Non-indigenous marine species, a global biorisk agent in selected regional Seas

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Outline

- Biorisk by alien species
- Abundance and distribution of NIS in European regional Seas
- The Northern Adriatic Sea and the Wadden Sea: two areas at high risk of invasion by NIS
- The Lagoon of Venice: a hotspot of introductions
- NIS impact is evident but not easily measured
- Prevention, remediation and adaptation to biological change

Biorisk in EU Directives

Introduction of non-indigenous species (NIS) has impacted the conservation of biodiversity, structure and function of ecosystems, sustainable exploitation of natural resources, and may negatively impact industries and pose threats to human health.

4.11.2014 EN Official Journal of the European Union L 317/35

REGULATION (EU) No 1143/2014 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 22 October 2014

on the prevention and management of the introduction and spread of invasive alien species

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty on the Functioning of the European Union, and in particular Article 192(1) thereof,

Non-Indigenous Species (NIS) in the EU Marine Strategy Framework Directive

NIS abundance and distribution is **qualitative Descriptor 2** for the assessment of GOOD ENVIRONMENTAL STATUS

Indicator 2.1.1: Trends in abundance, temporal occurrence and spatial distribution in the wild of NIS, particularly invasive NIS, **notably in risk areas**, in relation to the main vectors and pathways of spreading of such species.

Indicator 2.2.2 : Environmental impact of invasive non-indigenous species

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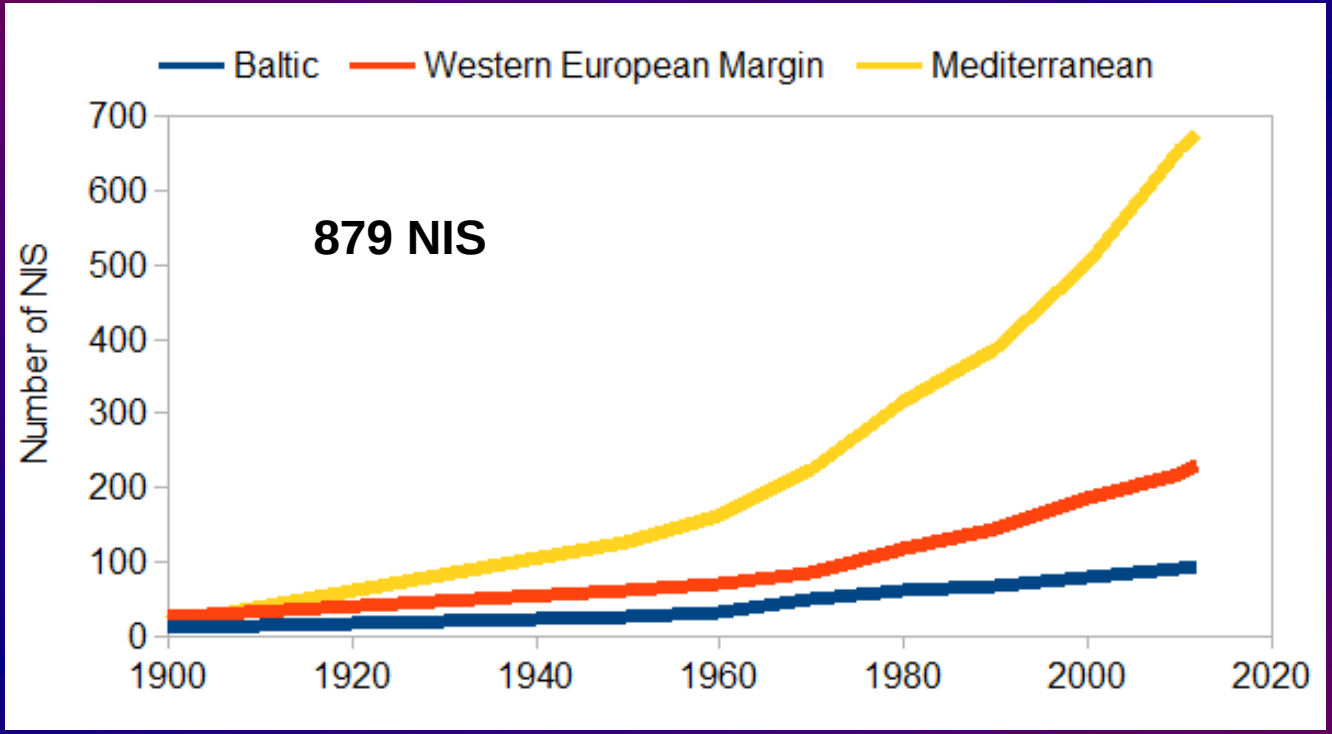
How many marine NIS in Europe ?

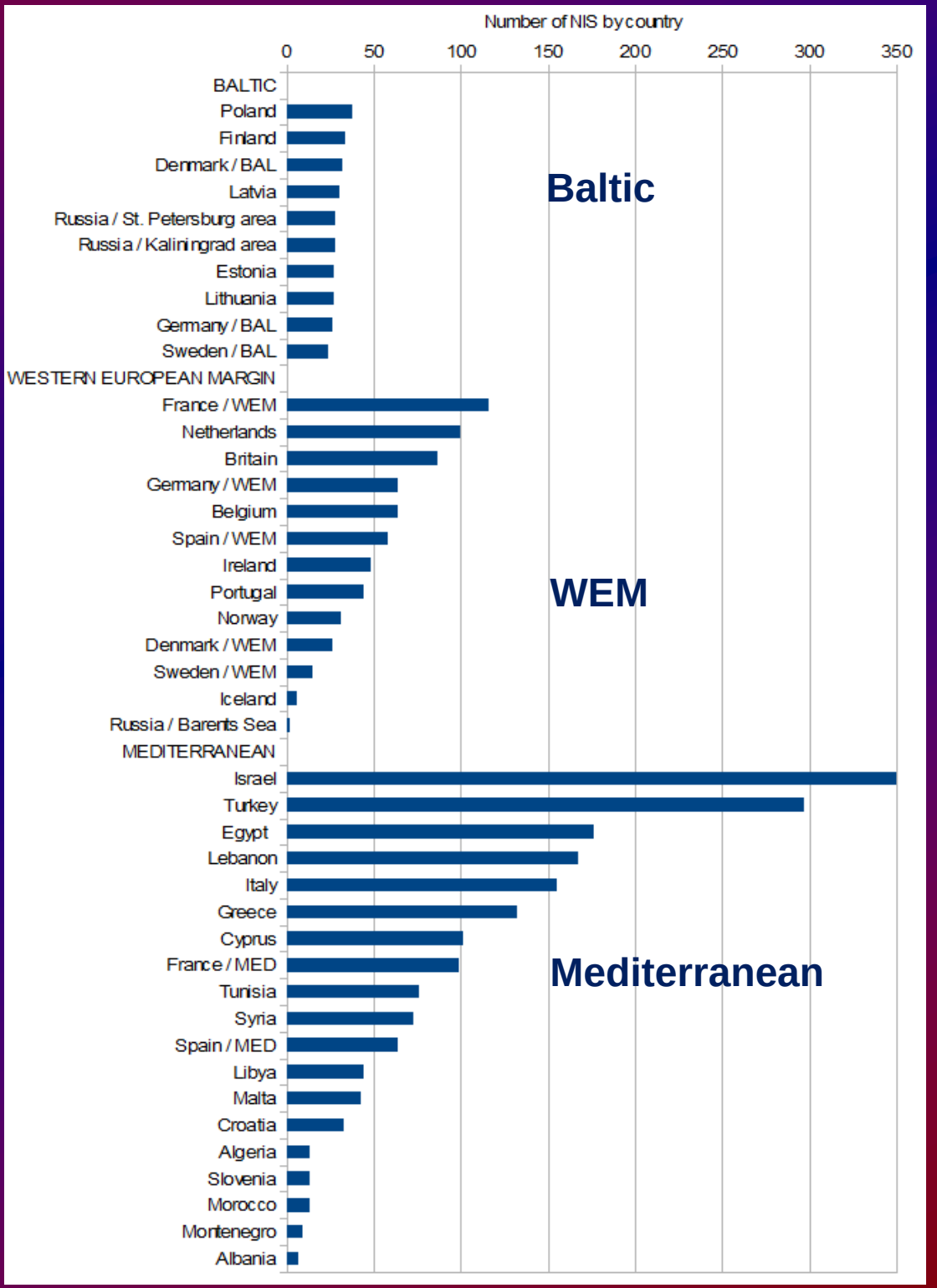


Cumulative number of non-indigenous species recorded in the Baltic Sea, Western European Margin and Mediterranean Sea.

Galil *et al*., 2014, Ethol.Ecol.Evol.

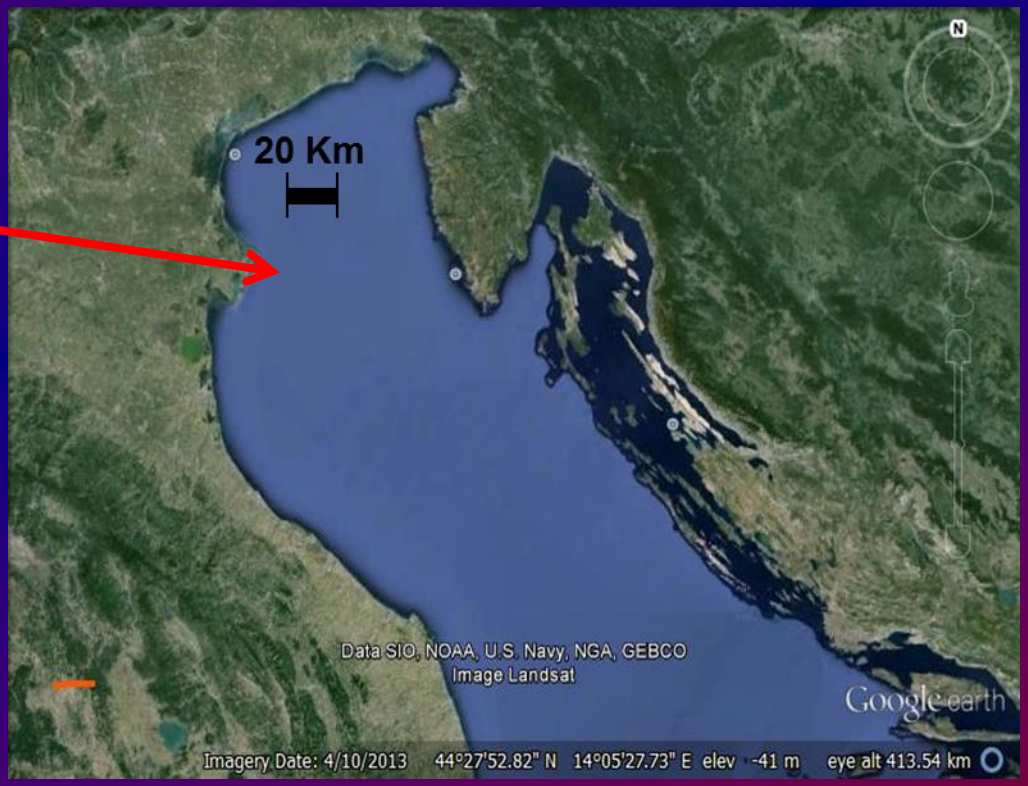
How many marine NIS in Europe ?

