; Bentur et al., 2017).<br>It can reach considerable densities (up to 10% of trawl catches by number of individuals) and interferes with fisheries as a bycatch species (Edelist et al., 2012).<br>At these densities predation and competition impacts are likely significant; Arndt et al. (2018) demonstrated a strong overlap in diet and habitat use preferences between *P. lineatus* and the native mullet species *Mullus barbatus* and *Mullus surmuletus* which have declined by approximately one order of magnitude in the shallow sandy coasts of Israel over the past 20 years. They concluded that *P. lineatus*, together with two non-indigenous *Upeneus* species, has likely contributed to the competitive exclusion of the two mullets from the region (Arndt et al., 2018). |
| 7. Describe any known socio-economic benefits of the organism in the risk assessment area. | *P. lineatus* has a low socio-economic benefit to the EU.<br>*P. lineatus* has commercial value in the aquarium industry (DEH-Australian Government, 2005). In Hong Kong it rated among the 25 most important aquarium species traded but yield commercial values at the low end of the price range (Chan and Sadovy, 2000). The species appears to be popular among aquarists in the US (Rhyne et al, 2012).<br>In relation to the UK and Europe, the retail trade in this species is low (OATA, pers. comm, May 2018). OATA estimates that in relation to the UK, sales of individuals of this species would, depending on annual demand, be in the region of 300 individuals | In its native range, *P. lineatus* is used in commercial fisheries. It is exploited by small scale fishers (Vijayakumaran 1997), but it is considered of low value (Manikandarajan et al., 2014; Situ & Sadovy, 2004)).<br>The species has been studied for potential biomedical applications (anti-tumor activity) of toxins found in the spines and epidermis (Shiomi et al., 1988; Fahim et al., 1996). This species has further been used in research in areas such as sibling recognition via chemoreception e.g. Matsumura et al., (2004) and its mitochondrial genome sequence, such as Ruan et al., (2016). |

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| | per annum. 20 to 50% of sales of this species are not to retail but to public aquaria and research institutions.<br><br>The species is currently displayed in public aquaria in Austria, Italy, Germany (x2), Monaco, Malta, Poland, while in the past it has been on display in at least 11 more public aquaria (Annex 3). | |

## SECTION B – Detailed assessment

**Important instructions:**

- In the case of lack of information the assessors are requested to use a standardized answer: "No information has been found."
- For detailed explanations of the CBD pathway classification scheme consult the IUCN/CEH guidance document.
- With regard to the scoring of the likelihood of events or the magnitude of impacts see Annex
- With regard to the confidence levels, see Annex.

### PROBABILITY OF INTRODUCTION and ENTRY

Important instructions:

- Introduction is the movement of the species into the EU.
- Entry is the release/escape/arrival in the environment, i.e. occurrence in the wild. Not to be confused with spread, the movement of an organism within Europe.
- For organisms which are already present in Europe, only complete this section for current active or if relevant potential future pathways. This section need not be completed for organisms which have entered in the past and have no current pathway of introduction and entry.

| QUESTION | RESPONSE [chose one entry, delete all others] | CONFIDENCE [chose one entry, delete all others] | COMMENT |
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| 1.1. How many active pathways are relevant to the potential entry of this organism?<br><br>(If there are no active pathways or potential future pathways respond N/A and move to the Establishment section) | few - 4 | high | CORRIDOR-introduction via the Suez Canal is the primary pathway- recipient countries are located in the Levantine basin.<br>UNAIDED Natural dispersal across borders from neighbouring countries, where the species has been introduced (Israel, Egypt, Turkey, Syria, Lebanon, Tunisia)<br>ESCAPE FROM CONFINEMENT Pet/aquarium/terrarium species (intentional release) |

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| | | | ESCAPE FROM CONFINEMENT Botanical gardens/zoo/aquaria and Research/Ex-situ breeding (unintentional release) |
| 1.2. List relevant pathways through which the organism could enter. Where possible give detail about the specific origins and end points of the pathways as well as a description of the associated commodities.<br><br>For each pathway answer questions 1.3 to 1.10 (copy and paste additional rows at the end of this section as necessary). Please attribute unique identifiers to each question if you consider more than one pathway, e.g. 1.3a, 1.4a, etc. and then 1.3b, 1.4b etc. for the next pathway. | CORRIDOR (Interconnected waterways, basins & seas – Suez Canal)<br><br>UNAIDED (natural dispersal from neighbouring countries)<br><br>ESCAPE FROM CONFINEMENT Pet/aquarium/terrarium species<br><br>ESCAPE FROM CONFINEMENT: Botanical gardens/zoo/aquaria and Research/ex-situ breeding | very likely<br><br>very likely<br><br>possible<br><br>possible | primary pathway<br><br>secondary pathway<br><br>primary pathway- from domestic aquaria<br><br>primary pathway - public/private aquaria and research facilities/Unintentional |
| Pathway name: | **CORRIDOR (Interconnected waterways, basins & seas – Suez Canal)** | | |
| 1.3a. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?<br><br>(If intentional, only answer questions 1.4, 1.9, 1.10, 1.11) | unintentional | very high | |

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| 1.4a. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?<br><br>Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place.<br>Subnote: In your comment discuss the volume of movement along this pathway. | very likely | very high | *P. lineatus* is a Lessepsian immigrant, present in the Suez Gulf and Suez Canal since the 1930's (Chabanaud, 1932). The species has demersal eggs and demersal larvae (Leis, 1991, Moriuchi & Dotsu 1973). Its fecundity ranges from 525 to 1176 eggs per year (Heo et al., 2007) and spawning in both the native and the invaded range occurs in the summer (Edelist et al., 2012 and references therein). The demersal larvae are likely to be carried by bottom currents for some distance but still remain nearshore (Leis, 1993) until they reach the juvenile free swimming stage (10-15 days), after which they start swarming, i.e. form large "balls" consisting of hundreds of juveniles. Adults are solitary or move in small groups, of up to 20 individuals. Dispersal along the Suez Canal for this species is thus assumed to occur through active swimming and is not affected by changes in current direction in the Canal (from winter to early summer the current flows from the Gulf of Suez to the Mediterranean; a complete reversal occurs in September when the current flows through the Canal from the Mediterranean into the Gulf of Suez; during the summer, changes in current direction transport water into the Bitter Lakes – Morcos, 1975).<br>Even if eradicated in the Mediterranean Sea (both inside and outside the EU) the likelihood of reinvasion in the first recipient countries (Egypt, Israel) and hence its spread in the rest EU countries is very high. |
| 1.5a. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)?<br><br>Subnote: In your comment consider whether the organism could multiply along the pathway. | very likely | very high | The organism has already successfully crossed the Suez Canal in numbers sufficient for successful establishment in the Mediterranean Sea. Since it belongs to the resident fauna of the canal it can both survive and multiply along this pathway. |

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| 1.6a. How likely is the organism to survive existing management practices during passage along the pathway? | very likely | very high | There are currently no management practices that can prevent the survival of marine invasive species during their passage along the Suez Canal (Galil et al., 2017). |
| 1.7a. How likely is the organism to enter Europe undetected? | NA (RA area)<br><br>very likely (neighbouring countries) | high | The organism will not enter the risk assessment area directly through this pathway but through natural dispersal from neighbouring countries. Given that the first record in the Mediterranean Sea was from Israel in 2002 (Golani, 2002), but *P. lineatus* was detected in Egypt only in 2012 (Temraz & Ben Souissi, 2013), the organism may remain undetected for a considerable time after its passage through the Suez Canal, depending on location and research effort. New introductions through this pathway will likely be indistinguishable from already established populations, unless genetic studies are conducted. |
| 1.8a. How likely is the organism to arrive during the months of the year most appropriate for establishment? | likely | high | Adults can cross the Suez Canal at any time of the year. Spawning in the native and invaded range takes place in late spring and summer; thus, reproductive adults and juveniles are more likely to arrive in the summer and early autumn respectively. Since the passive early life stages of *P. lineatus* only last approximately 10-15 days, after which free swimming begins, dispersal along this pathway is not constrained by current direction. |
| 1.9a. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host? | very likely | very high | The pathway itself constitutes suitable habitat. Given the generalist habitat preferences of *P. lineatus*, suitable habitats abound in the recipient region. |
| 1.10a. Estimate the overall likelihood of entry into Europe based on this pathway? | NA (RA area)<br>very likely (neighbouring countries) | very high | The organism will not enter the risk assessment area directly through this pathway but through natural dispersal from neighbouring countries. It has already entered the Mediterranean through the Suez Canal and has established successful populations in the East Mediterranean. This pathway is still active and repeated introductions are considered very likely. |
| *End of pathway assessment, repeat as necessary.* | | | |

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| Pathway name: | **UNAIDED Natural dispersal across borders of invasive alien species that have been introduced through other pathways** | | |
| 1.3b. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?<br><br>(If intentional, only answer questions 1.4, 1.9, 1.10, 1.11) | unintentional | very high | Since it was first reported in the Mediterranean (Israel, Golani 2002), the species has been recorded in neighbouring countries (Lebanon, Syria, Turkey, Egypt, Tunisia), hence its natural dispersal in marine (sub)regions of the risk assessment area is confirmed. |
| 1.4b. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?<br><br>Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place.<br>Subnote: In your comment discuss the volume of movement along this pathway. | very likely | very high | *P.lineatus* has demersal eggs and demersal larvae (Leis, 1991, Moriuchi & Dotsu 1973). It reaches sexual maturity after 1-3 years (Thresher 1984), its fecundity ranges from 525 to 1176 eggs per year (Heo et al., 2007) and spawning in Israel occurs in the summer (Edelist et al., 2012).<br>The demersal larvae are likely to be carried by bottom currents for some distance but still remain nearshore (Leis, 1993) until they reach the juvenile free swimming stage (10-15 days), after which they start swarming, i.e. form large “balls” consisting of hundreds of juveniles. These swarms can move hundreds of meters in one hour while feeding over sand and when they rest for the night they do not necessarily return to the point where they started in the day (Clark et al., 2011). In this manner, juveniles of *P. lineatus* may cover considerable distances over suitable habitats in the time it takes to reach maturity (1-3 years). Adults return to shallow waters to breed and deposit the eggs in the sand, under rocks or other debris (more refs Thresher, 1984). Riede (2004) characterizes *P. lineatus* as amphidromous, with migrations that can cover more than 100 km.<br>Edelist et al. (2012) and Occhipinti-Ambrogi & Galil (2010) have reported considerable populations of *P. lineatus* juveniles (and adults) along the coast of Israel |

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| | | | (total numbers in the order of 1000-10000 in trawl surveys).<br>In Tunisia, there are fewer reported specimens, hence propagule pressure is considered to be much lower.<br>*P. lineatus* is a Lessepsian immigrant, present in the Suez Gulf and Suez Canal since the 1930's (Chabanaud, 1932). Even if the species is eradicated in the Mediterranean Sea (both inside and outside the EU) the likelihood of reinvasion in the first recipient countries (Egypt, Israel) and hence its spread in the rest EU countries is very high. |
| 1.5b. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)?<br><br>Subnote: In your comment consider whether the organism could multiply along the pathway. | very likely | very high | The current natural dispersal of *P. lineatus* along the Levantine coast is unequivocal evidence that the species is able to survive and reproduce along this pathway (Golani, 2002), establishing populations along the way at suitable habitats and depths (0-83m) (Edelist et al., 2012).<br>However, due to the demersal nature, swarming behaviour and large dependency of the juveniles on benthic prey resources, dispersal is anticipated mainly during the adult phase over deep water (see Clark et al., 2011). |
| 1.6b. How likely is the organism to survive existing management practices during passage along the pathway? | very likely | very high | No management practices are in place concerning natural dispersal that can affect the organism's ability to survive along this pathway (personal communication with regional experts: Dr.Branko Dragičević (Croatia), Dr. Lovrenc Lipej (Slovenia), Dr. Francisco Alemany (Spain), Dr. Franco Andaloro, Dr. Ernesto Azzurro (Italy), Dr. Alan Deidun, Dr. Patrick Schembri (Malta), Dr. Michel Bariche (Lebanon). |
| 1.7b. How likely is the organism to enter Europe undetected? | likely | medium | *P. lineatus* is expected to arrive to Cyprus, Greece, Italy (Sicily) and possibly France (Corsica), South Spain, where it will most likely first be detected by trawl fishermen (similarly to its first record in the Mediterranean by Israeli fishermen – Golani, 2002), or |

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| | | | divers (Ali et al., 2015, Dogdu et al., 2016). *P. lineatus* inclusion in the EU HORIZON scanning list (Roy et al., 2015) and recently in the Cypriot Horizon scanning (RISKY project) has raised great scientific interest into this species, which may increase the likelihood of detection. Researchers know to look for it during surveys such as in MEDITS (International bottom trawl survey in the Mediterranean Sea, aimed at conducting co-ordinated surveys from bottom trawling in the Mediterranean). Some delays in the detection may occur depending on survey/monitoring efforts and frequency and specific fisheries restrictions, temporal or spatial, such that the first introduction events are unlikely to be detected (spawning and recruitment take place in the summer, when e.g. fisheries restrictions in the Mediterranean are generally in place).<br>Moreover, raising awareness in Greece has been attempted at various levels (meeting of stakeholders, NGOs, and citizen scientists). Relevant initiatives such as within ELNAIS (http://elnais.hcmr.gr/), ARCHIPELAGOS (http://archipelago.gr/) iSea (http://isea.com.gr/el/ ], greatly aid to the early detection of alien species.<br>The possibility of *P. lineatus* entering Greek waters has been advertised through media channels including newspapers and magazines.<br>Regarding other European countries, aside from the implementation of the relevant EU directives, formal and informal networks of scientists with various stakeholders (fishermen, divers, naturalists, etc.) operate in many Mediterranean countries for the early detection of alien species. (pers.comm. with regional experts – Annex 5). |
| 1.8b. How likely is the organism to arrive during the months of the year most appropriate for establishment? | very likely | very high | Spawning in the native range and Israel occurs in the summer (June-July) (Heo et al., 2007; Edelist et al., 2012), and recruitment follows soon after (larval lifespan |