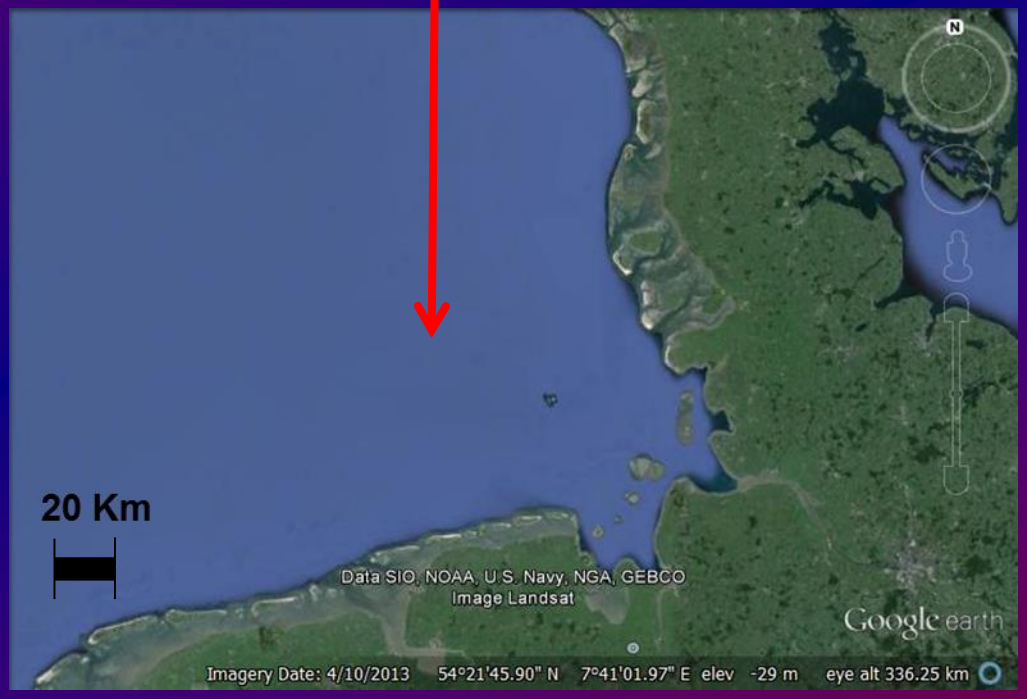
Number of non-indigenous species recorded by country in the Baltic Sea, Western European Margin and Mediterranean Sea.



Galil *et al*., 2014, Ethol.Ecol.Evol.

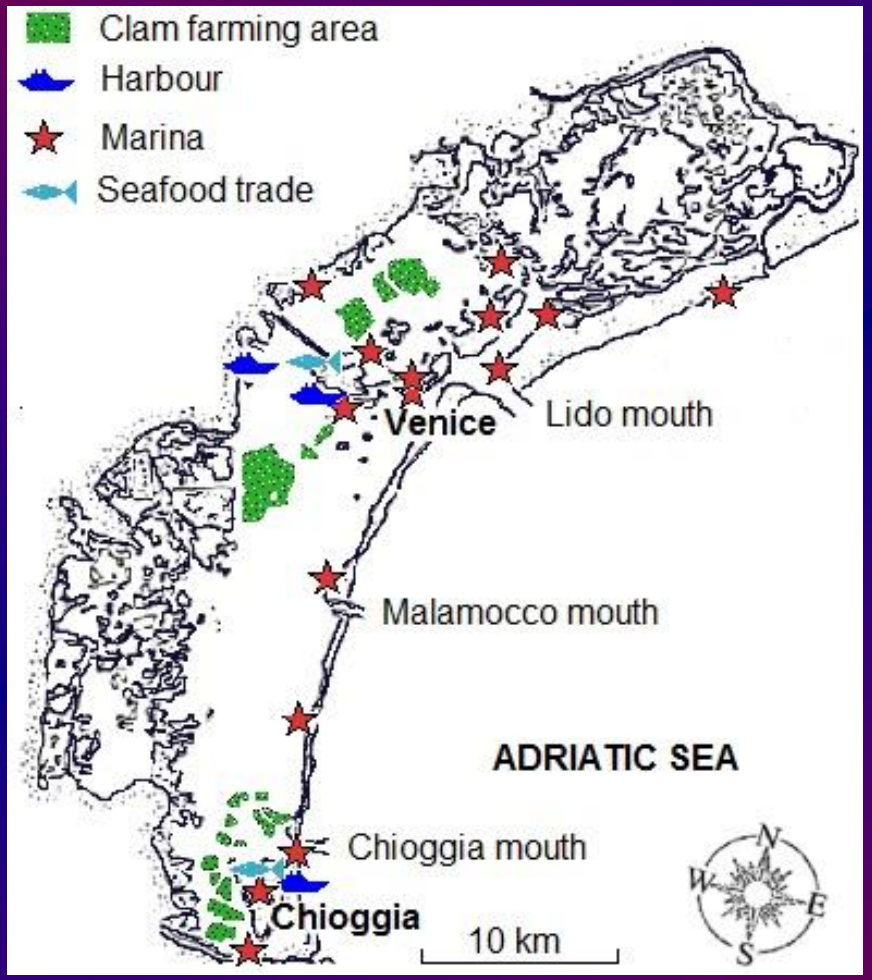
Two risk areas
Wadden Sea – Northern Adriatic





The Lagoon of Venice

a brackish water body of 550 km^2 connected to the Northern Adriatic



- **3 harbour terminals:** Venice, Marghera, Chioggia
- **33 marinas and yacht clubs** (>8000 moorings)
- **4,500 ha for clam farms** (~ 500 operators; ~ 450 tons of clam seeds imported yearly)
- **2 fish markets**, plus live seafood processing sites

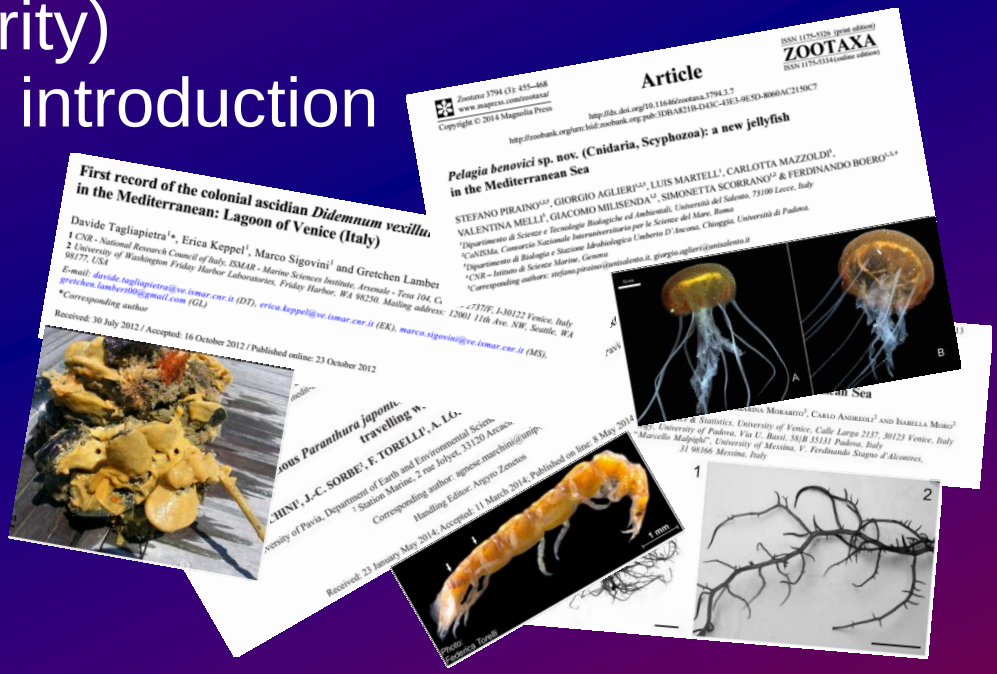
Data gathered from a variety of sources

- **Interviews and direct observations**

  (Chioggia fish market, Port Authority)
  → intensity of the main vectors of introduction

- **Literature survey**

  → update of the NIS inventory



- **Field surveys**

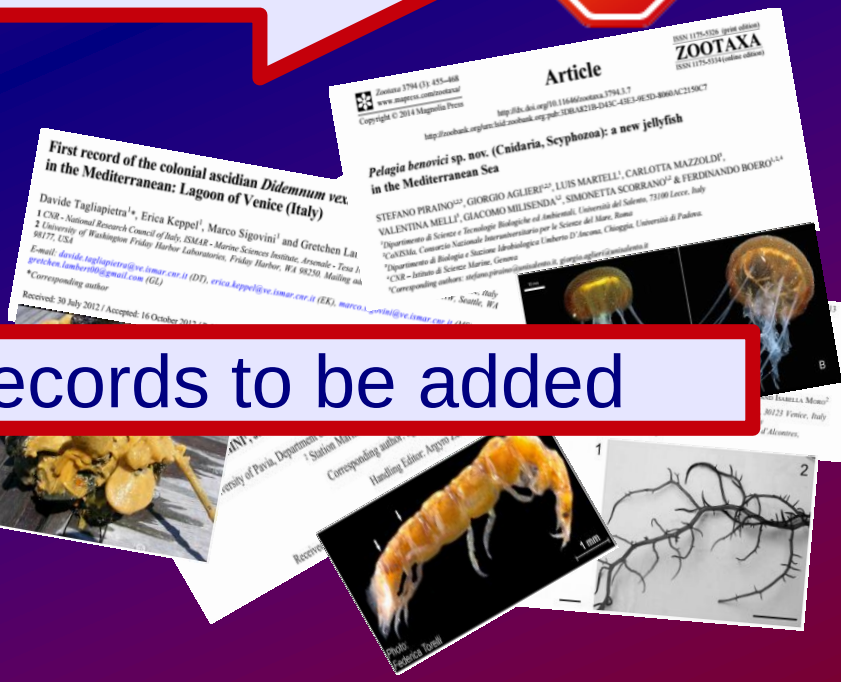
  → 54 samples collected in 2012

Updating the list of NIS in the Lagoon of Venice

Table 1. Alien species introduced into the benthic communities of the Lagoon of Venice. Species marked with an asterisk (*) were described in the Lagoon of Venice as the first record for the Mediterranean Sea.