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| | | | approximately 10-15 days, see also Q1.4a, 1.4b). Thus, reproductive adults and juveniles are more likely to arrive in the summer. |
| 1.9b. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host? | very likely | very high | During natural dispersal, organisms usually arrive and settle in suitable habitats or move on and if no suitable habitat is found within their maximum larval lifespan perish. However, its demersal nature, swarming behaviour and large dependency on benthic prey resources may prevent it from crossing large distances with over deep waters at the juvenile stage (see Clark et al., 2011). |
| 1.10b. Estimate the overall likelihood of entry into Europe based on this pathway? | very likely | very high | The likelihood of entry into the risk assessment area from neighbouring areas by unaided natural dispersal is very high. |
| *End of pathway assessment, repeat as necessary.* | | | |
| Pathway name: | **ESCAPE FROM CONFINEMENT Pet/aquarium/terrarium species** | | |
| 1.3c. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?<br><br>(If intentional, only answer questions 1.4, 1.9, 1.10, 1.11) | intentional | very high | This pathway represents situations where pet owners or hobbyists have allowed fauna to escape or have actively released the species into the wild. This is considered a “facilitated” escape and is assigned to the Pet / aquarium / terrarium species pathway (IUCN, 2017). |
| 1.4c. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?<br><br>Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place.<br>Subnote: In your comment discuss the volume of movement along this pathway. | unlikely | medium | A study of the marine ornamental fish trade in the EU (Leal et al., 2016) revealed that five countries alone accounted for 85% of all value of marine ornamental fish imported to the EU: United Kingdom (UK), Germany, Italy, France and the Netherlands. This value represents not only national sales within each country but also re-export to other countries (Leal et al., 2016). For example, the Dutch company De Jong Marinelife |

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| | | | http://www.dejongmarinelife.nl/shoppinglist/index) has installment in Turkey and supplies France and Italy with *P. lineatus* at 25$ each.<br>Even though *P. lineatus* is a popular ornamental species in the US (Rhyne et al., 2012), in the UK and Europe, the retail trade in this species is low (OATA, pers. comm, May 2018). The Ornamental Aquatic Trade Association representing retailers in the UK (OATA) estimates that in relation to the UK, sales of individuals of this species would, depending on annual demand, be in the region of 300 individuals per annum. 20 to 50% of sales of this species are not to retail but to public aquaria and research institutions (OATA, pers.comm.). Thus, we deduce that, for the UK, 150-240 individuals would be sold per year to hobby aquarists through aquarium shops. Based on Leal et al (2015) it is reasonable to expect that a non-negligible number of specimens is also circulated in the aquarium trade not only of the top 5 countries mentioned in that study but also in other EU countries that import from them.<br>OATA deduces that within the retail trade, there would be a very niche market for this species, which would be recommended only for specific types of marine reef aquaria.<br>In captivity *P. lineatus* juveniles are usually kept in small swarms. If a swarm is released, a small number of juveniles may be sufficient to allow the establishment of the species under suitable conditions. |
| 1.9c. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host? | likely | medium | If intentionally released in the wild, *P. lineatus*, as a habitat generalist, will likely be able to successfully transfer to a suitable habitat. |
| 1.10c. Estimate the overall likelihood of entry into Europe based on this pathway? | moderately likely | medium | *Plotosus lineatus* can be purchased and kept in private aquaria in all EU countries. Unwanted animals released in marine waters can easily survive and find a suitable habitat in the Mediterranean Sea, the Black Sea and a |

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| | | | limited area of the Iberian coast and the Bay of Biscay. However, given the relatively low numbers of the species in the aquarium trade, the likelihood of entry into Europe based on this pathway is not very high. |
| *End of pathway assessment, repeat as necessary.* | | | |
| Pathway name: | **ESCAPE FROM CONFINEMENT:** Botanical gardens/ zoo/ aquaria (excluding domestic aquaria) and Research/Ex-situ breeding | | |
| 1.3d. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?<br><br>(If intentional, only answer questions 1.4, 1.9, 1.10, 1.11) | unintentional | high | The species can escape from-aquaria or research facilities based near the sea.<br>*P. lineatus* is used as an experimental organism in research (See Q.7 in Section A for some examples), although spatial information regarding volume of movement along this pathway and the possibility of escapees to transfer to a suitable habitat is lacking. |
| 1.4d. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?<br><br>Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place.<br>Subnote: In your comment discuss the volume of movement along this pathway. | unlikely | medium | A query was addressed to the European Union Aquarium Curators (EUAC) members and other Aquarium curators, about the display of *P. lineatus*. (Annex 4).<br>Out of 108 recipients, 43 replied. Of those, 18 mentioned that *P. lineatus* has been or still is (in 7 cases) on display. These are: Haus des Meeres Vienna, Genova Aquarium, Aquarium Zoo Berlin, Aquarium Oceanographic Museum Monaco, Malta National Aquarium, Zoo Leipzig GmbH, Akvarium Gdinskie (Gdynia). That is 3 aquaria (that we know of) where release may occur to potentially suitable habitat: Genova, Monaco, Malta. In the remaining 11 positive responses, *P. lineatus* was kept for display for 1-8 years. We note that this is based on a response rate of 40% from the European Union Aquarium Curators, thus some uncertainty remains as to the presence of the species in a large number of EU public aquaria.<br>Information was also provided by EAZA (European Association of Zoos and Aquaria) on populations kept at approximately 300 of their Member zoos and aquariums |

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| | | | in 26 EU Member States (with the exceptions of Cyprus and Malta). The information provided by EAZA (EAZA, 2018 pers. comm.) indicates that 15 specimens in total are kept by 1 zoos/aquariums EAZA Members in 1 Member States (Denmark).<br>Moreover, the Ornamental Aquatic Trade Association representing retailers in the UK (OATA) estimates that in relation to the UK, sales of individuals of this species to public aquaria and research institutions would be in the region of 60-150 individuals per year (OATA, pers.comm,, May 2018 – see also Q1.4c).<br>In any case if an accidental escape occurs, it will be only small numbers of the organism that travel along this pathway. |
| 1.5d. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)?<br><br>Subnote: In your comment consider whether the organism could multiply along the pathway. | likely | high | According to the personal account of an aquarium curator, *P. lineatus* has the ability to successfully reproduce and reach the juvenile stage in aquarium conditions. Juveniles were found in a sand filter outside the species' exhibition tank (Lars Skou Olsen, pers.comm., see also Annex 5). |
| 1.6d. How likely is the organism to survive existing management practices during passage along the pathway? | unlikely | high | Article 3 of the EU Zoos Directive recognizes that for aquatic species, it is paramount to prevent incidental escapes from the water. A first line of actions is to secure enclosures against animal escape. In large public aquaria, circulation systems are closed. The recirculated water in the tanks is continuously filtered and disinfected (UV, ozonation, skimmers, etc.). At regular intervals, a part of the seawater is renewed. The water changed and discharged outside, is always subjected by law to strictly disinfection and filtration before outlet (both for coastal and inland aquaria). Consequently, assuming compliance with regulations, the probability that eggs or larvae survive is zero. Also, all equipment should be disinfected, mainly for parasites and diseases. However, |

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| | | | in public small open or semi-open circulation system aquaria displaying tropical organisms, if the outlet is in the sea or near the sea and is not subjected to control, or cleaning equipment is not appropriate, there is some probability to discharge eggs or larvae. Generally, in Mediterranean countries, the cost to warm continuously the water for tropical species in open-systems is too high, so these aquaria avoid showing these species or they use close circulation system tanks in these special cases.<br>In small aquaria displaying to the public a series of tropical small fish they use LSS, Life Support System (Biological and mechanical filter, UV lamp and skimmer). Accidental escape or cleaning operation without appropriate disinfection may be a risk. |
| 1.7d. How likely is the organism to enter Europe undetected? | likely | medium | If individuals accidentally escape from aquaria, it can be expected that specimens show up in marine habitats. This could be expected for Aquaria located in the vicinity of coastal cities surrounded by suitable habitat, such as: Genova Aquarium, Aquarium Oceanographic Museum Monaco, Malta National Aquarium.<br>Considering the public awareness on the species, stakeholdres (e.g. citizen scientists, divers, fishermen) are likely to be able to detect it, although detection will probably not occur for some time. |
| 1.8d. How likely is the organism to arrive during the months of the year most appropriate for establishment? | likely | medium | It depends on the frequency of cleaning operations.<br>Considering high numbers of juveniles produced, and responses above, it would be this life stage that is most likely to enter the RAA through this pathway. |
| 1.9d. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host? | likely | medium | Such an event is possible if the organism escapes from a facility that operates and has an outlet in or near the sea without appropriate management practices. |
| 1.10d. Estimate the overall likelihood of entry into Europe based on this pathway? | moderately likely | medium | *P. lineatus* is or has been displayed in large public aquaria in Europe, and is used as an experimental organism in research. It is assumed that large public |

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| | | | aquaria and research facilities follow strict biosecurity measures in accordance with legislation. Accidental escape of eggs or larvae through failure in management measures is considered more likely in smaller public or private aquaria, for which the little available information (OATA, Q 1.4d) does not have a spatial component. Moreover, the species can reproduce in captivity and survive outside its exhibition tank (*P. lineatus* larvae originating from the exhibition tank had grown into juveniles in a sand filter in Tivoli aquarium, DK – Annex 6). A failure in management measures may result in the accidental entry of the organism into European Seas. |
| *End of pathway assessment, repeat as necessary.* | | | |
| 1.11. Estimate the overall likelihood of entry into Europe based on all pathways in relevant biogeographical regions in current conditions (comment on the key issues that lead to this conclusion). | very likely | very high | *P. lineatus* is already proliferating through natural dispersal within marine ecoregions of the EU, having established important populations in EU neighbouring countries. Moreover, its primary pathway of introduction (i.e. the Suez Canal) is still active and will likely provide continuous propagule pressure to recipient countries (Israel, Egypt).<br>Parallel introduction events via aquarium trade (accidental or intentional release) and /or as escapee from public/private aquaria and research facilities are also a possibility (albeit not very likely) that may not have as notable an effect as natural dispersal but nevertheless increase the number of potential entry points for the species. |
| 1.12. Estimate the overall likelihood of entry into Europe based on all pathways in relevant biogeographical regions in foreseeable climate change conditions? | very likely | very high | *P. lineatus* is an Indo-Pacific species that entered the Mediterranean during the latest, intense wave of Lessepsian immigration the 2000's. This was linked to increased maximum and minimum temperatures of the previous decade (thermal regime shift – Raitsos et al., 2010) and the increased salinities associated with the |

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| | | | East Mediterranean Transient event that subsided in the late 1990's (Theoharis 1999).<br>It is foreseen that the species is very likely to enter the risk assessment area under current conditions via the aforementioned pathways. In addition, future warming of the Mediterranean is expected to favour it even more. |

## PROBABILITY OF ESTABLISHMENT

Important instructions:

- For organisms which are already established in parts of the Union, answer the questions with regard to those areas, where the species is not yet established. If the species is established in all Member States, continue with Question 1.16.

| QUESTION | RESPONSE | CONFIDENCE | COMMENT |
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| 1.13. How likely is it that the organism will be able to establish in the EU based on the similarity between climatic conditions in Europe and the organism's current distribution? | very likely | very high | *P. lineatus* is already established in most of the Levantine coast, neighboring EU marine subregions. Cyprus and the southern Aegean islands of Greece (southern Crete, some of the Dodecanese islands) belong to the same Mediterranean subregion characterized by similar climatic conditions. The same applies for the northern coast of Tunisia and western Sicily, which belong to the same subregion (Western Mediterranean Sea). |
| 1.14. How likely is it that the organism will be able to establish in the EU based on the similarity between other abiotic conditions in Europe and the organism's current distribution? | very likely | very high | The ability of *P.lineatus* to survive in a variety of coastal habitats with a wide range of salinities (estuaries, lagoons, sandy and rocky bottoms, shallow and open seas) down to 83 m (Job, 1959; Clark et al., 2011; Edelist et al., 2012) along with the widespread availability of these habitats in the Mediterranean Sea, Black Sea and Iberian-Bay of Biscay make its establishment very likely. See also Q2 - Chapeau |
| 1.15. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, terraria, zoological gardens) in Europe?<br><br>Subnote: gardens are not considered protected conditions | likely | medium | According to the personal account of an aquarium curator, (Lars Skou Olsen, curator of Tivoli Aquarium Denmark, pers, comm, May 2017) *P. lineatus* has the ability to successfully reproduce and reach the juvenile stage in aquarium conditions (the species was not intentionally bred in that particular case). |

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| 1.16. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Europe? | widespread | very high | *P. lineatus* live and reproduce in a variety of coastal habitats with a wide range of salinities (estuaries, lagoons, sandy and rocky bottoms, shallow and open seas) down to 83 m. These habitats are widespread in the Mediterranean Sea, the Black Sea and the Iberian -Bay of Biscay. |
| 1.17. If the organism requires another species for critical stages in its life cycle then how likely is the organism to become associated with such species in Europe? | NA | | *P. lineatus* does not require another species for completion of its life cycle. |
| 1.18. How likely is it that establishment will occur despite competition from existing species in Europe? | very likely | high | Based on the analysis of diet and habitat use related traits, *P. lineatus* has been implicated in the competitive exclusion of *M. barbatus* and *M. surmuletus* from soft-sediment habitats in Israel (Arndt et al., 2018 – see also QA.6). In the same study it is demonstrated that *P. lineatus* has overlapping feeding and habitat use habits with a number of other native Mediterranean fishes in the area. Besides the two mullet species, moderate to strong overlap was observed with *Chlorophthalmus agassizi*, *Merluccius merluccius* and *Uranoscopus scaber* with respect to habitat use and with *Lithognathus mormyrus* and *Trachinus draco* with respect to diet/feeding habits. The organism has successfully established despite this overlap, it is thus assumed to be a successful competitor. |
| 1.19. How likely is it that establishment will occur despite predators, parasites or pathogens already present in Europe? | very likely | high | Predators of *P. lineatus* in the Mediterranean are considered scarce (Edelist et al. 2012). Moreover, the swarming behavior of the juveniles and the venomous spines and toxic skin of the species offer additional protection from predation (Clark et al., 2011). |