Species	First record	Known from	Reference
Algae			
Sargassum muticum	1992	Japan	Gargiulo et al. 1992
Undaria pinnatifida			
Grateloupia doryphora			
~~*Radicilingua thysanorhizans*~~			
Antithamnion pectinatum			
~~*Sorocarpus* sp.~~			
~~*Ectocarpus siliculosus* var. *hiemalis*~~	1998	Black Sea	Bellemo et al. 1999
~~*Punctaria tenuissima*~~	1998	Boreal-Atlantic	Bellemo et al. 1999
Cnidaria			
Garveia franciscana *	1978	Indopacific	Morri 1982
Diadumene cincta *	1993	Atlantic	Birkemeyer 1996
Annelida Polychaeta			
Ficopomatus enigmaticus	1934	Australia	Fauvel 1938
Hydroides dianthus	1934	NW Atlantic	Fauvel 1938
Hydroides elegans	1934	Australia?	Fauvel 1938
Crustacea			
~~*Paracerceis sculpta*~~	1983	N Africa	Forniz and S
~~*Elasmopus pectenicrus* *~~	1983	Red Sea	Sconf
Callinectes danae *	1981	NW Atlantic	
Callinectes sapidus	1950	NW Atlantic	
Dyspanopeus sayi *	1992	NW Atlantic	Froglia and
Caprella scaura *	1994	Indopacific	Sconfietti and Dan
Arthropoda Chelicerata			
Ammothea hilgendorfi *	1979–1981	Pacific	Krapp and Sconfietti 1983
Bryozoa			
Tricellaria inopinata *	1982	Indopacific	d'Hondt and Occhipinti 1985
Celleporella carolinensis *	1994	W Atlantic	Occhipinti and d'Hondt 1996
Mollusca			
Crassostrea gigas	1966	Japan	Cesari and Pellizzato 1985a
Anadara (Scapharca) inaequivalvis	1976	Indopac	Cesari and Pellizzato 1985a
Saccostrea commercialis	1984	NW	Cesari and Pellizzato 1985a
Rapana venosa	1981		
Bursatella leachi	1985		
Xenostrobus securis *	1		
Tapes philippinarum	1983		
Tunicata			
Botrylloides violaceus *	1993	Indo	Zaniolo et al. 1998

Questionable records to be removed

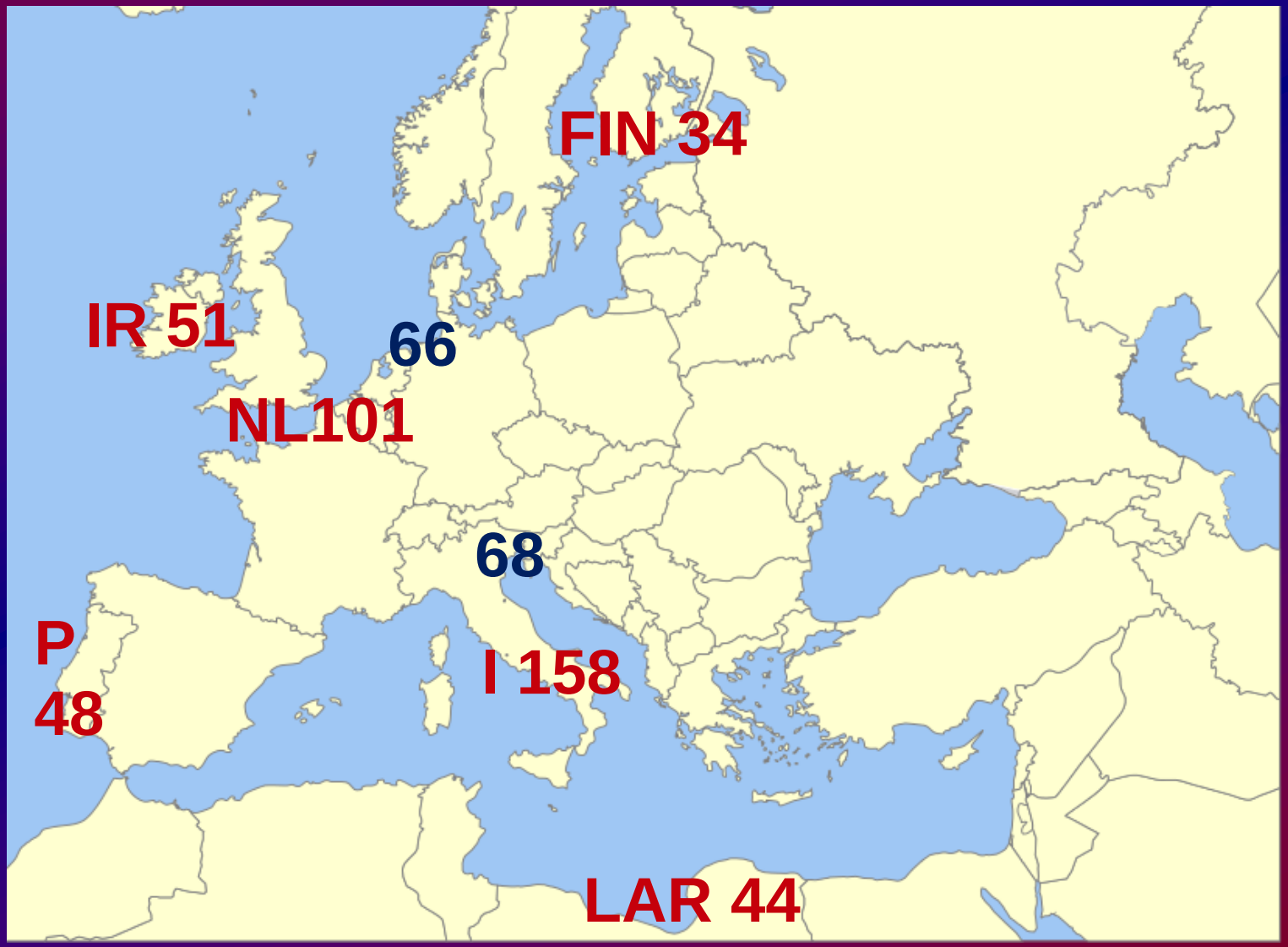


New records to be added

Old records of '*pseudo-indigenous species*'

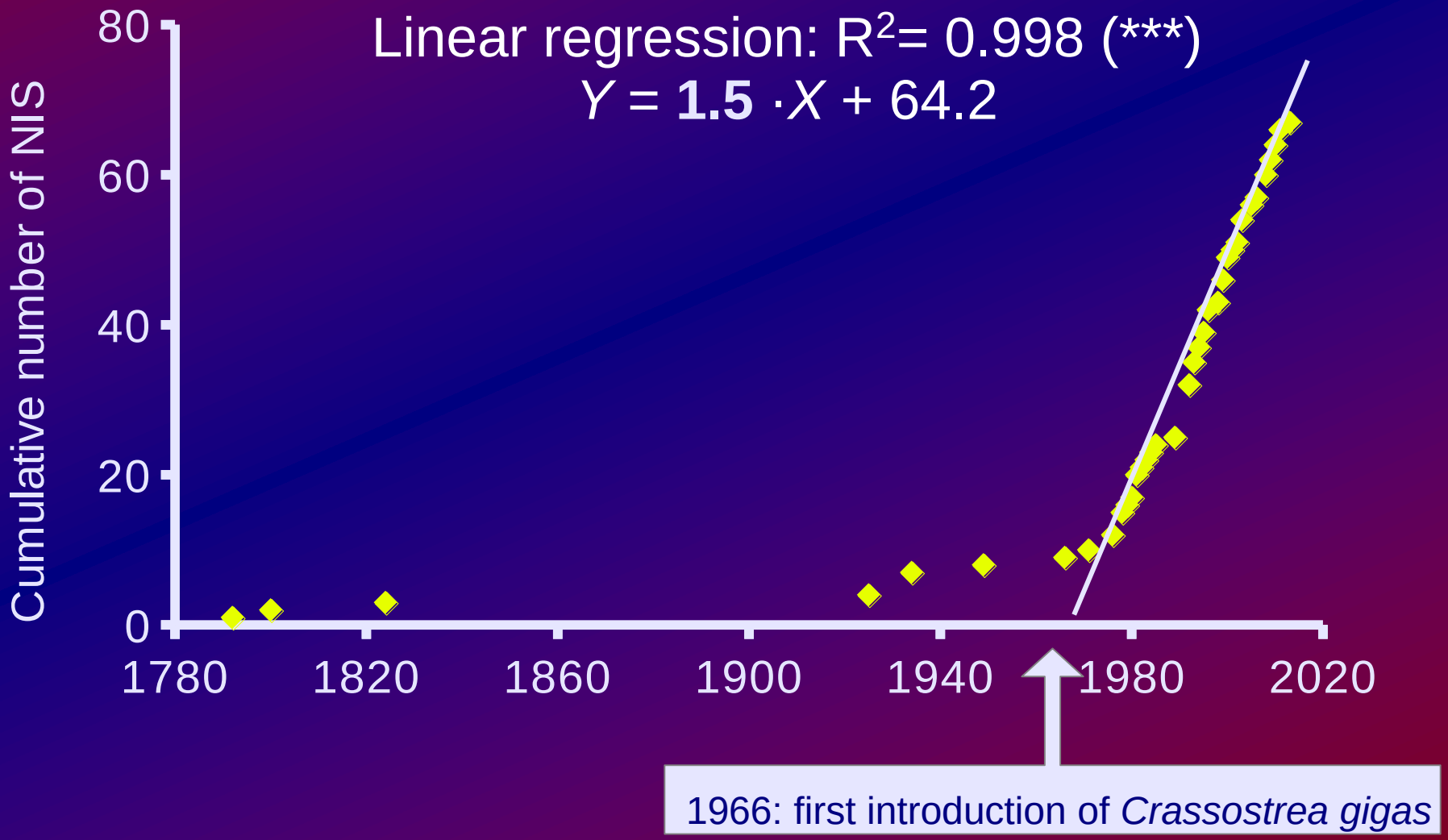
The Lagoon of Venice as a hotspot for NIS