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| | | | *Platycephalus indicus* (Linnaeus, 1758), another species of Indo-Pacific origin introduced to the Mediterranean, has been reported to predate on *Plotosus anguillaris* in Hong Kong (Wu 1984). However, *P. indicus* in the Eastern Mediterranean is not present in numbers high enough to constitute an invasion (Golani, 1998) and presumably exert significant predation pressure on *P. lineatus*. In Indonesia, a native species was observed feeding on the eggs of *P. lineatus* just after spawning (Clark et al., 2011).<br>Parasitic infestations (ectoparasites) are common in *P. lineatus* in the native range (Bailly, 2008; Froese & Pauly, 2017), but no data has been reported so far from the invaded range. |
| 1.20. How likely is the organism to establish despite existing management practices in Europe? | very likely | very high | No management practices are in place concerning natural dispersal that can affect the organism's ability to establish in the RA area.<br>Early detection systems could and do operate through official and unofficial networks of national experts with local stakeholders (see Q 1.6 and 1.7) but would not be of use to prevent establishment.<br>If a management practice such as intensive targeted fishery is to be applied, especially during the reproduction period, a reduction of probability to survive could be achieved, but this reduction is difficult to quantify and highly uncertain. |
| 1.21. How likely are existing management practices in Europe to facilitate establishment? | likely | high | Marine Protected Areas (MPAs) may offer protected conditions for juveniles to thrive and adults to be released from fishing pressure (Burfeind et al., 2013). Especially along the Levantine coast, MPAs are characterised by high abundances of Lessepsian species (Galil et al., 2017 and references therein) to the extent that |

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| | | | these authors consider that MPAs in the Eastern Mediterranean can act as "hubs" of secondary dispersal for lessepsian species. *P. lineatus* may not be a target species in the invaded range but it constitutes a large part of the by-catch of commercial trawlers and as such is subject to significant fisheries removals.<br>The EU Regulation 1967/2006, bans trawling at depths shallower than 50 m in the Mediterranean Sea throughout the year and will also afford protection to juveniles of the species which dominate shallow water assemblages. Additional fisheries restrictions implemented nationally in EU countries, mostly in the spring and summer months (for a comprehensive review and data collation see the MEDISEH project – http://imbriw.hcmr.gr/en/mediseh/), are likely to favour both the spawning and the early life stages of the species and may facilitate establishment. |
| 1.22. How likely is it that biological properties of the organism would allow it to survive eradication campaigns in Europe? | likely | low | The deposition of eggs under rocks and debris and the parental care protect the eggs, whereas spawning in shallow areas renders possible eradication measures (e.g. by trawling) destructive for native species and habitats<br>The movements and migrations of juveniles and adults generate a continuous distribution in shallow waters over suitable habitats (e.g. in Israel – Edelist et al., 2012).<br>On the other hand, swarming allows large groups of juveniles to be easily captured |
| 1.23. How likely are the biological characteristics of the organism to facilitate its establishment? | very likely | very high | For the reproductive characteristics and life history/dispersal capacity of the species see Q1.4. |

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| | | | *P. lineatus* has demersal eggs and demersal larvae (Leis, 1991, Moriuchi & Dotsu, 1973). It reaches sexual maturity after 1-3 years (Thresher 1984), its fecundity ranges from 525 to 1176 eggs (Heo et al., 2007) and the larvae have a short duration of up to 18 days (Moriuchi & Dotsu, 1973). Based on the above and the recruitment period observed in Israel by Edelist et al. (2012), spawning in Israel occurs in the summer (June-July), similar to what is reported by Heo et al. (2007) for Japan.<br><br>Based on temperature requirements for successful spawning and hatching of eggs in the wild (reported in Moriuchi & Dotsu, 1973 as 21$^{o}$ to 27$^{o}$ C), *P. lineatus* in July is within its thermal tolerance limits for reproduction in all the Mediterranean marine subregions, in the Bay of Biscay and in the Iberian coast only in the south coast of Portugal. This is an estimate, based on 2012-2016 SST data provided by Copernicus Marine Services - see URL http://marine.copernicus.eu/services-portfolio/access-to-products/?option=com_csw&view=details&product_id=GLOBAL_REP_PHY_001_021 |
| 1.24. How likely is the capacity to spread of the organism to facilitate its establishment? | likely | high | For a detailed description of the dispersal ability of the species see Q 1.4b. In short, *P. lineatus* is characterised by post-larval dispersal of juveniles and adults that has resulted in a continuous distribution in shallow waters over suitable habitats and a rate of spread of approximately 100-200 km per year along continuous coastlines of the Levantine. |
| 1.25. How likely is the adaptability of the organism to facilitate its establishment? | likely | low | Its tolerance for a wide range of salinities (Job, 1959; Pucke & Umminger, 1979; Goh & Goh, |

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| | | | 1989; Sin et al., 1991) is likely to facilitate establishment in areas with reduced salinity conditions (i.e. the Black Sea). High uncertainty is associated with the lack of information on specific salinity requirements for spawning and egg/larval survival, although juveniles are common in estuaries with salinities as low as 12ppt (see Q2 Chapeau). |
| 1.26. How likely is it that the organism could establish despite low genetic diversity in the founder population? | likely | low | The only available genetic study of *P. lineatus* in the invaded range by Bariche et al. (2015) found large genetic distances of *P. lineatus* specimens collected from Lebanon (>2%), (indicating the possibility of a species complex*)*. Not enough information was found to answer with any certainty whether the organism could establish with low initial genetic diversity. It is assumed that the founder population(s) were either genetically diverse or succeeded to establish despite low genetic diversity. |
| 1.27. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Europe? (If possible, specify the instances in the comments box.) | very likely | very high | Its invasion history along the Levantine coast attests to its ability to establish in the introduced range. In Israel, it only took three years from the first record in 2002 (Golani, 2002) until the species became widespread all along the Israeli coast (Otero et al., 2013). Its subsequent population explosion rendered it one of the most abundant and frequent species of the soft-sediment ichthyofauna in Israel (Edelist et al., 2012). Moreover, the species is considered—established in Syria (Malek Ali, pers.comm.) three years after the first sighting and in Turkey (Cemal Turan, pers.comm.) one year after the first sighting. |
| 1.28. If the organism does not establish, then how likely is it that casual populations will continue to occur? | very likely | very high | Given the continuous propagule pressure from established populations in neighbouring countries, casual populations are very likely to continue to |

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| Subnote: Red-eared Terrapin, a species which cannot reproduce in GB but is present because of continual release, is an example of a transient species. | | | occur in habitats unsuitable for reproduction/establishment through natural dispersal.<br>Casual populations may also continue to appear from the escape or release of the species from aquaria in areas where conditions will not allow it to establish. |
| 1.29. Estimate the overall likelihood of establishment in relevant biogeographical regions in current conditions (mention any key issues in the comment box). | very likely<br>*Mediterranean Sea*<br><br>likely<br>*Black Sea*<br><br>unlikely<br>*Iberian Coast and the Bay of Biscay* | very high<br><br><br>low<br><br><br>medium | Based on its invasion history in the Mediterranean Sea, the abiotic requirements, existence of similar conditions and availability of preferred habitats, the establishment of *P. lineatus* in the risk assessment area is considered very likely throughout the Mediterranean Sea (see map in Annex 1). In the Bay of Biscay, even though abiotic conditions permit it in a limited area, establishment may occur only after a new introduction via a human-mediated pathway (unaided dispersal is limited to southern Portugal), a rather unlikely event. For the Black Sea, there is some uncertainty as to whether the species can complete its life cycle under permanently reduced salinity conditions, although evidence from the native range indicates that this is possible (Goh & Goh, 1989; Sin et al., 1991). |
| 1.30. Estimate the overall likelihood of establishment in relevant biogeographical regions in foreseeable climate change conditions | very likely<br>*Mediterranean Sea*<br><br>likely<br>*Black Sea*<br><br>unlikely<br>*Iberian Coast and the Bay of Biscay* | very high<br><br><br>low<br><br><br>medium | See comment in Q.2 of the EU Chapeau and Q 1.23 above about temperature requirements for successful reproduction. In a future scenario of temperature increase by 2 °C, these requirements will be met further north along the west coast of Portugal and for more prolonged periods in the summer over the whole potential range. The Bay of Biscay will provide more suitable habitat for establishment but the likelihood of introduction in this region remains unchanged (low). |

## PROBABILITY OF SPREAD

Important notes:

- Spread is defined as the expansion of the geographical distribution of an alien species within the assessment area.
- Repeated releases at separate locations do not represent spread and should be considered in the probability of introduction and entry section.

| QUESTION | RESPONSE | CONFIDENCE | COMMENT |
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| 2.1. How important is the expected spread of this organism in Europe by natural means? (Please list and comment on each of the mechanisms for natural spread.) | major | high | *P. lineatus* is known from depths of up to 83 m and feed mostly on benthic invertebrates and small fish. The species is characterized by demersal development (relatively large eggs, low fecundity, spawns once a year, nest guarding). Its lecithotrophic larvae stay close to the seabed for 10-15 days, when the free-swimming juveniles emerge and start forming swarms, i.e. tight formations that move incessantly over sand in a "steamroller" fashion, probing the sediment for food (Clark et al., 2011). In this way, juveniles can cover large distances during the 1-3 years it takes for them to reach maturity. Adults are considered amphidromous, with migrations that can cover more than 100 km and return to shallow inshore waters to spawn (Riede, 2004).<br>The short life cycle and demersal nature of the larvae and the population explosion of *P. lineatus* in Israel point to larval retention (see also Levin 2006). It appears that post-larval dispersal of the juveniles and adults has driven the spread of this species in the Mediterranean so far; however it is probably left to the adults to cross large distances isolated by deeper waters. The juveniles move incessantly over sand while feeding so it is unlikely that they will venture (or survive well) into the deep where food is more scarce. |

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| | | | The adults are much more likely to move to deeper waters, especially if the local population has reached high densities.<br>Its climatic requirements are not anticipated to pose significant barriers for spread.<br>See also Q1.5,Q1.23 |
| 2.2. How important is the expected spread of this organism in Europe by human assistance? (Please list and comment on each of the mechanisms for human-assisted spread) and provide a description of the associated commodities. | minor | medium | ESCAPE FROM CONFINEMENT Pet/aquarium/terrarium species and Botanical gardens/zoo/aquaria (captured and sold in the aquarium trade)<br>It is possible that specimens could be collected from the wild and sold for private and public aquaria (both activities within the RA area), facilitating spread if these individuals are subsequently released or escape from confinement<br><br>RELEASE IN NATURE (other intentional release – fisheries discard)<br>Human-assisted spread may also occur if *Plotosus lineatus* is caught as bycatch in fishing activity and discarded at a different location. |
| 2.2a. List and describe relevant pathways of spread. Where possible give detail about the specific origins and end points of the pathways.<br><br>For each pathway answer questions 2.3 to 2.9 (copy and paste additional rows at the end of this section as necessary). Please attribute unique identifiers to each question if you consider more than one pathway, e.g. 2.3a, 2.4a, etc. and then 2.3b, 2.4b etc. for the next pathway. | UNAIDED (natural dispersal)<br><br>ESCAPE FROM CONFINEMENT Pet/aquarium/terrarium species and Botanical gardens/zoo/aquaria (captured and sold in the aquarium trade) | | Specimens of *P. lineatus* could be collected from the wild and sold for private and public aquaria within the RA area, facilitating spread if these individuals are subsequently released or escape from confinement. |

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| | RELEASE IN NATURE (other intentional release – fisheries discard) | | Bycatch and discard of demersal trawling. While there is no literature to support this for *P. lineatus*, there are examples of this phenomenon for other species (e.g. the alga *Caulerpa taxifolia* and the decapod *Necora puber* spread by fishing gear – Relini & Trochia, 2000 and Berggren, 2007 respectively). As a matter of fact, on-board observations of by-catch and discards data of fishing activities is one of the recommended methods for the monitoring of marine NIS (Olenin, 2015). Based on reported high bycatch rates in Israel (Edelist et al., 2012), it is possible that this can be a mechanism for spread for *P. lineatus* as well. |
| *Pathway name:* | **UNAIDED (secondary natural dispersal from neighbouring countries)** | | |
| 2.3a. Is spread along this pathway intentional (e.g. the organism is released at distant localities) or unintentional (the organism is a contaminant of imported goods)? | unintentional | very high | |
| 2.4a. How likely is it that large numbers of the organism will spread along this pathway from the point(s) of origin over the course of one year? | very likely | very high | See Q1.4b<br>Currently, based on records/status in Turkey and Tunisia and the possibility of a depth limitation to spread, the answer is very likely along continuous coastlines but moderately likely across deep waters towards islands<br>Similar for reinvasion after eradication. |
| 2.5a. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)?<br><br>Subnote: In your comment consider whether the organism could multiply along the pathway. | very likely | very high | See Q1.5b |
| 2.6a. How likely is the organism to survive existing management practices during spread? | very likely | very high | See Q1.6b |

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| 2.7a. How likely is the organism to spread in Europe undetected? | likely | medium | See Q1.7b |
| 2.8a. How likely is the organism to be able to transfer to a suitable habitat or host during spread? | very likely | very high | See Q1.14 and 1.16 |
| 2.9a. Estimate the overall likelihood of spread into or within the Union based on this pathway? | very likely | very high | |
| *End of pathway assessment, repeat as necessary.* | | | |
| *Pathway name:* | **ESCAPE FROM CONFINEMENT Pet/aquarium/terrarium species and Botanical gardens/zoo/aquaria (captured and sold in the aquarium trade)** | | |
| 2.3b. Is spread along this pathway intentional (e.g. the organism is released at distant localities) or unintentional (the organism is a contaminant of imported goods)? | intentional | very high | |
| 2.4b. How likely is it that large numbers of the organism will spread along this pathway from the point(s) of origin over the course of one year? | unlikely | medium | *P. lineatus* is not very popular in domestic aquaria and is displayed in a small number of public aquaria throughout Europe (see Q 1.4c and 1.4d for details). It is possible that specimens could be collected from the wild and sold for private and public aquaria (there is anecdotal information that this is already happening for other ornamental invasives in the Mediterranean, such as *Pterois miles* (Bennett, 1828) and *Sargocentron rubrum* (Forsskål, 1775). |
| 2.5b. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)?<br><br>Subnote: In your comment consider whether the organism could multiply along the pathway. | likely | high | Capturing individuals from the wild to supply the aquarium trade is common practice for reef fishes in general and *P. lineatus* in particular (Chan & Sadovy, 2000; DEH-Australian Government, 2005)<br>The success of *P. lineatus* as an ornamental species is evidence that the species survives well in captivity and during the transport process. |