68 NIS in the Lagoon of Venice alone



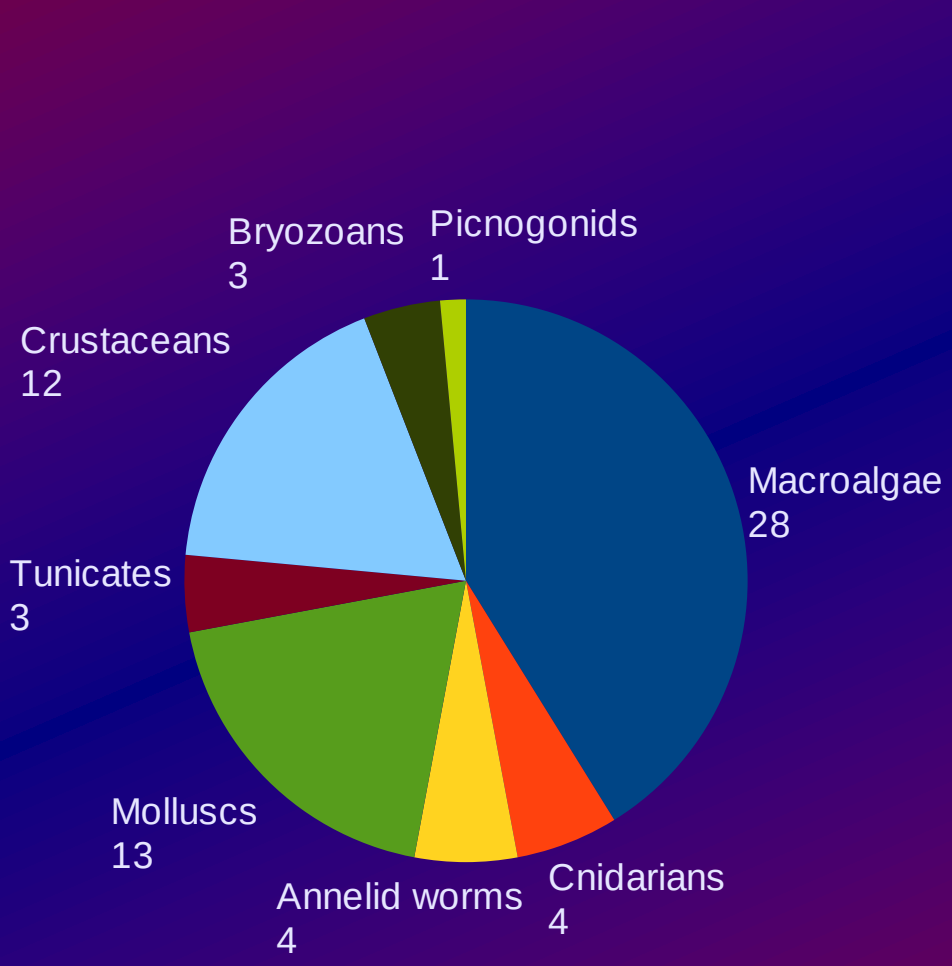
(Buschbaum et al., 2012.; Galil et al., 2014; Marchini et al., in press)

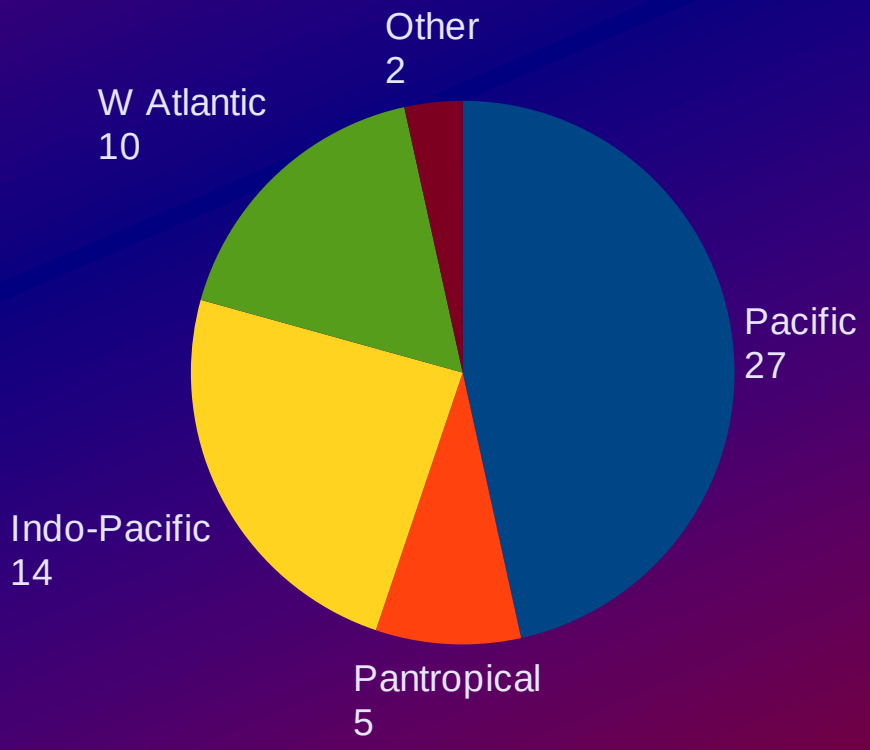
Timeline of introductions in the Lagoon of Venice



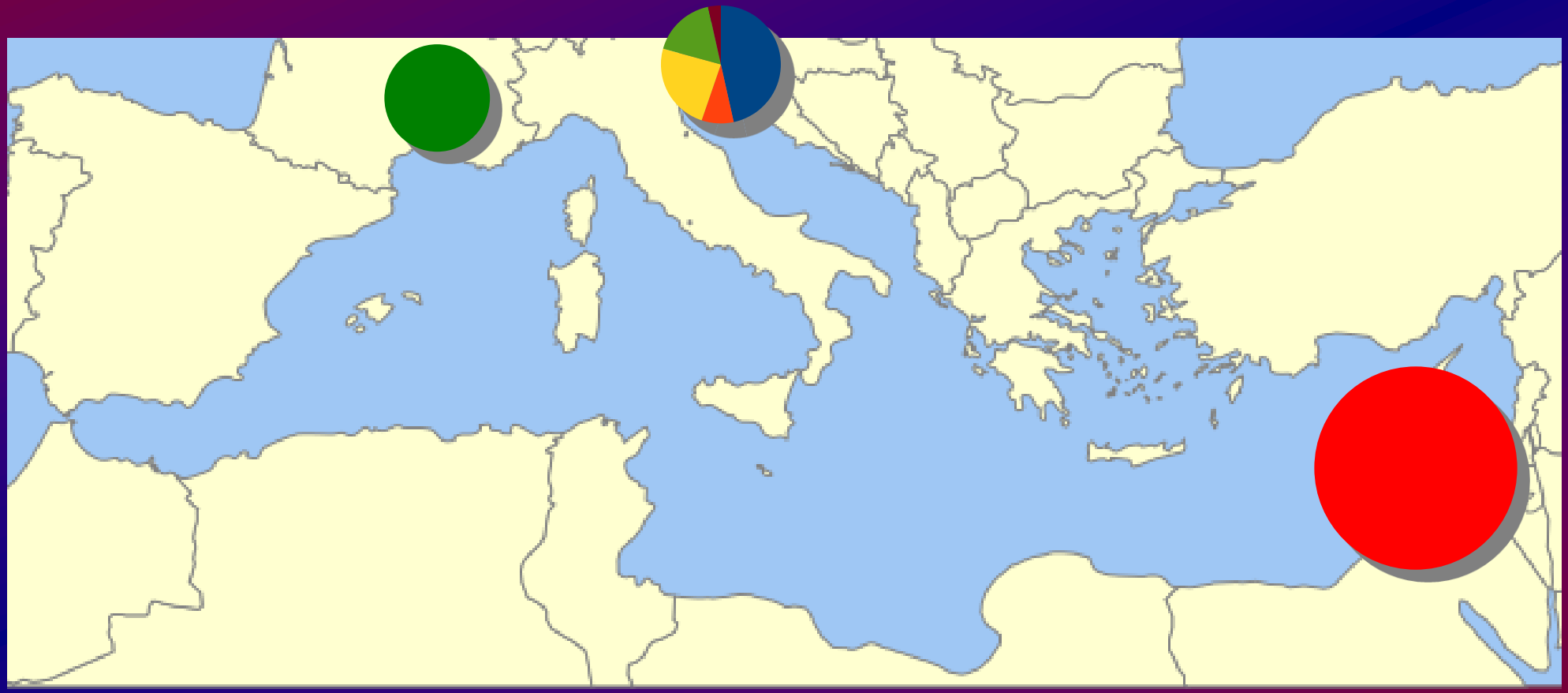
What kind of NIS and where do they come from ?