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| 2.6b. How likely is the organism to survive existing management practices during spread? | likely | high | There are no current management practices that can affect the species' survival during its passage through the aquarium trade. |
| 2.7b. How likely is the organism to spread in Europe undetected? | very likely | medium | Declarations pertaining to shipments from outside the EU are recorded on the Common Veterinary Entry Document (CVED) through the TRACES system and it is optional to list species (Biondo 2017). However, no import declarations or licences are required for intra-EU movement of goods, such that *P. lineatus* could spread in EU aquarium/pet shops undetected unless a dedicated search was conducted. |
| 2.8b. How likely is the organism to be able to transfer to a suitable habitat or host during spread? | unlikely | high | The transfer of *P. lineatus* during the transport process to a suitable habitat is considered unlikely<br>Any subsequent escape or release from public and private aquaria respectively would constitute secondary introduction event and is addressed in the relevant RA Section. |
| 2.9b. Estimate the overall likelihood of spread into or within the Union based on this pathway? | unlikely | medium | |
| *End of pathway assessment, repeat as necessary.* | | | |
| *Pathway name:* | **RELEASE IN NATURE (other intentional release – fisheries discard)** | | |
| 2.3c. Is spread along this pathway intentional (e.g. the organism is released at distant localities) or unintentional (the organism is a contaminant of imported goods)? | intentional | very high | This pathway is of more immediate concern in the Mediterranean Sea, where establishment is very likely (with high certainty) and dense populations may be anticipated. Moreover, in the Mediterranean Sea, a discard ban, as mandated by the Common Fisheries Policy (CFP), has not been implemented yet. |
| 2.4c. How likely is it that large numbers of the organism will spread along this pathway from the point(s) of origin over the course of one year? | unlikely | low | This will depend on the densities the species has achieved at depths where trawling is permitted (deeper than 50 m), the time of the year, the trawling effort and the discard practices, i.e. whether discards are thrown |

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| | | | overboard immediately or accumulated and shovelled over in one or more large lots or if the catch is sorted after returning to port. Discard numbers of up to 100 individuals per haul per hour may be possible (estimate based on Edelist et al., 2012 for Israel at depths >37m) |
| 2.5c. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)?<br><br>Subnote: In your comment consider whether the organism could multiply along the pathway. | moderately likely | low | Mortality rates of fisheries discards can vary widely (Revill, 2012), depending on the species, fishing gear and discard practice. No information has been found on the survival rate of discarded *P. lineatus*, it is considered however likely that some individuals will survive being fished and released back to the sea. |
| 2.6c. How likely is the organism to survive existing management practices during spread? | likely | medium | The reform of the Common Fisheries Policy (CFP) of 2013 aims at gradually eliminating the wasteful practice of discarding through the introduction of the landing obligation by 2019, but this applies to regulated commercial species.<br><br>Management plans for discards of demersal fisheries include:<br>Commission Delegated Regulation (EU) 2017/86 of 20 October 2016 establishing a discard plan for certain demersal fisheries in the **Mediterranean Sea (currently not implemented)**<br>Commission Delegated Regulation EU) 2017/87 of 20 October 2016 establishing a discard plan for turbot fisheries in the **Black Sea**<br>Commission Delegated Regulation (EU) 2016/2375 of 12 October 2016 establishing a discard plan for certain demersal fisheries in **North-Western waters**<br>Commission Delegated Regulation (EU) 2016/2250 of 4 October 2016 establishing a discard plan for certain demersal fisheries in the **North Sea and in Union waters of ICES Division IIa** |

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| | | | Commission Delegated Regulation (EU) 2016/2374 of 12 October 2016 establishing a discard plan for certain demersal fisheries in **South-Western waters** |
| 2.7c. How likely is the organism to spread in Europe undetected? | unlikely | medium | |
| 2.8c. How likely is the organism to be able to transfer to a suitable habitat or host during spread? | likely | high | See Q1.14 and 1.16 for habitat requirements and availability.<br>This will depend again on discard practices. If discarded at sea, it is more likely that individuals will survive and be released over suitable depths and substrates |
| 2.9c. Estimate the overall likelihood of spread into or within the Union based on this pathway? | unlikely | low | This will depend on fishing and discard practices, with the biggest potential for spread from bottom trawlers, throwing *P. lineatus* at sea immediately after the catch is sorted. Moreover, the geographic spread of the species via this route would be relatively limited. |
| *End of pathway assessment, repeat as necessary.* | | | |
| 2.10. Within Europe, how difficult would it be to contain the organism? | very difficult | very high | There is a large consensus that naturally dispersing organisms are very difficult to contain (e.g. Carlton, 1996 and personal communications with local experts in the Annex 5), although no attempts have been made for this particular species.<br>However, introductions due to intentional releases, or escapees from aquaria can be managed. |
| 2.11. Based on the answers to questions on the potential for establishment and spread in Europe, define the area endangered by the organism. | very likely<br>*Mediterranean Sea*<br><br>likely<br>*Black Sea*<br><br>unlikely<br>*Iberian Coast and the Bay of Biscay* | very high<br><br><br>low<br><br><br>medium | See Questions 2, 5 & 7 of the Chapeau and Q1.29 |

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| 2.12. What proportion (%) of the area/habitat suitable for establishment (i.e. those parts of Europe were the species could establish), if any, has already been colonised by the organism? | 0-10 | high | Currently 0% for the European Union |
| 2.13. What proportion (%) of the area/habitat suitable for establishment, if any, do you expect to have been invaded by the organism five years from now (including any current presence)? | 0-10 | medium | The Mediterranean EU coastline is 33,000 km long, with ≈ 22,000km belonging to Greece, Italy and Cyprus, the first three countries which are expected to be colonised by *P. lineatus* through natural dispersal. Considering that, in order to reach the RAA, *P. lineatus* will have to cross over to Sicily (IT) from Tunisia, Cyprus from Syria and/or Turkey and the Dodecanese (GR) from the west coast of Turkey, a small percentage of the RAA suitable habitats is expected to be invaded five years from now.<br>The decrease in the confidence rating refers to lower confidence levels for the rate of spread towards islands, as opposed to continuous coastline. |
| 2.14. What other timeframe (in years) would be appropriate to estimate any significant further spread of the organism in Europe? (Please comment on why this timeframe is chosen.) | 10 | very high | Within 15 years of its first Mediterranean record (2002 in Israel) the species has significantly proliferated along most of the Levantine coast and to the west until Tunisia. Available suitable habitats and abiotic conditions are very likely to allow it to spread at similar rates throughout the area along continuous coastline and over shallow areas. Within 10 years, adult movements are anticipated to facilitate its spread to islands separated by deeper waters. |
| 2.15. In this timeframe what proportion (%) of the endangered area/habitat (including any currently occupied areas/habitats) is likely to have been invaded by this organism? | 10-33 | medium | In this timeframe, *P. lineatus* is likely to have also reached the Mediterranean coast of Spain through westward expansion from Tunisia<br>The proportion of the area likely to have been invaded is assumed to be closer to the low end of the 10-33% range |
| 2.16. Estimate the overall potential for spread in relevant biogeographical regions under current conditions for this | moderately rapidly | high | Invasion history in Israel indicates spread with a speed of ≈100 km per year along continuous |

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| organism in Europe (using the comment box to indicate any key issues). | | | coastline, involving movement of both juveniles and adults. The organism is expected to spread to the Southern Aegean at similar speeds. As discussed above, active swimming of adults is the most likely mechanism of dispersal over large distances separated by deep waters; hence some uncertainty is associated with its rate of spread to Cyprus, Sicily, Malta and some Aegean Islands that can act as stepping stones on its pathway to the Ionian Sea. A similar pattern has been observed in the distribution of other alien species such as *Fistularia commersonii* (Azzuro et al., 2013). |
| 2.17. Estimate the overall potential for spread in relevant biogeographical regions in foreseeable climate change conditions | very likely | very high | It is foreseen that the species is very likely to spread in the risk assessment area under current conditions; in addition future warming of the Mediterranean is expected to favour it even more.<br>See Q1.12 and 1.23 for more details |

## MAGNITUDE OF IMPACT

Important instructions:

- Questions 2.18-2.22 relate to environmental impact, 2.23-2.25 to impacts on ecosystem services, 2.26-2.30 to economic impact, 2.31-2.32 to social and human health impact, and 2.33-2.36 to other impacts. These impacts can be interlinked, for example a disease may cause impacts on biodiversity and/or ecosystem functioning that leads to impacts on ecosystem services and finally economic impacts. In such cases the assessor should try to note the different impacts where most appropriate, cross-referencing between questions when needed.
- Each set of questions above starts with the impact elsewhere in the world, then considers impacts in Europe separating known impacts to date (i.e. past and current impacts) from potential future impacts (including foreseeable climate change).
- Assessors are requested to use and cite original, primary references as far as possible.

| QUESTION | RESPONSE | CONFIDENCE | COMMENTS |
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| **Biodiversity and ecosystem impacts** | | | |
| 2.18. How important is impact of the organism on biodiversity at all levels of organisation caused by the organism in its non-native range excluding the Union? | moderate | low | *P. lineatus* is present in significant numbers over sandy substrata in Israel (Edelist et al., 2012). In 160 trawl catches between 2008-2011, *P. lineatus* accounted for 17.7 and 2.4% of all fishes in shallow (<37 m) and in medium (37-83m) depth strata respectively. In shallow strata, catfishes amounted to 10.4% of all organisms in catches.<br>Predation effects of feeding juvenile swarms or adults on benthic invertebrates have not been studied but deserve some consideration. At these densities, it is likely that *P. lineatus* exerts significant predation pressure on preferred prey (crustaceans, molluscs, polychaetes and small fish), and competes for prey resources with other native predators.<br>Other competition effects may involve competition for daytime refuge with native species, since adult *P. lineatus* are active during the night and spend most of the daytime hiding in caves or under ledges (Froese & Pauly, 2017; Clark et al., 2011; C. Turan, pers.comm.). |

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| | | | Arndt et al. (2018) demonstrated a strong overlap in diet and habitat use preferences between *P. lineatus* and the native mullet species *Mullus barbatus* and *Mullus surmuletus* which have declined by approximately one order of magnitude in the shallow sandy coasts of Israel over the past 20 years. They concluded that *P. lineatus*, together with two non-indigenous *Upeneus* species, has likely contributed to the competitive exclusion of the two mullets from the region (Arndt et al., 2018). |
| 2.19. How important is the impact of the organism on biodiversity at all levels of organisation (e.g. decline in native species, changes in native species communities, hybridisation) currently in the different biogeographical regions or marine sub-regions where the species has established in Europe (include any past impact in your response)? | N/A | | The species has not yet established in the risk assessment area. |
| 2.20. How important is the impact of the organism on biodiversity at all levels of organisation likely to be in the future in the different biogeographical regions or marine sub-regions where the species can establish in Europe? | major | low | The ecological role of *P. lineatus* in invaded habitats through competition and predation is expected to be important (Gil Rilov, Marek Ali, pers.comm., Q2.18)<br>With a high likelihood for establishment and subsequent population explosions (Edelist et al., 2012), the species has the potential to drastically change the structure of native communities in the invaded areas (Otero et al., 2013) and outcompete similar native species.<br>Moreover, the venom extracted from its spinal gland has proven lethal for a number of vertebrates, including the freshwater fish Largemouth Bass *Micropterus salmoides* in laboratory experiments (Wright, 2009), it could thus represent a danger as a prey to naïve predators.<br>Regarding ecosystem functioning, feeding swarms with their constant probing of the sand may increase turbidity and alter properties of the sediment (Cline et al., 1994) with consequences for nutrient cycling, mobilization of |

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| | | | demersal eggs or dormant cysts (Drillet et al., 2014). Yahel et al. (2002), conducting studies in the Red Sea, observed that benthivorous fish (with similar feeding behavior as *P. lineatus*) are primarily responsible for sediment resuspension in coral reef habitats. This may have implications for benthic suspension feeders, such as corals, hydroids, sedentary polychaetes, etc., but also for benthic habitats and associated community structure (Kröncke et al., 2000). |
| 2.21. How important is decline in conservation value with regard to European and national nature conservation legislation caused by the organism currently in Europe? | N/A | | The species has not yet established in the assessment area. |
| 2.22. How important is decline in conservation value with regard to European and national nature conservation legislation caused by the organism likely to be in the future in Europe? | moderate | medium | *P. lineatus* has been observed in two Marine Protected Areas in the invaded range (in Israel, where it is present in considerable numbers (B. Galil, pers.comm), and in Tunisia, in the Zembra-Haouaria marine reserve, where it is considered established – (Ben Amor et al., 2016). Its spread in other MPAs in EU marine regions is very likely, it thus poses a threat to protected marine communities and habitats. |
| **Ecosystem Services impacts** | | | |
| 2.23 How important is the impact of the organism on provisioning, regulating, and cultural services in its non-native range excluding the Union? | moderate | medium | With respect to ecosystem services, *P. lineatus* affects the provisioning of food for human consumption as it interferes with local fisheries (discarded species present in significant amounts) (Edelist et al., 2012; Katsanevakis et al., 2014). This had even caused temporary changes to normal activities at local level, such as prawn trawlers in Israel avoiding shallow waters in the daytime when *P. lineatus* is most abundant and active. Since then, trawling restrictions have been implemented in Israel (trawling prohibited <40m depth), such that this temporary change in fishing activities is no |

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| | | | longer an issue attributed to *P. lineatus* (Dor Edelist, personal communication). |
| 2.24. How important is the impact of the organism on provisioning, regulating, and cultural services currently in the different biogeographical regions or marine sub-regions where the species has established in Europe (include any past impact in your response)? | N/A | | |
| 2.25. How important is the impact of the organism on provisioning, regulating, and cultural services likely to be in the different biogeographical regions or marine sub-regions where the species can establish in Europe in the future? | minor | medium | Even if *P. lineatus* achieves in the European area comparable densities with the peak densities reported for Israel, provisioning services are likely to be less severely affected due to the different trawling restrictions in the EU and the generally lower densities of *P. lineatus* in waters deeper than 50m. (see Q2.18 for depth distribution in Israel and Q1.21 for EU fisheries regulations) |
| **Economic impacts** | | | |
| 2.26. How great is the overall economic cost caused by the organism within its current area of distribution, including both costs of damage and the cost of current management | moderate | low | *P. lineatus* during its population explosion in Israel reached significant abundance (see Q 2.18) and was discarded at all sizes by Israeli fishermen. The main problem identified with these discard rates was an increase in the time required to sort the catch, as *P. lineatus* is highly venomous and extra care is needed for its handling. Additional loss of working time can occur due to injuries to fishermen caused by *P. lineatus* stings (see later section on health impacts).<br>Since 2011, *P. lineatus* numbers in the area have decreased (Dor Edelist, pers.comm., 2017) but it still constitutes a significant amount of the catch.<br>Relevant data/studies for a monetary estimate are not available at the moment.<br>A note on scale: The above impacts are related to 22-24 trawling vessels (Edelist et al., 2013), operating along an approximately 200km long coastline. |

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| 2.27. How great is the economic cost of damage* of the organism currently in the Union (include any past costs in your response)?<br><br>*i.e. excluding costs of management | N/A | | The organism has not been reported from the Union at the time of the risk assessment. |
| 2.28. How great is the economic cost of damage* of the organism likely to be in the future in the Union?<br><br>*i.e. excluding costs of management | Minor | low | The depth limit on trawling of 50m (and locally deeper) and the seasonal (spring/summer) fisheries closures in the Mediterranean EU states are likely to limit the high discard rates of *P. lineatus* in trawl catches compared to what was observed in Israel (autumn months are characterised by high abundances of *P. lineatus* juveniles but these are predominant at shallow depths - <37m in Edelist et al. (2012), in countries however with a large trawling fleet (e.g. Italy, Greece – FAO 2016), the net impact may be comparable if not higher. Reduced beach use with associated impacts on the tourism has not been reported in the species' current invaded range (Daniel Golani, Dori Edelist, Gil Rilov, pers.comm.). |
| 2.29. How great are the economic costs associated with managing this organism currently in the Union (include any past costs in your response)? | N/A | | There are no current management costs for *P. lineatus* in the Union |
| 2.30. How great are the economic costs associated with managing this organism likely to be in the future in the Union? | moderate | medium | Management costs might include national action plans, awareness campaigns, citizen science programs. Specific control/eradication actions are difficult to undertake and probably not cost-effective. |
| **Social and human health impacts** | | | |
| 2.31. How important is social, human health or other impact (not directly included in any earlier categories) caused by the organism for the Union and for third countries, if relevant (e.g. with similar eco-climatic conditions). | moderate | medium | *P. lineatus* is a highly venomous catfish, with the venom glands located along the dorsal and pectoral spines. Envenomation by catfishes can result in severe pain, numbness, fever, weakness, nausea, local paralysis, dizziness and can occasionally prove fatal (Haddad 2008, Halstead 1978, Fahim et al., 1996), although fatal |

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| | | | injuries caused by *P. lineatus* have never been reported (Bentur et al., 2017).<br>Numerous injuries to fishermen and beachgoers have been recorded by the Poison Information Center in Rambam Health Care Campus, Haifa, Israel (Gweta et al., 2008; Edelist et al., 2012, Bentur et al., 2017), some of them involving severe pain, hypertension and tachycardia (ANNEX 4). Mild symptoms were mostly self-treated, especially by fishermen. Discarded fish, washed ashore and stepped on or picked up by people walking on the beach were the main cause of injury to beach-goers (Daniel Golani, pers.comm,, see also Haddad 2016 for marine catfish injuries). In such injuries, a common complication is the breakage of stingers in the wound. If the fish have rotted, this is associated with a higher likelihood of severe bacterial infection (Haddad 2016). As such, *P. lineatus* affects the health and the safe access to resources and amenities for identifiable groups, no information however was found to suggest that people are deterred from carrying out these activities in the impacted areas due to the presence of the species.<br>In addition to the economic costs mentioned in the previous section, minor economic costs should be taken into account for the treatment of injuries caused by stings to fishermen and beachgoers.<br>A note on scale: The above impacts are related to 22-24 trawling vessels and ≈100 artisanal fishing vessels (Edelist et al., 2013) operating along an approximately 200km long coastline plus recreational fishermen, |
| 2.32. How important is social, human health or other impact (not directly included in any earlier categories) caused by the organism in the future for the Union. | major | low | With a significant spread expected in the Mediterranean Sea, the venomous sting of *P. lineatus* is likely to cause reversible health impacts over a large area, while more severe symptoms associated with secondary infections and deep puncture wounds remain a possibility. |

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| | | | Fisheries restrictions potentially leading to lower discard rates in the EU may result in a lower frequency of injuries. |
| **Other impacts** | | | |
| 2.33. How important is the impact of the organism as food, a host, a symbiont or a vector for other damaging organisms (e.g. diseases)? | minimal | low | Parasitic infestations (mostly ectoparasites) are common in *P. lineatus* in the native range (Froese & Pauly, 2017) but no information has been found on the issue from the invaded range |
| 2.34. How important might other impacts not already covered by previous questions be resulting from introduction of the organism? (specify in the comment box) | NA | | |
| 2.35. How important are the expected impacts of the organism despite any natural control by other organisms, such as predators, parasites or pathogens that may already be present in Europe? | major | low | The magnitude of impacts is not expected to be modified through natural control by other organisms<br><br>See Q1.18 (competition), 1.19 (predation, parasitism) |
| 2.36. Indicate any parts of Europe where any of the above impacts are particularly likely to occur (provide as much detail as possible). | [insert text + attach map if possible] | high | Ecological impacts are equally likely to occur in all the Mediterranean EU countries where the species is expected to arrive. Impacts on provisioning services and economic impacts through the fisheries sector are more likely to occur in those countries with large fishing fleets, i.e. Greece, Italy and Croatia, particularly Italy, which has the largest number of trawlers (FAO 2016).<br>Likewise for health impacts to fishermen. On the other hand, health impacts to beach-goers are expected to be more frequent/extensive in countries with well-developed coastal tourism industry, such as Greece and Spain, followed by Italy, Cyprus, Croatia, Malta |

| **ADDITIONAL QUESTIONS - CLIMATE CHANGE** | | | |
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| 3.1. What aspects of climate change, if any, are most likely to affect the risk assessment for this organism? | Temperature increase (2$^{o}$C) | very high | Areas of the risk assessment area that currently have temperatures below the thermal limit for spawning of *P. lineatus* (21 $^{o}$C) will become more amenable to establishment, all else being equal.<br><br>Moreover, if temperature increase is accompanied by the proliferation of the Lessepsian species which are preferred prey items of *P. lineatus* (Edelist et al., 2012) into the rest of the Mediterranean Sea, its establishment and spread may be favoured. |
| 3.2. What is the likely timeframe for such changes? | 80 years | high | Future climate conditions for mapping and distribution assessment purposes were approximated as an overall 2 °C sea surface temperature (SST) increase by 2098, projected according to the RCP4.5 scenario of IPCC which corresponds to medium-high anthropogenic radiative forcing RF; an increase in SST of up to 3 °C is predicted under the RCP8.5 scenario corresponding to high anthropogenic RF – IPCC AR5 report, 2013 |
| 3.3. What aspects of the risk assessment are most likely to change as a result of climate change? | Establishment<br><br>Spread<br><br>Impact | high | Increased establishment and spread, to the extent they are favoured by climate change, will expose more areas and stakeholder groups to socio-economic and health impacts of the species. |
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| **ADDITIONAL QUESTIONS - RESEARCH** | | | |
| 4.1. If there is any research that would significantly strengthen confidence in the risk assessment please summarise this here. | Establishment & population dynamics | high | Edelist et al. (2012) point out that, as observed in the past with other Lessepsian immigrants, *P. lineatus* may be currently overshooting its carrying capacity in the Levant. As a matter of fact, there is some indication that, since 2011, *P. lineatus* numbers in the area have decreased (Dor Edelist, pers.comm., 2017) but it still |

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| | | | constitutes a significant amount of the catch. Modelling the natural carrying capacity and dynamic equilibrium of *P. lineatus* in the East Mediterranean would increase our confidence in predicting the invasiveness potential of the species. |
| | Environmental impacts | | Further studies are required with respect to predation effects, trophic interactions and other ecosystem functions. Ecological aspects that should be examined include the potential impacts of *P. lineatus* on habitat structure and function, competition for daytime refuge with native species and the possibility of deleterious effects on naive predators, such as fish, marine mammals and birds. |
| | Economic impacts | | Socio-economic studies pertaining to the loss of income and the increase in health risk exposure for fishermen would allow the better estimation of monetary costs. The possibility of reduced beach use for fear of injury and any subsequent damage to the tourism industry need also be considered. |
| | Rate of spread | | Modelling studies on the dispersal of the adult stage could give us a better indication of the rate and level of success of reaching areas isolated by deep waters (e.g. by testing out various scenarios and doing sensitivity analysis for selected parameters). |
| | Risk of entry and spread | | Finally, more comprehensive and formally organised information on the aquarium trade of *P. lineatus* and other ornamental marine NIS need to be a priority for a better informed assessment of the risk of introduction and spread of ornamental species through aquaria related pathways. |

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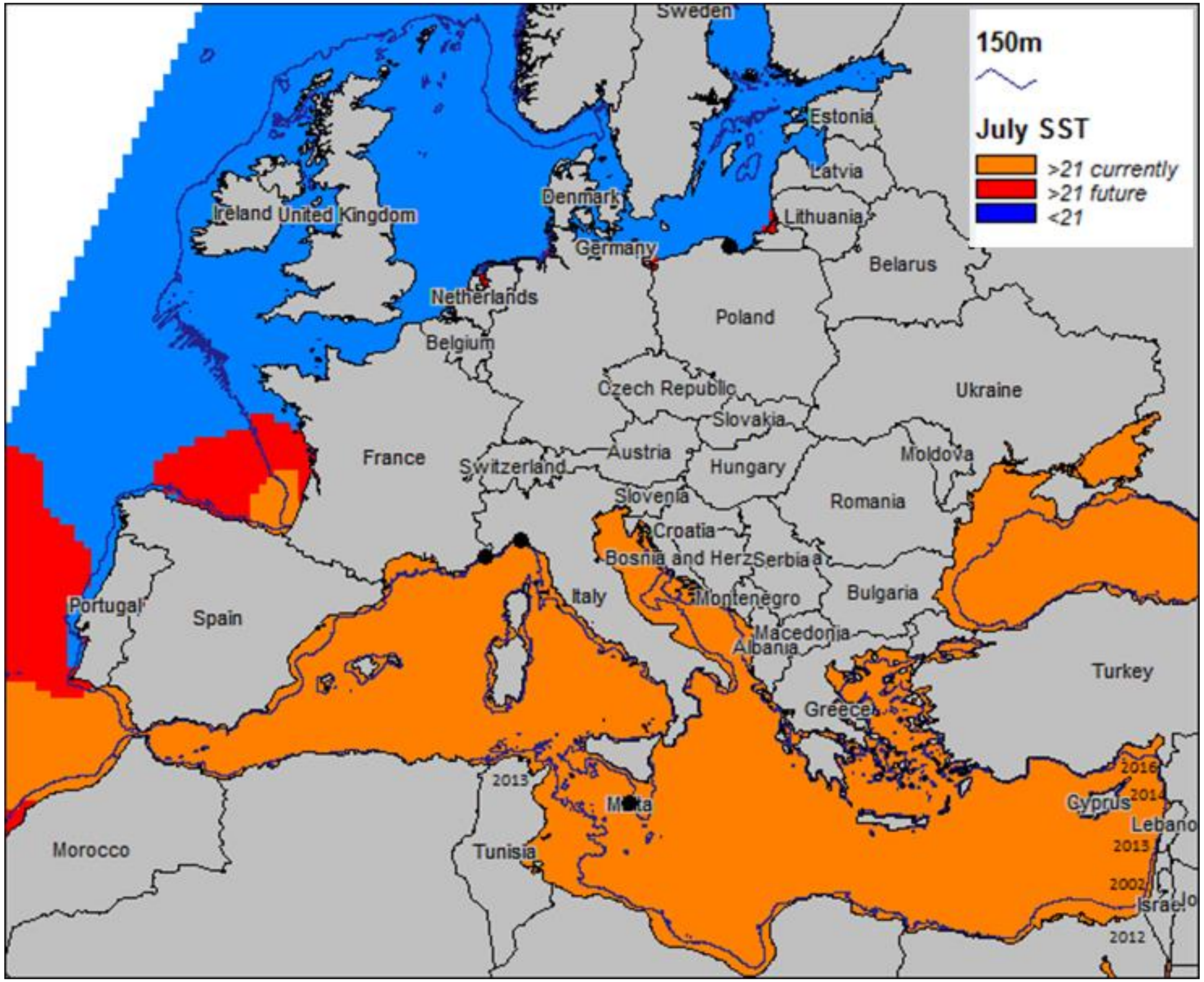
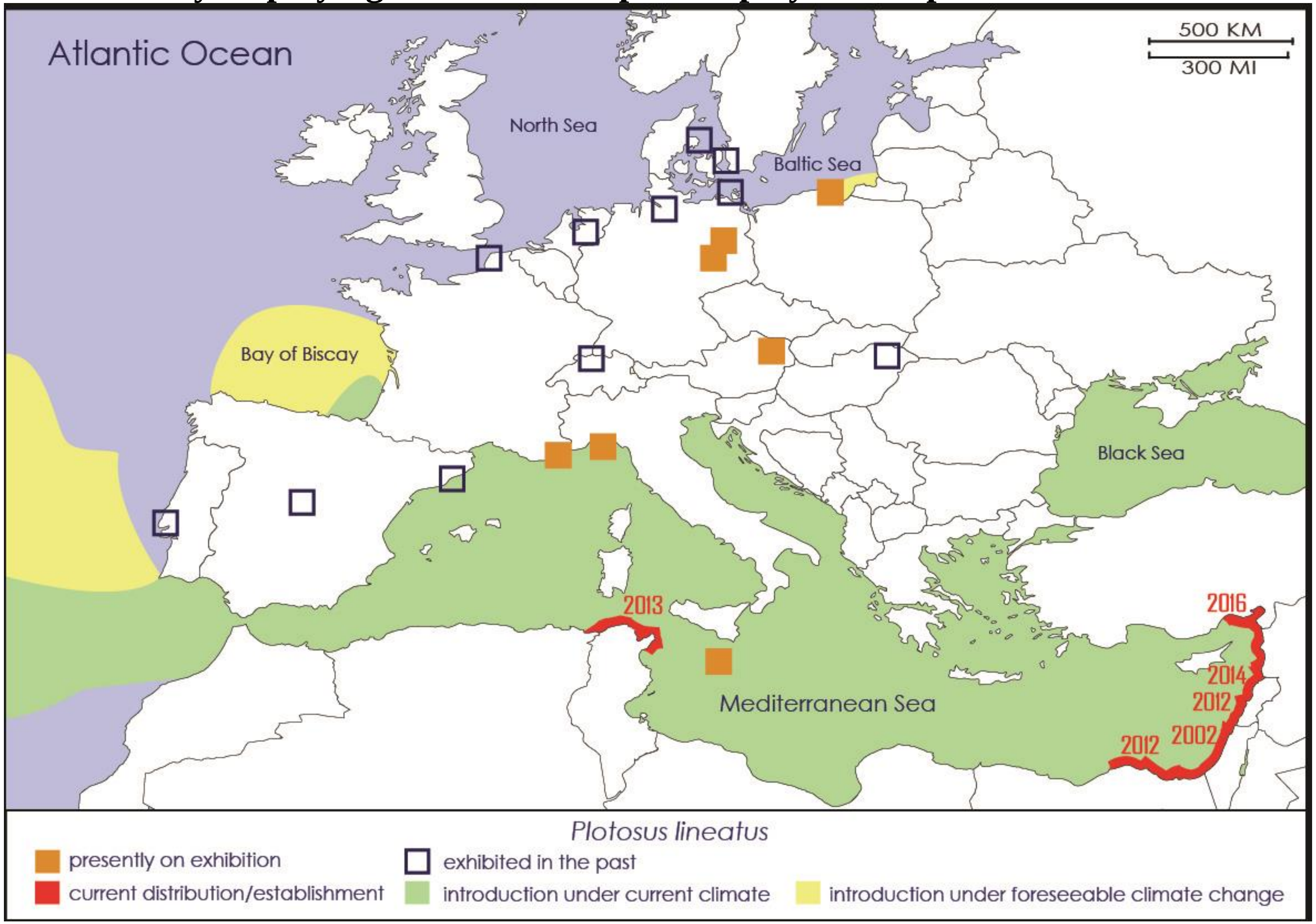
# ANNEX 1. Climatic conditions that allow the establishment of *P. lineatus* currently and under future climate change