Taxa and native origin of Venice NIS

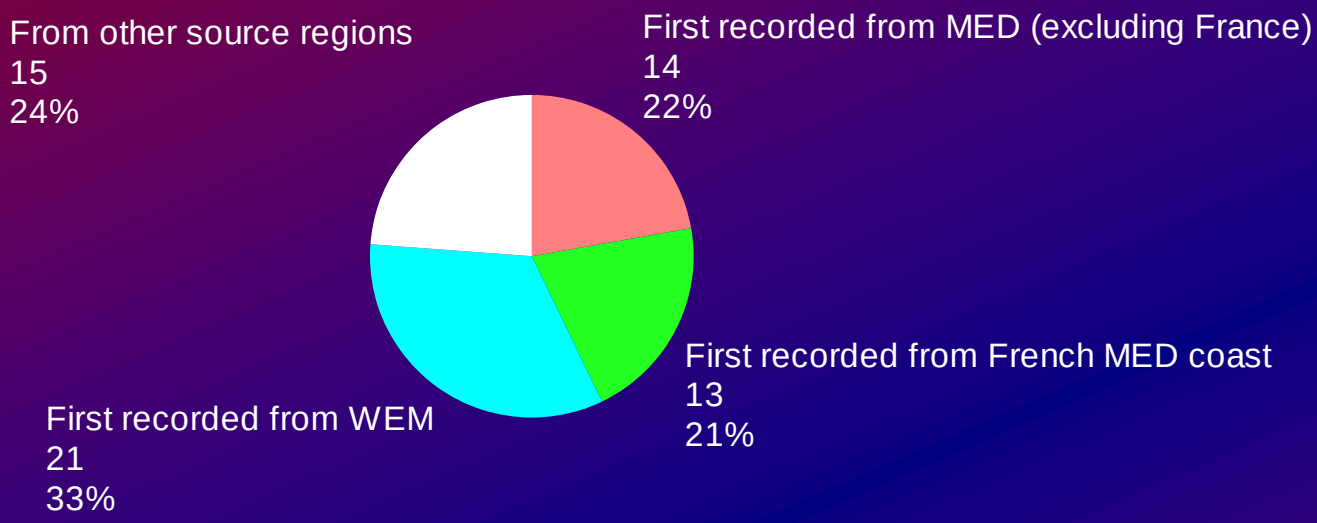




The “melting pot” biota of the Lagoon of Venice

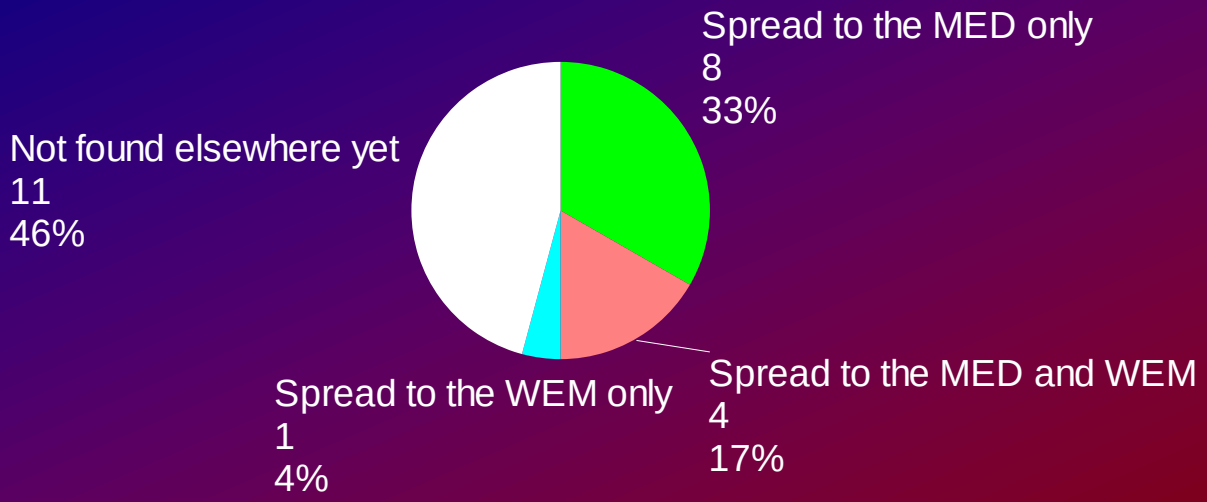


The Lagoon of Venice as a sink and source of NIS



sink

source



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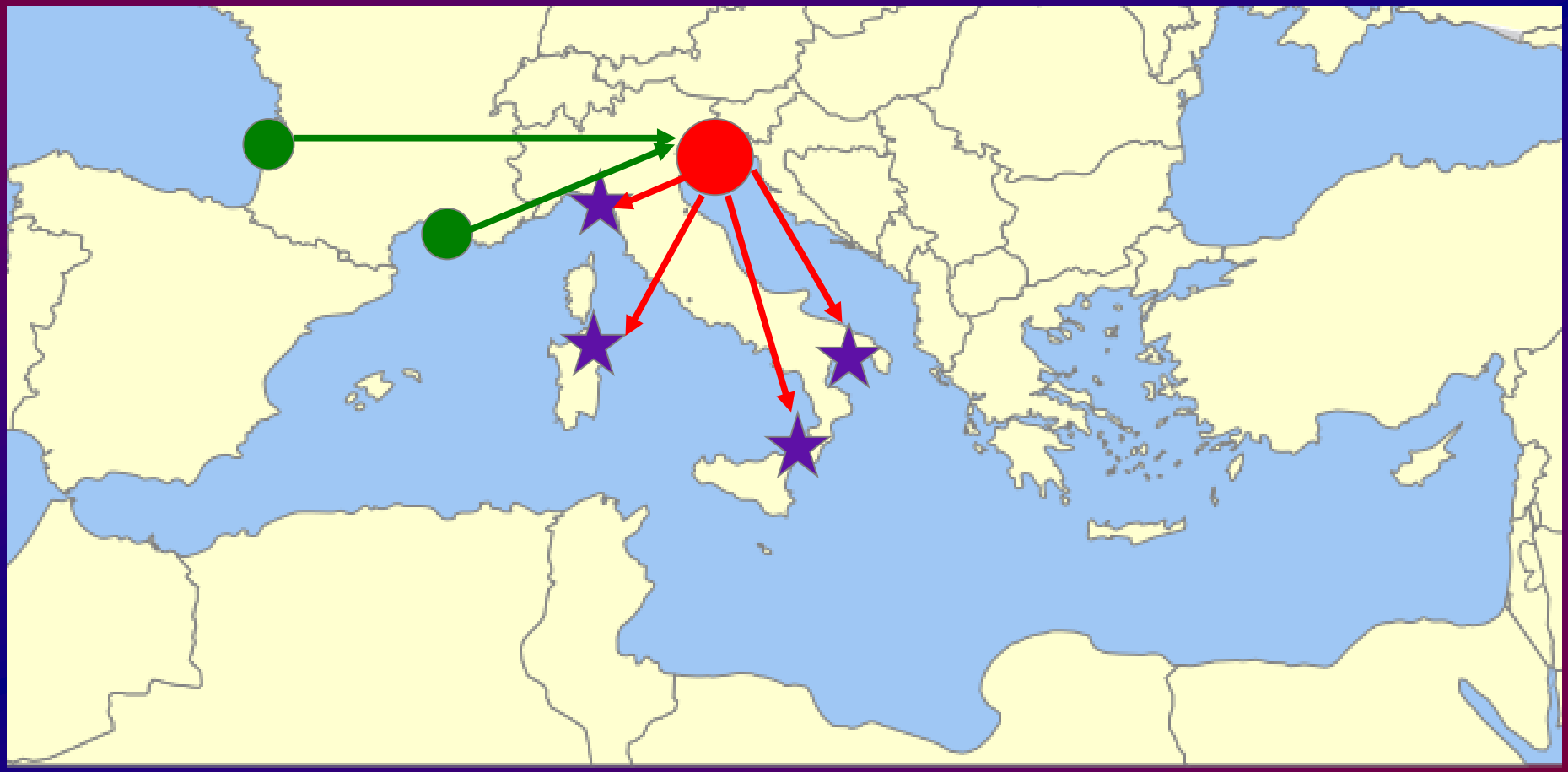
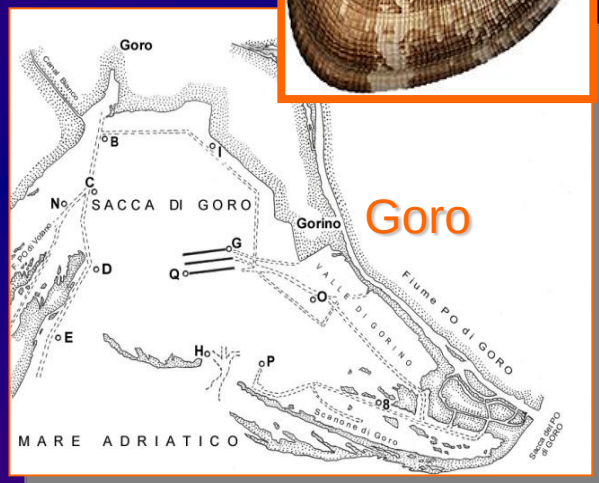


Algal invasions in the Lagoon of Venice

Algal invasions in the Lagoon of Venice

Clam culture:
Ruditapes philippinarum

Interactions with nutrients and sediment dynamics



***Ruditapes philppinarum* has invaded the Lagoons of Venice and the Po River delta:**

Biofiltration has increased → higher fluxes

O_2 (⇓), CO_2(⇑), NH_4^+(⇑), PO_4^{3-}(⇑)

Phytoplankton consumption increased → *is food limitation an issue?*

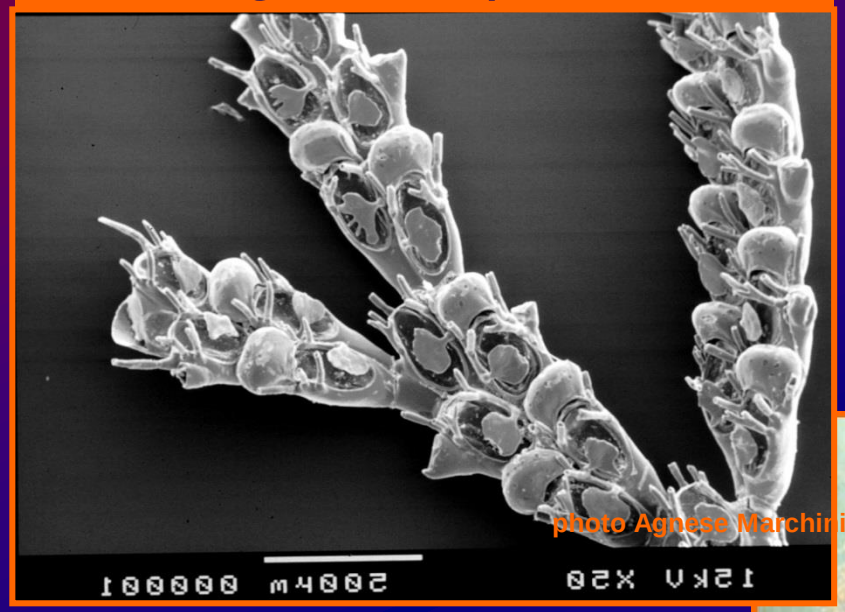
The collection of clams accelerates organic matter turnover→ this additional supply of food determines the ***Tapes* paradox**

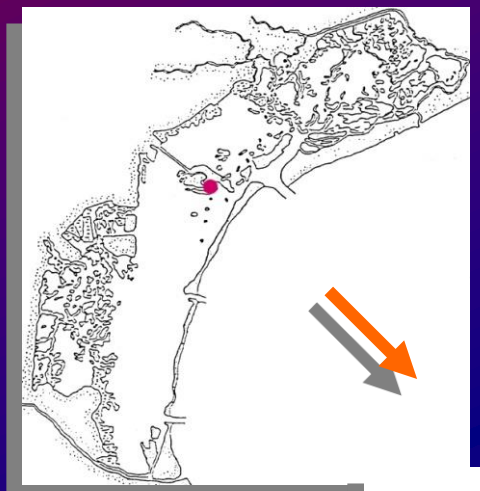
top-down* e *bottom-up control

Bartoli *et al*., 2001 (*Hydrobiologia*); Pranovi *et al*., 2006 (*Biol. Inv*.)

The case of Bryozoans

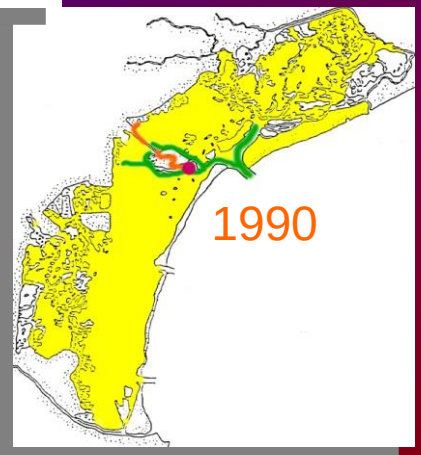
Tricellaria inopinata
(d'Hondt & Occhipinti-Ambrogi, 1985)





1982

1985



1990

Present distribution of *Tricellaria inopinata*

Lodola *et al*. (2012) Marine Biodiversity Records

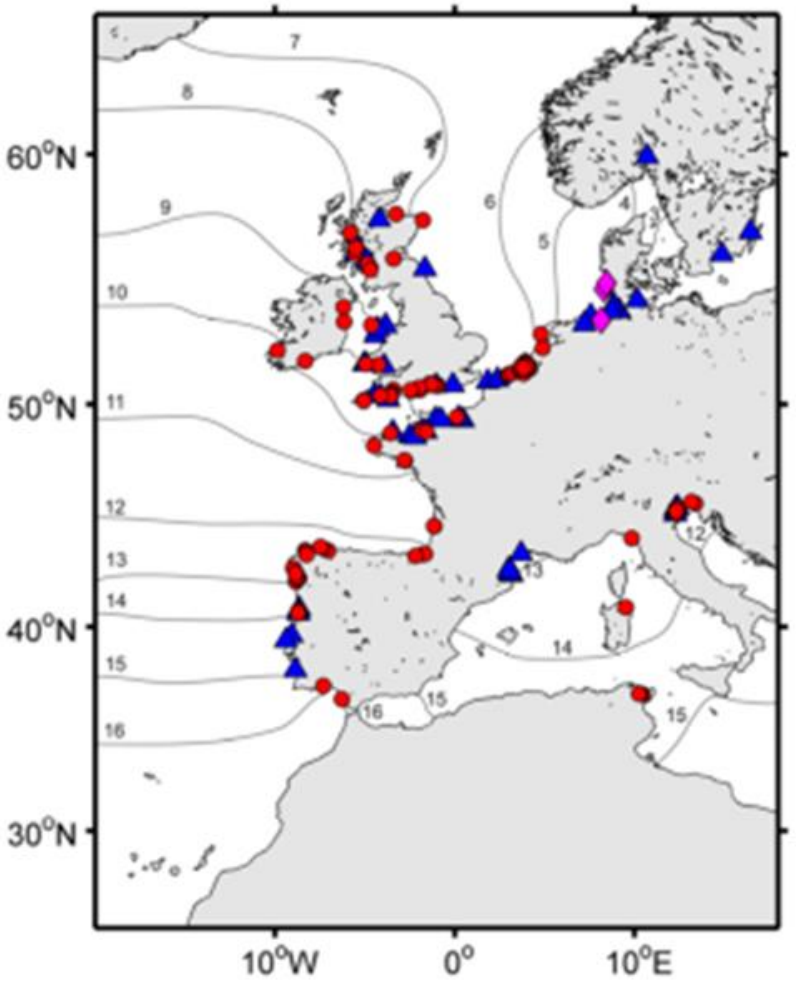


Figure 3. European distribution of *Tricellaria inopinata*, including the minimum winter sea surface temperature data averaged from 1856 to 1995 (see Appendix 1). Positive sightings (●); negative sighting (▲), previous positive sighting, now negative (◆).