(limiting factor is considered temperature for spawning in July>21 $^{o}$C , Sea Surface Temperature (SST) used as proxy, future conditions defined as a SST increase of 2 $^{o}$C, according to the RCP4.5 scenario, IPCC AR5 2013)



# ANNEX 2. Current and potential distribution map of *P. lineatus*, with locations where public aquaria are currently displaying or have in the past displayed the species



# ANNEX 3. Question to European Union Aquarium Curators (EUAC) members

| | | | | |
|---|---|---|---|---|
| Maria Corsini-Foka, HSR-HCMR/25-6-2017 | | | | |
| Question to European Union Aquarium Curators (EUAC) members and other Aquarium curators: Do you display Plotosus lineatus?: YES-NO | | | | |
| Email posted by M. Corsini-Foka on 11-5-2017 and again on 22-6-2017 | | | | |
| 108 email addresses linked, 15 absent, 8 not delivered | | | | |
| | | | | |
| **Name of Curator** | **Aquarium** | **Country** | **YES** | **NO** |
| Isabel Koch | Wilhelma der zoologisch-botanische Garten-Stuttgart | Germany | | No |
| Daniel Abed-Navandi | Haus des Meeres Vienna | Austria | Yes, now | |
| Lars Skou Olsen | Den Blå Planet Danmarks Akvarium | Denmark | Yes (in Tivoli Aquarium Denmark, in past) | |
| Marion Wille | Aquazoo Löbbecke Museum-Düsseldorf | Germany | | No |
| Espen Hansen | Akvariet i Bergen | Norway | | No |
| Claudia Gili and Silvia Lavorano | Genova Aquarium | Italy | Yes, ten years ago and some specimens now | |
| Rainer Kaiser | Aquarium Zoo Berlin | Germany | Yes, 52 semiadults since 2015 up to now | |
| Ester Alonso | Loro Parque-Tenerife | Spain | | No |
| Stefan Farkasdi | Tropicarium Budapest | Hungary | | No |
| Olivier Brunel | Aquarium Oceanographic Museum Monaco | Montecarlo | Yes, now | |
| Max Janse | Burgers Zoo Arnhem | Netherlands | Yes, a school of juveniles in 2001-2006 | |
| Brian Zimmerman | ZSL – London Zoo | UK | | No |

| | | | | |
|---|---|---|---|---|
| Primo Micarelli | Acquario Mondo Marino-Grosseto | Italy | | No |
| James Wright | National Marine Aquarium in Plymouth | UK | | No |
| Espen Rafter | Stiftelsen Polaria-TROMSØ | Norway | | No |
| Anke Oertel | Haus der Natur - Museum für Natur und Technik-Salzburg | Austria | | No |
| Stéphane HÉNARD, Catherine….. | NAUSICAA, Centre National de la Mer-Boulogne sur Mer | France | Yes, between 1991-2001 | |
| Kristina Ydesen | Nordsoen Oceanarium-Hirtshals | Denmark | | No |
| Attila Varga | Sosto Zoo-Nyiregyhaza-Sostofürdö | Hungary | Yes, 10-15 specimens in 2010. Eaten by a nurse shark (Ginglymostoma cirratum). The shark is still alive. | |
| Amalia Martínez de Murguía | Aquarium Donostia-San Sebastian | Spain | | No |
| Guido Westhoff | Tierpark Hagenbeck Gemeinnützige Gesellschaft mbH-Hamburg | Germany | Yes, in 2014-2015 | |
| Daniel de Castro | Malta National Aquarium | Malta | Yes, since 2013 up to now | |
| Ulrich Graßl | Zoo Leipzig GmbH | Germany | Yes, 15 specimens, now | |
| Fátima Gil | Aquário Vasco da Gama - Lisboa | Portugal | | No |
| Aspasia Sterioti | Cretaquarium-Eraklion | Greece | | No |
| Patrici Bultó | L' Aquàrium de Barcelona | Spain | Yes, from 2002 to 2008 | |
| Rune Kristiansen | Kattegatcentre-Grenaa | Denmark | Yes , from 2009 to 2011 | |
| Rune Veiseth | Atlanterhavsparken-Alesund | Norway | | No |
| Jens P. Jeppesen | The Øresund Aquarium-University of Copenhagen | Denmark | | No |
| Pedro Garcia Miguel | Instanbul Akvaryum | Turkey | | No |
| Nerine Badawy | Alexandria Aquarium | Egypt | | No |
| Nikos G. Koutsoloukas | Ocean Aquarium Cyprus | Cyprus | | No |

| | | | | |
|---|---|---|---|---|
| Milena Mičić | Aquarium Pula | Croatia | | No |
| Jakub Kordas | Kierownik ds. akwariów/ Afrykarium-Zoo Wrocław | Poland | | No |
| Thomas Jermann | Aquarium-Vivarium, ZOOLOGISCHER GARTEN BASEL | Switzerland | Yes, from 1996 to 2004 | |
| Nicolas Hirel | Mare Nostrum Aquarium Monpellier | France | | No |
| Marcin Betlejewski | Akvarium Gdinskie (Gdynia) | Polland | Yes, from 2015 up to now | |
| Nicol Kube | Museum für Meereskunde und Fischerei · Aquarium, Stralsund | Germany | Yes, in the 1990s, for two years | |
| Philip Jouk | Antwerp Zoo-Aquarium | Belgium | | No |
| Julia Duhem | Pairi Daiza Zoo Brugelette (Belgium) | Belgium | | No |
| Pablo Montoto Gasser | ZooAquarium de Madrid | Spain | Yes, from 2004 to 2006 and in 2013 | |
| Marie Bournonville | Liège University aquarium | Belgium | | No |
| Nuria Baylina | Oceanarium Lisboa | Portugal | Yes, from 2000 to 2008 | |
| 43 | 43 | | 18 | 25 |
| Steven L. Bailey | New England Aquarium-Boston | Massachusetts-USA | Yes, from 1990 to 1992 | |
| Yaarub F. Al-Yahya | Aquarium Scientific Center | Kwait | Yes | |
| | | | | |
| | | | | |
| | Yes, today | Yes, in past | Never | |
| N. of Public Aquaria | 7 | 11 | 24 | |

# ANNEX 4. Clinical manifestations of victims of *Plotosus lineatus* injured in the Southeastern Mediterranean Sea.

(After Bentur et al, 2017)

| Clinical manifestation | Number of victims | Percent of all victims |
|---|---|---|
| **Local manifestations** | | |
| Pain | 76 | 90.5% |
| Puncture wound | 59 | 70.2% |
| Swelling | 28 | 33.3% |
| Erythema | 14 | 16.7% |
| Hematoma | 3 | 3.6% |
| Paresthesia | 3 | 3.6% |
| Tenosynovitis | 1 | 1.2% |
| Necrosis | 1 | 1.2% |
| | | |
| **Systemic manifestations** | | |
| Hypertension | 6 | 7.1% |
| (systolic >140 mmHg, and/or diastolic >90 mmHg) | (highest systolic 160 mmHg)<br><br>(highest diastolic 100 mmHg) | |
| **Tachycardia** | 2 | 2.4% |
| (>100 beats/min) | (highest 109 beats/min) | |
| Vomiting | 2 | 2.4% |
| Chills | 2 | 2.4% |
| Weakness | 2 | 2.4% |
| Agitation | 1 | 1.2% |
| Dizziness | 1 | 1.2% |

Some victims had more than one clinical manifestation.

# ANNEX 5. Communication with local experts

We contacted a number of local experts from the countries where *P. lineatus* could potentially arrive and establish. We sought their input on the likelihood of establishment of *P. lineatus* in their country based on their knowledge of local habitats, regulations and policies concerning the marine environment and IAS in particular and their experience with other marine IAS establishing in these areas. Specifically we posed the following questions:

**'How likely is the organism to establish despite existing management practices in Europe?'**
**Given that "*Plotosus lineatus* has the ability to live in a variety of coastal habitats with a wide range of salinities (estuaries, lagoons, sandy and rocky bottoms, shallow and open seas) down to 150m" how would you answer this for your country?**
**Which existing policies in your country would favour or prevent its spread?**

Country: Croatia

Person contacted: Dr.Branko Dragičević Affiliation: Institute of Oceanography and Fisheries

Communication: "I'm really not aware of any policy that might have any influence on establishment or prevention of establishment of any marine fish species in Croatia as long as we are talking about active migration."

Country: Slovenia

Person contacted: Dr. Lovrenc Lipej Affiliation: National Institute of Biology, Marine Biology Station Piran

Communication: "With respect to detectability a) the Marine Biology Station of the National Institute of biology (MBS) is regularly surveying the occurrence of less known, rare and non-indigenous species. This is especially true for coastal environments, such as lagoons, estuaries, shallow water habitats, rocky bottom) b. a network in which many local elements are involved offer the possibility to rapidly detect such peculiar fish species (Aquarium Piran, fishermen communities, recreational fishermen, diving associations, naturalists, others...).

With respect to legislation a) the Act of nature conservation (Republic of Slovenia) is defining how to deal with aliens, what is an alien, that aliens are strictly prohibited to be introduced in Slovenia; however, there is no word at all about prevention or eradication. b) If somebody wants to introduce a certain fish (and other) species in Slovenia, there is a list of specialists who are invited to prepare a document regarding all possible impacts of the NISD in question and recommendations how to deal with the requested NIS."

Country: Spain

Person contacted: Dr. Francisco Alemany Affiliation: Spanish Institute of Oceanography, Balearic Islands

Communication: "If the species arrives and the environmental conditions are suitable, I do not know how the spreading could be prevented…there are also several national laws regarding alien species, even a relatively recent one, from 2013, listing the priority species, terrestrial and marine (Plotosus is not there). We are applying all the international legal framework for preventing aliens introductions, and the monitoring of marine aliens under WFD and MSFD, but I'm afraid this is not enough for preventing the "natural" secondary spreading of Plotosus."

Country: Italy

Person contacted: Dr. Franco Andaloro Affiliation: ISPRA

Communication: "In Italy we don't have any authority that is directly involved in prevention against dangerous alien species. We have competence of health ministry regarding veterinary inspection in fish market that received information by our data bank. The only fishes (excluding the protected species of course) that are not possible to sell are Tetradontiformes. Another competence, regarding the action against alien species, is of the environmental ministry in application of international conventions and the EU directives. Finally the agriculture and fishery ministry ha competence on the catch and has a collaboration with the coastal guard regarding control on fish and fishing, this ministry has also the register of alien species in aquaculture managed by my institute that give the authorisation to use species not native in aquaculture. The only measures applied in Italy are the early warnings launched by ISPRA in the media and the fishing ports as well as the case of *Lagochephalus sceleratus* and the lionfish."

Person contacted: Dr.Ernesto Azzurro Affiliation: ISPRA

Communication: "Italy is enforcing national legislation for specific introduction pathways, such as aquaculture and vessels, but for Lessepsian species and other range expanding NIS, we generally make reference to the principles included in the EU regulation 1143/2014, even if these species are not listed in the list of species of union concern."

Country: Malta

Person contacted: Dr.Alan Deidun Affiliation: International Ocean Institute - Malta Centre

Communication: "The Maltese Islands are notoriously lacking in terms of large-scale and permanent coastal wetlands and estuaries, with freshwater runoff from land being limited to the period immediately following heavy rainfall during the wet season. Even watercourses are temporary and highly intermittent. In fact, non-indigenous species dependent on a freshwater contribution and recorded from adjacent regions (e.g. *Callinectes sapidus*) are notoriously missing from Malta. Sea salinity is relatively homogenous throughout Maltese coastal waters, which, however, support a wide range of habitats and seabed, ranging from vegetated rocky reefs, to seagrass meadows, to coralligenous assemblages and bare sandy bottoms. Hence, I would rate the introduction risk for Maltese waters associated with *Plotosus lineatus* as moderate.

The aquarium trade in Malta is very poorly regulated, such that anyone can purchase an exotic species, including Pterois miles, with relative ease. Malta at the moment is implementing EU regulations concerning the control of terrestrial invasive species and has yet to act where it comes to marine invasive species management"

Person contacted: Dr.Patrick Schembri Affiliation: University of Malta, Faculty of Science

Communication: "While there are no estuaries or lagoons in Malta, there are large areas of sandy bottom bordered by rocky outcrops with underhangs, which seem to be one preferred habitat for the species, so potentially, the species may yet occur.
There is no official (i.e. Government) monitoring programme for aliens. No monitoring programmes are being implemented in any of the local MPAs by the authorities in charge. Research on aliens is being conducted by university academics, who have formal (i.e. citizen science) or informal networks of contacts who report occurrences of 'unusual' species. Plotosus is sufficiently distinctive that if it occurs, it is likely to be reported through one of these networks.
As far as I am aware there are no policies in place that would either favour or prevent the spread of this species. There are also no contingency plans for any eventual occurrence of this (or other) alien species in local waters."

Additionally, aquaria curators were contacted through the European Union of Aquarium Curators, in search of information on P.lineatus in protected conditions. We received the following information:

Person contacted: Lars Skou Olsen  Affiliation: Technical manager, Research and conservation-Den Blå Planet-Danmarks Akvarium

Communication: "When I was working in the Tivoli Aquarium here in Copenhagen we had *Plotosus lineatus* in the exhibition tank. The LSS system is built over a break tank where there is a pump that delivers water to the sand filters from the tank before any filters has filtered the water. In the sand filter is a sight glass, one day when we looked in the sand filters there was some 5 cm juvenile *Plotosus lineatus* that had grown from larvae to juvenile inside the sand filters."

# ANNEX 6. Scoring of Likelihoods of Events

(taken from UK Non-native Organism Risk Assessment Scheme User Manual, Version 3.3, 28.02.2005)

| Score | Description | Frequency |
|---|---|---|
| Very unlikely | This sort of event is theoretically possible, but is never known to have occurred and is not expected to occur | 1 in 10,000 years |
| Unlikely | This sort of event has not occurred anywhere in living memory | 1 in 1,000 years |
| Possible | This sort of event has occurred somewhere at least once in recent years, but not locally | 1 in 100 years |
| Likely | This sort of event has happened on several occasions elsewhere, or on at least one occasion locally in recent years | 1 in 10 years |
| Very likely | This sort of event happens continually and would be expected to occur | Once a year |

# ANNEX 7. Scoring of Magnitude of Impacts

(modified from UK Non-native Organism Risk Assessment Scheme User Manual, Version 3.3, 28.02.2005)

| **Score** | **Biodiversity and ecosystem impact** | **Ecosystem Services impact** | **Economic impact (Monetary loss and response costs per year)** | **Social and human health impact** |
|---|---|---|---|---|
| | *Question 2.18-24* | *Question 2.25-27* | *Question 2.28-32* | *Question 2.33-38* |
| Minimal | Local, short-term population loss, no significant ecosystem effect | No services affected[1] | Up to 10,000 Euro | No social disruption. Local, mild, short-term reversible effects to individuals. |
| Minor | Some ecosystem impact, reversible changes, localised | Local and temporary, reversible effects to one or few services | 10,000-100,000 Euro | Significant concern expressed at local level. Mild short-term reversible effects to identifiable groups, localised. |
| Moderate | Measureable long-term damage to populations and ecosystem, but little spread, no extinction | Measureable, temporary, local and reversible effects on one or several services | 100,000-1,000,000 Euro | Temporary changes to normal activities at local level. Minor irreversible effects and/or larger numbers covered by reversible effects, localised. |
| Major | Long-term irreversible ecosystem change, spreading beyond local area | Local and irreversible or widespread and reversible effects on one / several services | 1,000,000-10,000,000 Euro | Some permanent change of activity locally, concern expressed over wider area. Significant irreversible effects locally or reversible effects over large area. |
| Massive | Widespread, long-term population loss or extinction, affecting several species with serious ecosystem effects | Widespread and irreversible effects on one / several services | Above 10,000,000 Euro | Long-term social change, significant loss of employment, migration from affected area. Widespread, severe, long-term, irreversible health effects. |

[1] Not to be confused with „no impact“.

# ANNEX 8. Scoring of Confidence Levels

(modified from Bacher et al. 2017)

| **Confidence level** | **Description** |
|---|---|
| Low | There is no direct observational evidence to support the assessment, e.g. only inferred data have been used as supporting evidence *and/or* Impacts are recorded at a spatial scale which is unlikely to be relevant to the assessment area *and/or* Evidence is poor and difficult to interpret, e.g. because it is strongly ambiguous *and/or* The information sources are considered to be of low quality or contain information that is unreliable. |
| Medium | There is some direct observational evidence to support the assessment, but some information is inferred *and/or* Impacts are recorded at a small spatial scale, but rescaling of the data to relevant scales of the assessment area is considered reliable, or to embrace little uncertainty *and/or* The interpretation of the data is to some extent ambiguous or contradictory. |
| High | There is direct relevant observational evidence to support the assessment (including causality) *and* Impacts are recorded at a comparable scale *and/or* There are reliable/good quality data sources on impacts of the taxa *and* The interpretation of data/information is straightforward *and/or* Data/information are not controversial or contradictory. |
| Very high | There is direct relevant observational evidence to support the assessment (including causality) from the risk assessment area *and* Impacts are recorded at a comparable scale *and* There are reliable/good quality data sources on impacts of the taxa *and* The interpretation of data/information is straightforward *and* Data/information are not controversial or contradictory. |

# ANNEX 9. Ecosystem services classification (CICES V4.3) and examples

For the purposes of this risk analysis, please feel free to use what seems as the most appropriate category / level of impact (Division – Group – Class), reflecting information available.

| Section | Division | Group | Class | Examples |
|---|---|---|---|---|
| **Provisioning** | Nutrition | Biomass | Cultivated crops | Cereals (e.g. wheat, rye, barely), vegetables, fruits etc. |
| | | | Reared animals and their outputs | Meat, dairy products (milk, cheese, yoghurt), honey etc. |
| | | | Wild plants, algae and their outputs | Wild berries, fruits, mushrooms, water cress, salicornia (saltwort or samphire); seaweed (e.g. Palmaria palmata = dulse, dillisk) for food |
| | | | Wild animals and their outputs | Game, freshwater fish (trout, eel etc.), marine fish (plaice, sea bass etc.) and shellfish (i.e. crustaceans, molluscs), as well as equinoderms or honey harvested from wild populations; Includes commercial and subsistence fishing and hunting for food |
| | | | Plants and algae from in-situ aquaculture | In situ seaweed farming |
| | | | Animals from in-situ aquaculture | In-situ farming of freshwater (e.g. trout) and marine fish (e.g. salmon, tuna) also in floating cages; shellfish aquaculture (e.g. oysters or crustaceans) in e.g. poles |
| | | Water | Surface water for drinking | Collected precipitation, abstracted surface water from rivers, lakes and other open water bodies for drinking |
| | | | Ground water for drinking | Freshwater abstracted from (non-fossil) groundwater layers or via ground water desalination for drinking |
| | Materials | Biomass | Fibres and other materials from plants, algae and animals for direct use or processing | Fibres, wood, timber, flowers, skin, bones, sponges and other products, which are not further processed; material for production e.g. industrial products such as cellulose for paper, cotton for clothes, packaging material; chemicals extracted or synthesised from algae, plants and animals such as turpentine, rubber, flax, oil, wax, resin, natural remedies and medicines (e.g. chondritin from sharks), dyes and colours, ambergris (from sperm whales used in perfumes); Includes consumptive ornamental uses. |
| | | | Materials from plants, algae and animals for agricultural use | Plant, algae and animal material (e.g. grass) for fodder and fertilizer in agriculture and aquaculture |
| | | | Genetic materials from all biota | Genetic material from wild plants, algae and animals for biochemical industrial and pharmaceutical processes e.g. medicines, fermentation, detoxification; bio-prospecting activities e.g. wild species used in breeding programmes etc. |

| | | | | |
|---|---|---|---|---|
| | | Water | Surface water for non-drinking purposes | Collected precipitation, abstracted surface water from rivers, lakes and other open water bodies for domestic use (washing, cleaning and other non-drinking use), irrigation, livestock consumption, industrial use (consumption and cooling) etc. |
| | | | Ground water for non-drinking purposes | Freshwater abstracted from (non-fossil) groundwater layers or via ground water desalination for domestic use (washing, cleaning and other non-drinking use), irrigation, livestock consumption, industrial use (consumption and cooling) etc. |
| | Energy | Biomass-based energy sources | Plant-based resources | Wood fuel, straw, energy plants, crops and algae for burning and energy production |
| | | | Animal-based resources | Dung, fat, oils, cadavers from land, water and marine animals for burning and energy production |
| | | Mechanical energy | Animal-based energy | Physical labour provided by animals (horses, elephants etc.) |
| **Regulation & Maintenance** | Mediation of waste, toxics and other nuisances | Mediation by biota | Bio-remediation by micro-organisms, algae, plants, and animals | Bio-chemical detoxification/decomposition/mineralisation in land/soil, freshwater and marine systems including sediments; decomposition/detoxification of waste and toxic materials e.g. waste water cleaning, degrading oil spills by marine bacteria, (phyto)degradation, (rhizo)degradation etc. |
| | | | Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals | Biological filtration/sequestration/storage/accumulation of pollutants in land/soil, freshwater and marine biota, adsorption and binding of heavy metals and organic compounds in biota |
| | | Mediation by ecosystems | Filtration/sequestration/storage/accumulation by ecosystems | Bio-physicochemical filtration/sequestration/storage/accumulation of pollutants in land/soil, freshwater and marine ecosystems, including sediments; adsorption and binding of heavy metals and organic compounds in ecosystems (combination of biotic and abiotic factors) |
| | | | Dilution by atmosphere, freshwater and marine ecosystems | Bio-physico-chemical dilution of gases, fluids and solid waste, wastewater in atmosphere, lakes, rivers, sea and sediments |
| | | | Mediation of smell/noise/visual impacts | Visual screening of transport corridors e.g. by trees; Green infrastructure to reduce noise and smells |
| | Mediation of flows | Mass flows | Mass stabilisation and control of erosion rates | Erosion / landslide / gravity flow protection; vegetation cover protecting/stabilising terrestrial, coastal and marine ecosystems, coastal wetlands, dunes; vegetation on slopes also preventing avalanches (snow, rock), erosion protection of coasts and sediments by mangroves, sea grass, macroalgae, etc. |
| | | | Buffering and attenuation of mass flows | Transport and storage of sediment by rivers, lakes, sea |
| | | Liquid flows | Hydrological cycle and water flow maintenance | Capacity of maintaining baseline flows for water supply and discharge; e.g. fostering groundwater; recharge by appropriate land coverage that captures effective rainfall; includes drought and water scarcity aspects. |

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| | | | Flood protection | Flood protection by appropriate land coverage; coastal flood prevention by mangroves, sea grass, macroalgae, etc. (supplementary to coastal protection by wetlands, dunes) |
| | | Gaseous / air flows | Storm protection | Natural or planted vegetation that serves as shelter belts |
| | | | Ventilation and transpiration | Natural or planted vegetation that enables air ventilation |
| | Maintenance of physical, chemical, biological conditions | Lifecycle maintenance, habitat and gene pool protection | Pollination and seed dispersal | Pollination by bees and other insects; seed dispersal by insects, birds and other animals |
| | | | Maintaining nursery populations and habitats | Habitats for plant and animal nursery and reproduction e.g. seagrasses, microstructures of rivers etc. |
| | | Pest and disease control | Pest control | Pest and disease control including invasive alien species |
| | | | Disease control | In cultivated and natural ecosystems and human populations |
| | | Soil formation and composition | Weathering processes | Maintenance of bio-geochemical conditions of soils including fertility, nutrient storage, or soil structure; includes biological, chemical, physical weathering and pedogenesis |
| | | | Decomposition and fixing processes | Maintenance of bio-geochemical conditions of soils by decomposition/mineralisation of dead organic material, nitrification, denitrification etc.), N-fixing and other bio-geochemical processes; |
| | | Water conditions | Chemical condition of freshwaters | Maintenance / buffering of chemical composition of freshwater column and sediment to ensure favourable living conditions for biota e.g. by denitrification, re-mobilisation/re-mineralisation of phosphorous, etc. |
| | | | Chemical condition of salt waters | Maintenance / buffering of chemical composition of seawater column and sediment to ensure favourable living conditions for biota e.g. by denitrification, re-mobilisation/re-mineralisation of phosphorous, etc. |
| | | Atmospheric composition and climate regulation | Global climate regulation by reduction of greenhouse gas concentrations | Global climate regulation by greenhouse gas/carbon sequestration by terrestrial ecosystems, water columns and sediments and their biota; transport of carbon into oceans (DOCs) etc. |
| | | | Micro and regional climate regulation | Modifying temperature, humidity, wind fields; maintenance of rural and urban climate and air quality and regional precipitation/temperature patterns |
| **Cultural** | Physical and intellectual interactions with biota, | Physical and experiential interactions | Experiential use of plants, animals and land-/seascapes in different environmental settings | In-situ whale and bird watching, snorkelling, diving etc. |