Cook *et al*. Aquatic Invasions (2013) 8 (3): 281–288.

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How can NIS impact the invaded environment and community?

ECOLOGICAL IMPACT :
any (measurable?) change in abundance, biomass or distribution of native species and/or habitats

SOCIO ECONOMIC IMPACT :
any negative effect on human activities

COMPETITION
PREDATION
HYBRIDISATION
TRANSMISSION OF DISEASES
PARASITISM
POISONING/TOXICITY
BIOFOULING
GRAZING/HERBIVORY/BROWSING
PHYSICAL IMPACT
CHEMICAL IMPACT
INTERACTION WITH OTHER NIS
FOOD-PREY
OTHER IMPACTS (SOCIO-ECONOMIC)
IMPACT STUDIES PERFORMED, BUT NO IMPACTS OBSERVED

Blackburn *et al*., 2014

Ojaveer & Kotta, 2014

Which NIS are invasive ?

- Number of introductions, timing, spatial distribution and even abundance are not measures of impact *per se*
- Not much specific experimental work has been devoted to the effect of NIS, not even in the Lagoon of Venice
- At a European scale, we proposed to concentrate on the literature meta-analysis of the most widespread species
- We gathered the available information on impacts of a limited number of species

How to define invasive species?

A **geographic approach** (Galil *et al.*, 2014):

MOST WIDESPREAD NON-INDIGENOUS SPECIES (MW-NIS) IN EUROPEAN SEAS

→ Species recorded in 10 or more, and/or recorded and spread to five or more countries since 1990 as ('post-1990 widespread')

69 SPECIES

Sargassum muticum

Ruditapes philippinarum

Callinectes sapidus

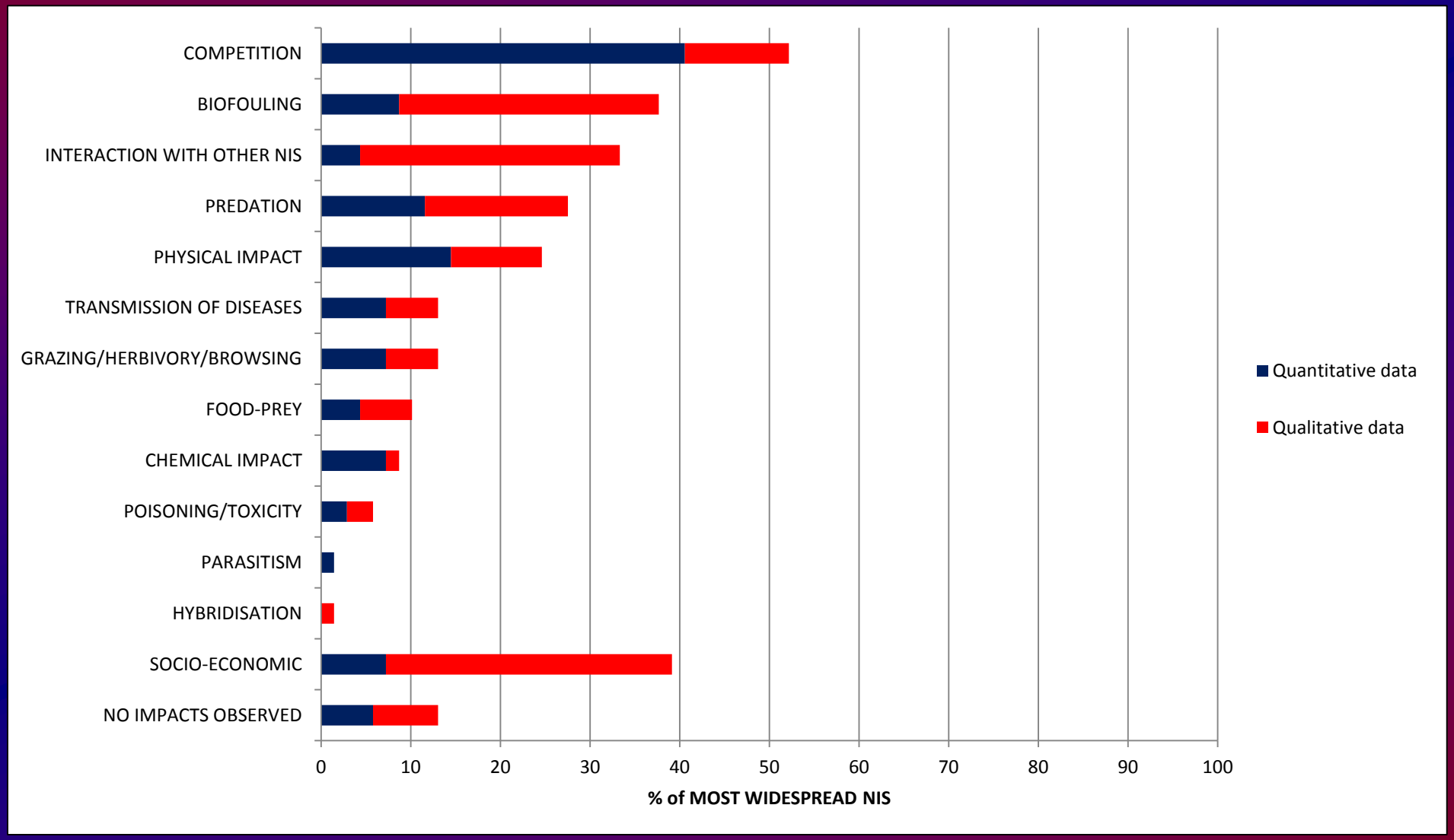
Lagocephalus sceleratus

Most Widespread-NIS in Europe

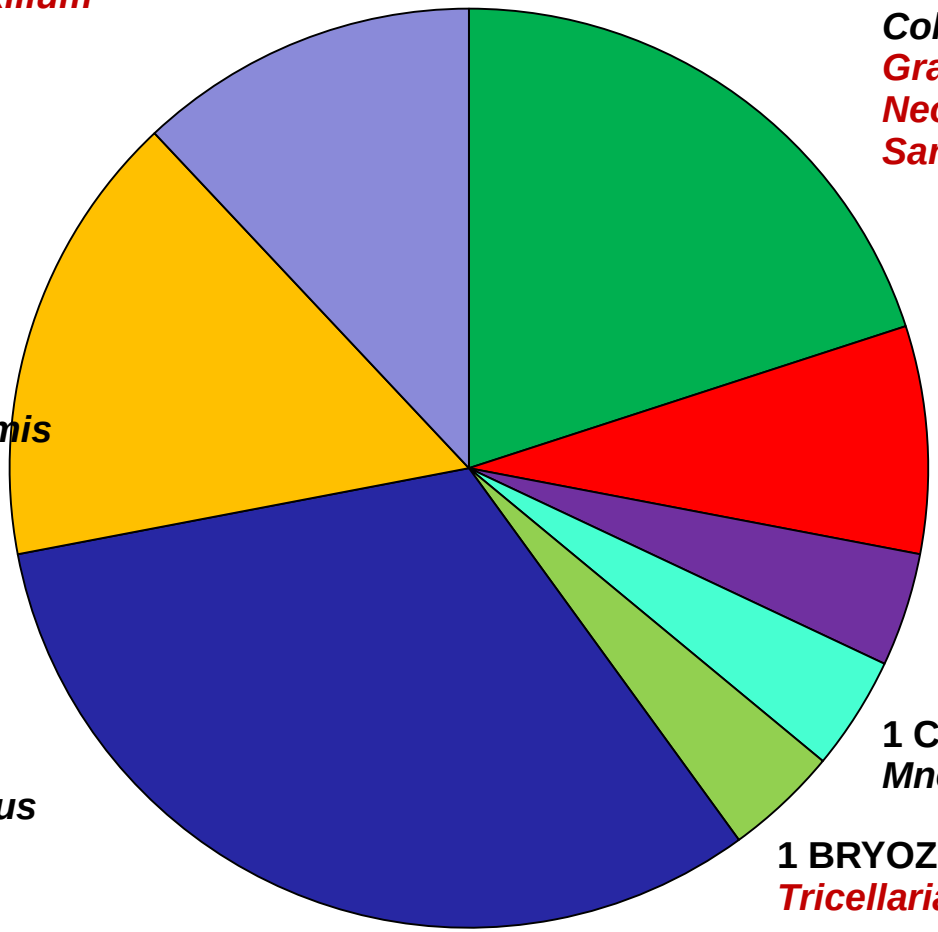
69 Species from different taxa: from Algae to Fish!!

Functional Group	
ZOOBENTHOS	**PHYTOBENTHOS**
Crustacea	***Red algae***
Austrominius modestus (Darwin, 1845)	*Asparagopsis armata*
Callinectes sapidus (Rathbun, 1896)	*Bonnemaisonia hamifera*
Caprella mutica (Shurin, 1935)	*Gracilaria vermiculophylla*
Caprella scaura (Templeton, 1836)	*Heterosiphonia japonica*
Eriocheir sinensis (Milne Edwards, 1853)	*Lophocladia lallemandii*
Gammarus tigrinus (Sexton, 1939)	*Neosiphonia harveyi*
Hemigrapsus sanguineus (De Haan, 1835)	***Brown algae***
Hemigrapsus takanoi (Hasakura & Watanabe, 2005)	*Colpomenia peregrina*
Hemimysis anomala (Sars, 1907)	*Sargassum muticum*
Marsupenaeus japonicus (Bate, 1888)	***Green algae***
Palaemon macrodactylus (Rathbun, 1902)	*Caulerpa racemosa var. cylindracea*
Percnon gibbesi (Milne Edwards, 1853)	*Codium fragile fragile*
Rhithropanopeus harrisii (Gould, 1841)	***Higher plants***
Mollusca	*Halophila stipulacea*
Brachidontes pharaonis (Fischer, 1870)	**PARASITE**
Bursatella leachii (Blainville, 1817)	***Nematoda***
Cerithium scabridum (Philippi, 1848)	*Anguillicoloides crassus* (Kuwahara, Niimi & Itagaki, 1974)
Chama asperella (Broderip, 1835)	**ZOOPLANKTON**
Crassostrea gigas (Thunberg, 1793)	***Crustacea***
Crepidula fornicata (Linnaeus, 1758)	*Acartia (Acanthacartia) tonsa* (Dana, 1849)
Dreissena polymorpha (Pallas, 1771)	*Cercopagis (Cercopagis) pengoi* (Ostroumov, 1891)
Ensis directus (Conrad, 1843)	*Evadne anonyx* (Sars, 1897)
Ergalatax junionae (Houart, 2008)	*Pseudodiaptomus marinus* (Sato, 1913)
Fulvia fragilis / Fulvia (fulvia) fragilis (Forsskal, 1775)	***Ctenophora***
Goniobranchus annulatus (Eliot, 1904)	*Mnemiopsis leidyi* (Agassiz, 1865)
Petricolaria pholadiformis (Lamarck, 1818)	**NECTON**
Pinctada imbricata radiata (Leach, 1814)	***Chordata***
Potamopyrgus antipodarum (Gray, 1843)	*Fistularia commersonii* (Rüppel, 1838)
Ruditapes philippinarum (Adams & Reeve, 1850)	*Hemiramphus far* (Forsskal, 1775)
Tunicata	*Lagocephalus sceleratus* (Gmelin, 1789)
Botrylloides violaceus (Oka, 1927)	*Neogobius melanostomus* (Pallas, 1814)
Corella eumyota (Traustedt, 1882)	*Oncorhynchus mykiss* (Walbaum, 1792)
Didemnum vexillum (Kott, 2002)	*Pteragogus pelycus* (Randall, 1981)
Styela clava (Herdman, 1881)	*Saurida macrolepis* (Tanaka, 1917)
Annelida	*Siganus luridus* (Rüppell, 1829)
Ficopomatus enigmaticus (Fauvel, 1923)	*Siganus rivulatus* (Forsskal & Niebuhr, 1775)
Hydroides dianthus (Verrill, 1873)	*Sphyraena flavicauda* (Rüppell, 1838)
Hydroides elegans (Haswell, 1883)	*Stephanolepis diaspros* (Fraser-Brunner, 1940)
Marenzelleria viridis (Verrill, 1873)	***Cephalopoda***
Other taxa	*Sepioteuthis lessoniana* (Lesson, 1830)
Oculina patagonica (De Angelis, 1908)	
Paraleucilla magna (Klautau, Monteiro & Borojevic, 2004)	
Tricellaria inopinata (d'Hondt & Occhipinti-Ambrogi, 1985)	
Zoobotryon verticillatum (Della Chiaje, 1822)	

Information available for each impact category



MW-NIS in the Wadden Sea and in the Venice Lagoon



3 ASCIDIACEA
Botrylloides violaceus*
Didemnum vexillum*
Styela clava

5 ALGAE
Codium fragile fragile
Colpomenia peregrina
Gracilaria vermiculophylla *
Neosiphonia harveyi
Sargassum muticum

4 MOLLUSCA
Crassostrea gigas
Crepidula fornicata
Ensis directus
Petricolaria pholadiformis

2 ANNELIDA
Ficopomatus enigmaticus
Marenzelleria viridis

1 NEMATODA
Anguillicoloides crassus

1 CTENOPHORA
Mnemiopsis leidyi *

1 BRYOZOA
Tricellaria inopinata

8 CRUSTACEA
Austrominius modestus
Callinectes sapidus
Caprella mutica *
Eriocheir sinensis
Hemigrapsus sanguineus *
Hemigrapsus takanoi *
Palaemon macrodactylus *
Rhithropanopeus harrisii

How to face the change?

- The lagoon of Venice and the Wadden Sea are "hotspots of change" where management efforts should be concentrated
- Prevention, remediation and adaptation to biological change by alien species can be addressed at varying degrees
- The European dimension is essential, in order to face a global issue

Which vectors and pathways to control ? (1)

- **Eradication** : hardly possible, except very special cases

- **Ballast water** treatment:
  - water exchange only outside the coastal area, for transoceanic transport
  - limitations for ballast water charging in hot spot areas
  - chemical – physical treatments still under scrutiny

Which vectors and pathways to control ? (2)

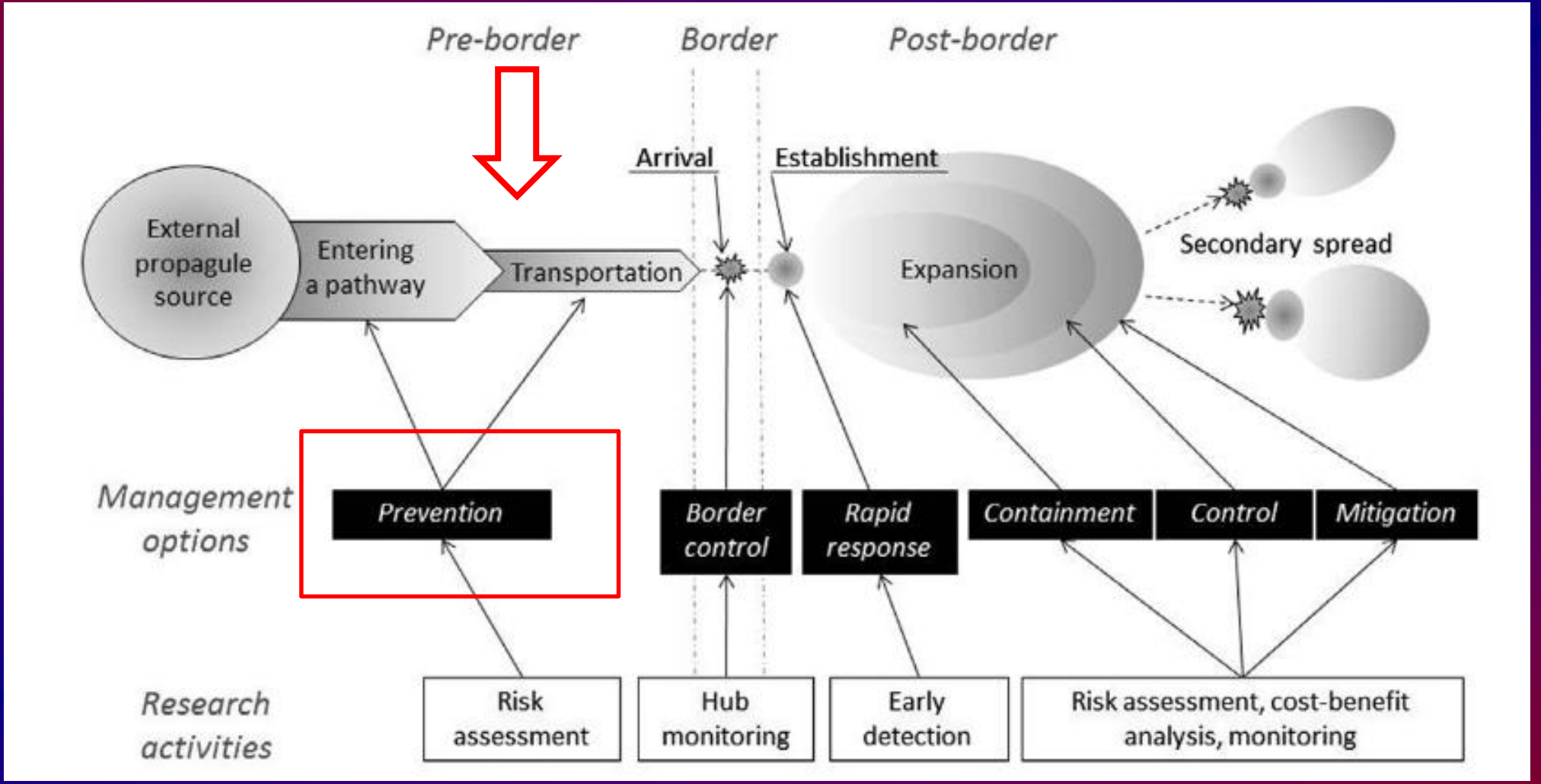
- **Fouling** control :
  - the ban of TBT has increased the possibility of developing growth of benthic organisms
  - limitations and careful procedures for wet scraping of hulls
  - assesment of small vessels for leisure boats

Which vectors and pathways to control ? (3)

- **Aquaculture :**
  - control of stocking and seeding of bivalves
  - assessment of hitchhikers

- **Sea food processing**
  - Rigorously on land and treatment of discharge

Process of invasion, management and science



Olenin, S., et al. Recommendations on methods for the detection and control of biological pollution in marine coastal waters. Mar. Pollut. Bull. (2011), doi:10.1016/j.marpolbul.2011.08.011

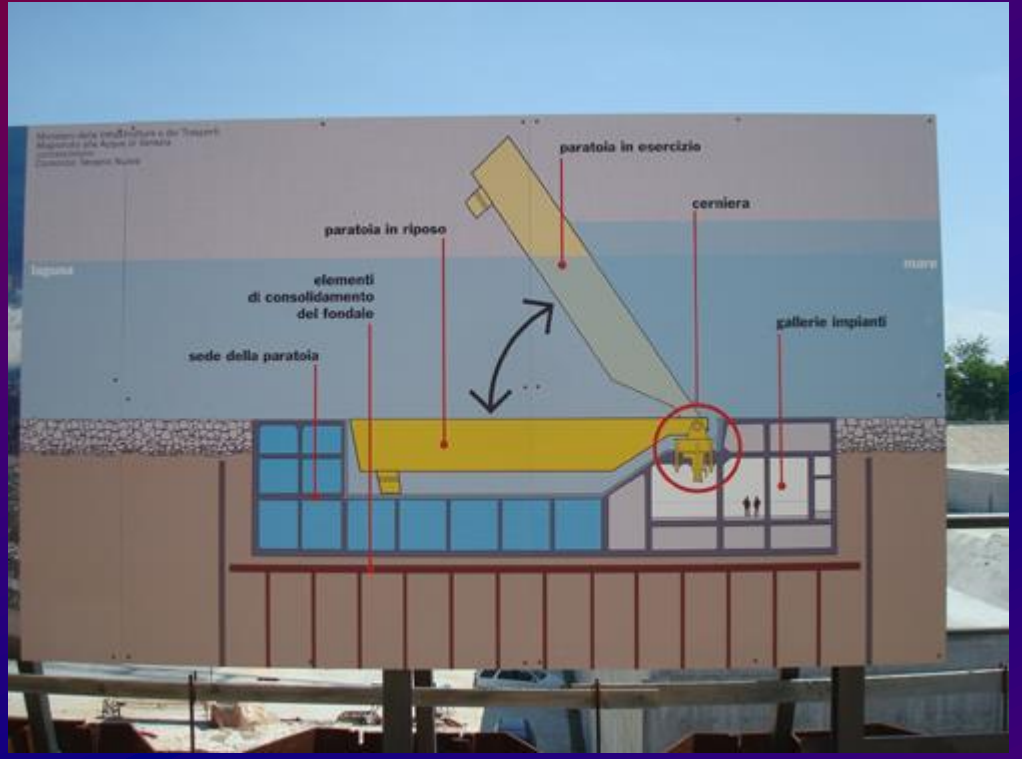
Acknowledgements

This work was carried out as part of

Task 2.1.4 "*Data analysis to test the role of aquaculture as a vector for invasions*"

within the project VECTORS - Vectors Change in Oceans and Seas marine Life, Impact on Economics Sectors