| | | | | |
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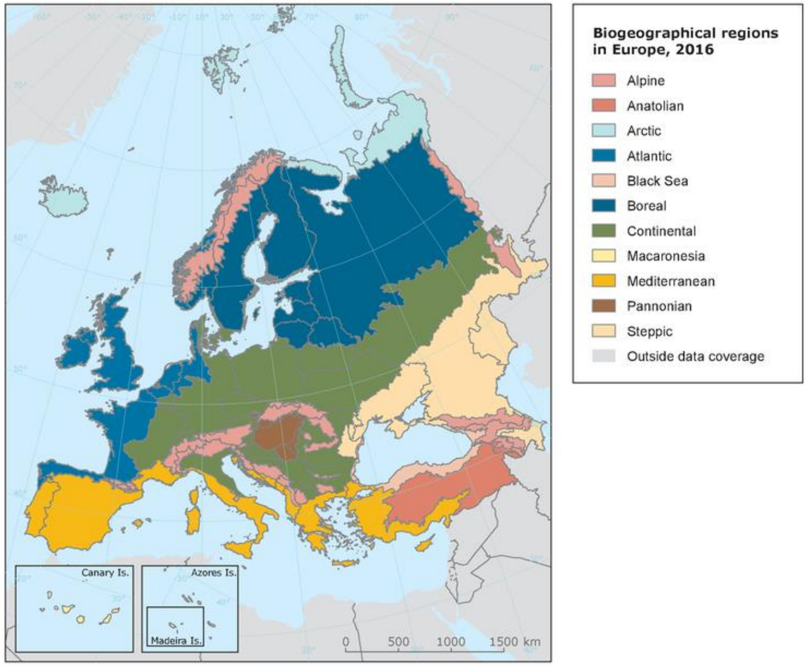
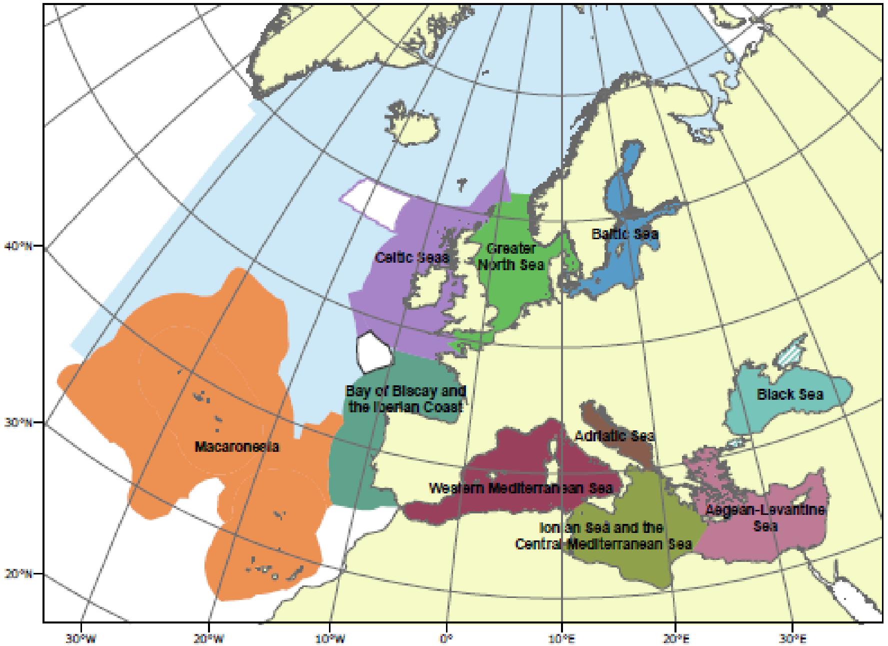
| | ecosystems, and land-/seascapes [environmental settings] | | | |
| | | | Physical use of land-/seascapes in different environmental settings | Walking, hiking, climbing, boating, leisure fishing (angling) and leisure hunting |
| | | Intellectual and representative interactions | Scientific | Subject matter for research both on location and via other media |
| | | | Educational | Subject matter of education both on location and via other media |
| | | | Heritage, cultural | Historic records, cultural heritage e.g. preserved in water bodies and soils |
| | | | Entertainment | Ex-situ viewing/experience of natural world through different media |
| | | | Aesthetic | Sense of place, artistic representations of nature |
| | Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings] | Spiritual and/or emblematic | Symbolic | Emblematic plants and animals e.g. national symbols such as American eagle, British rose, Welsh daffodil |
| | | | Sacred and/or religious | Spiritual, ritual identity e.g. 'dream paths' of native Australians, holy places; sacred plants and animals and their parts |
| | | Other cultural outputs | Existence | Enjoyment provided by wild species, wilderness, ecosystems, land-/seascapes |
| | | | Bequest | Willingness to preserve plants, animals, ecoystems, land-/seascapes for the experience and use of future generations; moral/ethical perspective or belief |

# ANNEX 10. EU Biogeographical Regions and MSFD Subregions

See https://www.eea.europa.eu/data-and-maps/figures/biogeographical-regions-in-europe-2
and https://www.eea.europa.eu/data-and-maps/data/msfd-regions-and-subregions/technical-document/pdf



# ANNEX 11. Evidence on measures and their implementation cost and cost-effectiveness

| | |
|---|---|
| Species (common name) | Striped eel catfish |
| Species (scientific name) | *Plotosus lineatus* (Thunberg, 1787) |
| Date Completed | 17.11.17 |
| Authors | Marika Galanidi, Argyro Zenetos, Jack Sewell |
| Version | V2_ 6.10.17 |

| | Description of measures | Assessment of implementation cost and cost-effectiveness (per measure) | Level of confidence |
|---|---|---|---|
| Methods to achieve prevention (P1-P4) | **P1**. Installation of high-salinity locks in the Suez Canal (Goren & Galil, 2005) / Reinstating the former salinity barrier of the Bitter Lakes (Galil et al., 2017)<br><br>Policy co-ordination at the regional level, including non EU states (Barcelona Convention). | This is a major technical and financial undertaking, requiring international co-operation. Edelist et al. (2013) consider this a highly impractical suggestion.<br><br>To date, proposed management measures for species introductions in the Mediterranean in the framework of the Barcelona convention have excluded introductions through the Suez Canal (Galil et al., 2016).<br><br>Moreover, in the framework of the MSFD, Descriptor 2 (Non-indigenous species), species entering through the Suez Canal are excluded from indicator 2.1.1 (i.e.trends in abundance, temporal occurrence and spatial distribution in the wild of non-indigenous | Medium<br>The much lower rate of species introductions through the Panama Canal, which includes a locked freshwater corridor (consisting partly of the natural Gatun Lake) and the increase in species introductions through the Suez Canal after the |

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| | | species, particularly invasive non-indigenous species, notably in risk areas, in relation to the main vectors and pathways of spreading of such species). COMMISSION DECISION (EU) 2017/848. See also Palialexis et al. (2015). | salinity changes in the Bitter Lakes and the Nile estuary provide evidence that a salinity barrier could be an effective solution for the canal pathway (Gollasch, 2011). However, despite the recent enlargement (2015) and no salinity barrier, the number of new introductions in the Mediterranean via the Suez appears to be declining after 2015 (Zenetos, 2017) |
| | **P2.** To prevent ESCAPE from confinement from open or semi-open circulation aquaria: stricter control/enforcement of cleaning operations (filters, disinfection), especially at the outlet to the sea | Improved biosecurity measures in private, public and research aquaria would address a potential pathway for a range of species, providing value beyond the management of *P. lineatus*. | Low |
| | **P3.** To prevent intentional RELEASE from domestic aquaria: awareness campaigns to | Awareness raising campaigns run in association with aquarium suppliers, trade organisations and aquarist | Low |

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| | educate the public on the threats posed by *P. lineatus* to the environment, ecosystem services and human well-being. | forums already exist but it is difficult to assess the long-term effectiveness of these programmes.<br>Public aquaria could also serve as a useful educational tool in promoting awareness. | |
| | **P4**. Prohibit trade of *P. lineatus* by including it in EU 1143/2014 | Existing information indicates that *P. lineatus* as an ornamental species is not very highly in demand by European aquarists and has a limited distribution in large public/private aquaria and research facilities (Murray & Watson, 2014; OATA/EPO/OFI, pers.comm), thus, a ban on sale would be unlikely to have a major impact on the aquarium industry. A potential ban however may have negative implications for public aquaria and research institutions. | Medium |
| Methods to achieve eradication (E1-E3) | Theoretically, eradication may be possible for localised, newly established populations at low densities with limited dispersal capabilities (Delaney & Leung, 2010; Ojaveer et al, 2015). This would require an early warning system, monitoring efforts and a removal program. | Physical removal of invasive species is generally endorsed by informed stakeholders, as long as it can easily be stopped and has no long-term consequences for the marine environment (Thresher & Kuris 2004)<br>In the marine environment, eradication of naturally dispersing species is generally considered unrealistic and has only been achieved in a handful of cases, when the introduced species had sessile adult stages, the populations were small and restricted, human and financial resources were available, and early action was taken (Williams & Grosholz, 2008).<br>Nevertheless, population control that leads to minimising the severity of impacts and the risk of transfer to yet uncolonised areas is considered feasible (Ojaveer et al., 2015). | |
| | **E1. Early warning systems / awareness raising** | | |

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| | Such initiatives are in place for *Plotosus lineatus* in a number of Mediterranean EU countries, if not on official species lists, at least through the networks of local/regional experts with stakeholders (see Annex of the RA document), national and regional collaboration platforms on invasive/alien species (e.g. ESENIAS, Karachle et al., 2017; ELNAIS), citizen science programmes and the press (see Q1.7a of the RA Document). | As an indication of effectiveness, awareness campaigns in the public media on *Pterois miles* have led to its early detection in Italy (Sicily: Azzurro et al, 2017), Greece (Rhodes: Corsini-Foka & Kondylatos in Crocetta et al., 2015), Cyprus (Kletou et al., 2016).<br><br>Part of the work can be materialized within the framework of existing programs, such as the Horizon 2020 'Doing It Together Science' (DITOs) project, in which the European Citizen Scientist Association is involved and coordinate a series of events and activities with the aim to provide networking opportunities and to facilitate the exchange of good practices for the **BioBlitz** approach. BioBlitz events are important opportunities for public engagement with science, environmental management and policy. These are broad scale and not specific to *Plotosus lineatus.*<br>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 (IAS) and biological invasions globally (Lucy et al., 2016). | Medium<br><br>Early warning systems have proved effective for the early detection of Lessepsian invasive fishes. |
| | **E2.Monitoring**<br><br>Monitoring can be achieved through scientific (e.g. MEDITS International bottom trawl survey in the Mediterranean Sea) and fisheries dependent surveys and should focus on the areas of the first | <br><br>A cost effective method, utilising existing survey programmes and commercial fishing activities. | |

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| | expected entry points via natural dispersal. These are: Sicily (IT) from Tunisia, Cyprus from Syria and/or Turkey and the Dodecanese islands (GR) from Turkey once *P. lineatus* reaches the Aegean coast of Turkey. | | |
| | **E3.Removal program**<br><br>Direct removal with intensive targeted fishery, especially during the spawning period, i.e. trawling in shallow waters in the summer months. Alternatively, concerted efforts with multiple gears can be employed, e.g. seine nets, cages, spearfishing, angling. | This presents major problems as it goes against EU Regulation 1967/2006, which bans trawling at depths shallower than 50m throughout the year and additional fisheries restrictions implemented nationally in EU countries, mostly in the spring and summer months, to protect spawning stocks of commercial and other protected species. *P. lineatus* has been captured with different fishing methods as well, i.e. seine nets, cages, spearfishing (Ali et al., 2015, 2017), angling (Gil Rilov, pers.comm), but the efficiency of these gears for large-scale removal is not known.<br>Eradication has not been attempted for *Plotosus lineatus* in the invaded range but it is not expected to be a cost-effective, ecologically acceptable and realistic option. The deposition of eggs under rocks and debris and the parental care protect the eggs, whereas the general preference and spawning in shallow areas renders possible eradication measures (e.g. by trawling) destructive for native species and habitats, particularly sensitive habitats, such as reefs and seagrass beds. Additionally, local eradication would require ongoing, long-term, regular interjections due to the ongoing risk of re-introduction | Medium<br>Eradication attempts for marine fish species are limited to a small number of species and indicate that success in unlikely |

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| | | and spread from surrounding populations or through the Suez canal.<br>A case where one could derive information to arrive at a monetary estimate is that of *Lagocephalus sceleratus* in Cyprus. They implemented a targeted fishery program by collective groups of artisanal professional fishermen. The amount paid to beneficiaries was based on the weight of fish that they would catch and deliver to an authorized waste management company (€3/kg). The amount paid to fishermen was approximately 145.000 € for two eradication campaigns during the reproductive season in 2011 and 2012 (DFMR Cyprus 2011, 2012) and eradication was not successful, however the species was already well established in Cyprus and has pelagic life stages. Eradication attempts of the lionfish *Pterois volitans* in the Carribean have also demonstrated that complete eradication is unlikely but population control under certain conditions is possible (Barbour et al., 2011; Frazer et al., 2012, Green et al. 2014). | |
| Methods to achieve management (M1 – M5) | **M1. Population control and/or “containment” through targeted fishing activities.**<br>If eradication is not possible at the core of the species’ distribution, in which case re-introduction through natural dispersal will be very likely, it could still be theoretically possible to contain the invader and control the newly established populations (Grosholz & Ruiz, 2002) with targeted fishing activities surrounding the core or | Containment/population control would most likely require a long-term commitment over consecutive years over localized areas (Barbour et al., 2011) and would involve a considerable cost. As with eradication campaigns, it may require changes in legislation on fishing restrictions and prove detrimental to other species and habitats. The lack of a larval pelagic phase (Leis, 1993) and the preference of *P. lineatus* for | Medium |

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| | new populations within a radius slightly larger than the yearly dispersal capability (Edwards & Leung, 2009). | shallow waters will act as impediments to rapid dispersal and may facilitate containment efforts. | |
| | **M2. Human consumption, commercial fisheries and the Discard Ban** Another control measure that has been implemented for marine invasive fishes is to encourage human consumption (Nunez et al 2012 and the example of *Pterois volitans*). In this context, including *P. lineatus* in the list of species covered by the landings obligation of the EU CFP (a.k.a. the Discard Ban) could promote commercial exploitation, alleviate some of the economic and health impacts of the species, and help control human-assisted spread through fisheries discards. | In its native range *P. lineatus* is considered edible and is exploited by small scale fishers (Vijayakumaran 1997; Manikandarajan et al. 2014).<br><br>The relevant legislation has not been implemented yet (i.e. the relevant EU Regulations for the landings obligations) but a similar solution has been proposed for the invasive fish *Neogobius melanostomus* in the Baltic Sea (Ojaveer et al. 2015). An argument against this practice is that encouraging commercial utilisation risks institutionalising a pest (Thresher & Kuris, 2004). However, if the species is already well established, a commercial, regulated fishery may be the best option for long term population control and damage restriction. On the other hand, even though *P. lineatus* is not a poisonous species, public concern about the toxicity of the skin and the gland beneath the dorsal spine (Shiomi et al., 1988), may make consumption problematic. | Low |
| | **M3.** Regional co-**ordination** and policy integration with non-EU countries bordering the Mediterranean where *P. lineatus* is already present or expected to arrive | This would be important both for monitoring and for containment efforts between introduction "hotspots" and surrounding populations.<br>*P. lineatus* is already included in the priority list of non-indigenous species for monitoring in relation to fisheries in the East Mediterranean in a pilot study by FAO/GFCM (UNEP/MAP, 2017). The proposal is that the species is monitored through the Data | |

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| | | Collection Reference Framework (DCRF) (CFP requirement) of EU Member States and the discards monitoring program of the GFCM (GFCM – UNEP/MAP, 2018). | |
| | **M4.** The EU **Trade control** and Expert System (TRACES) could be adjusted to gather compulsory information on the intra-EU trade of *P. lineatus* as an ornamental species (Biondo 2017). This system can currently be used to track imports of the species from third countries. | Builds on existing mechanism and could help track the spread of *P. lineatus* through the aquarium trade in EU countries | Low |
| | **M5.** For the mitigation of impacts: **awareness campaigns** to fishermen and the general public for the dangerous sting of the species and how to safely handle the organism and treat the injuries | A recent study reporting on injuries from *P. lineatus* in Israel between 2007-2016 (Bentur et al., 2017) hypothesized that a decrease in the number of cases recorded by the Israel Poison Information Center after 2009 might be related (among other reasons) to the awareness of victims and physicians to the generally mild nature of the injury and the favourable response to supportive treatment. | High |

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