A European Community's Seventh Framework Program (FP7/2007–2013) under Grant Agreement no. 266445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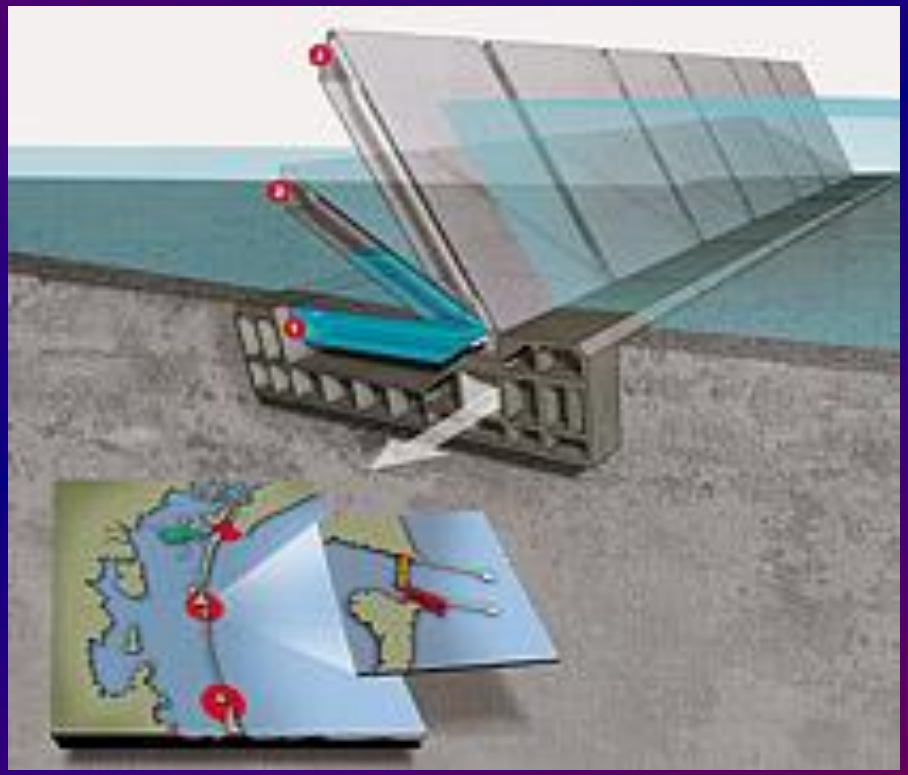
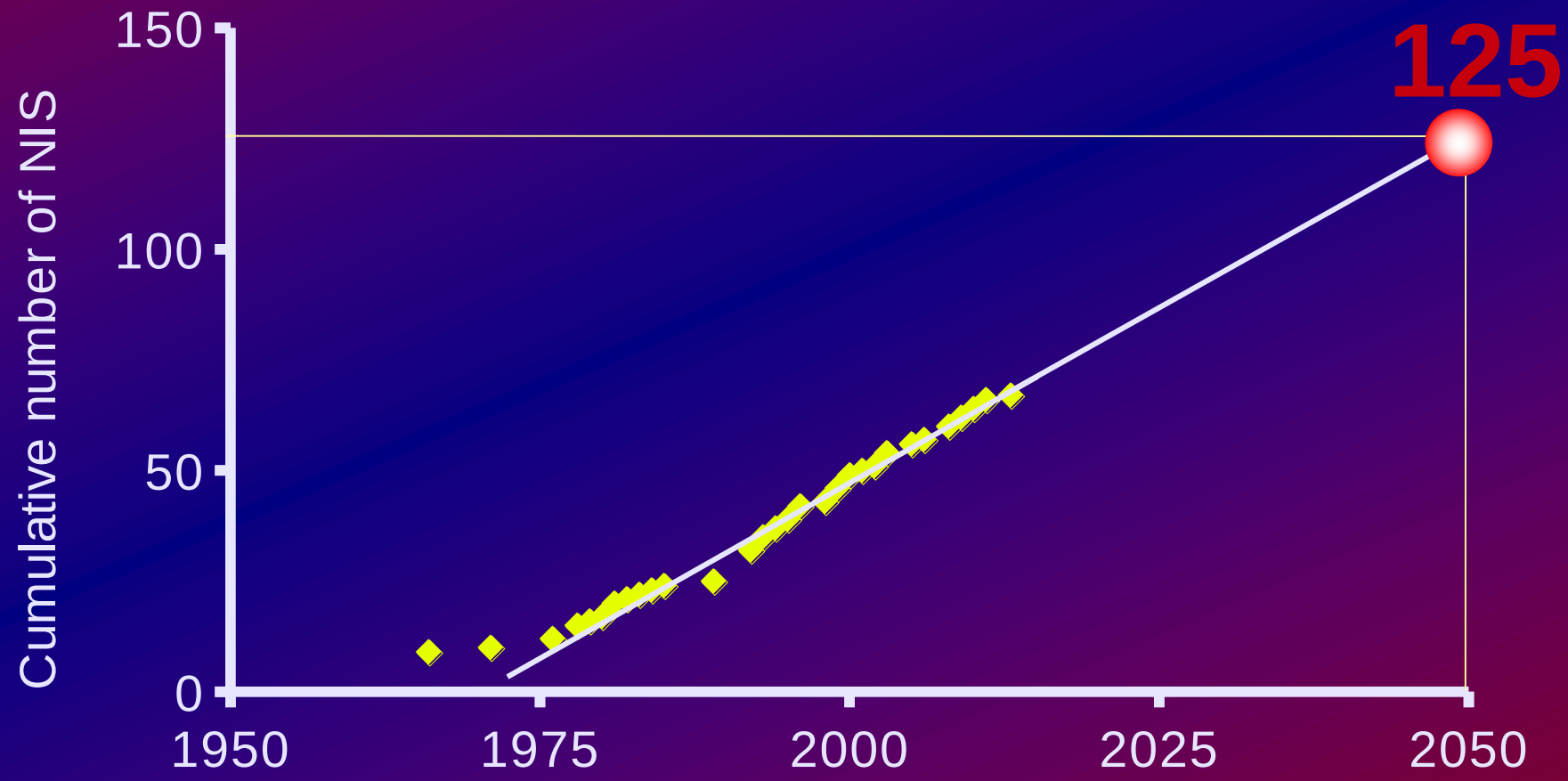
cerniera
paratoia in riposo
elementi
di consolidamento
del fondale
sede della paratoia
gallerie impianti

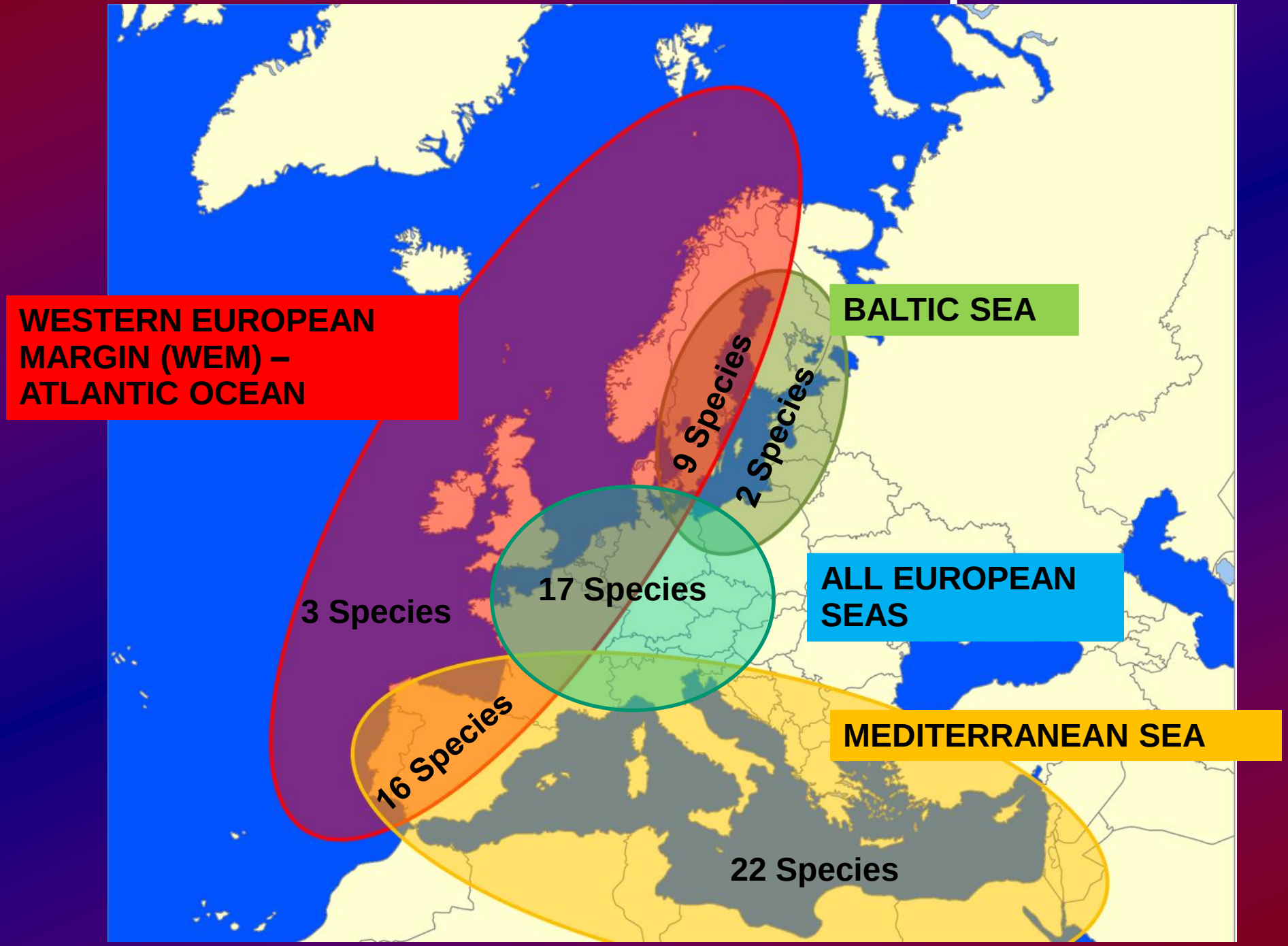


What is the likely future trend for the NIS in the Lagoon of Venice?

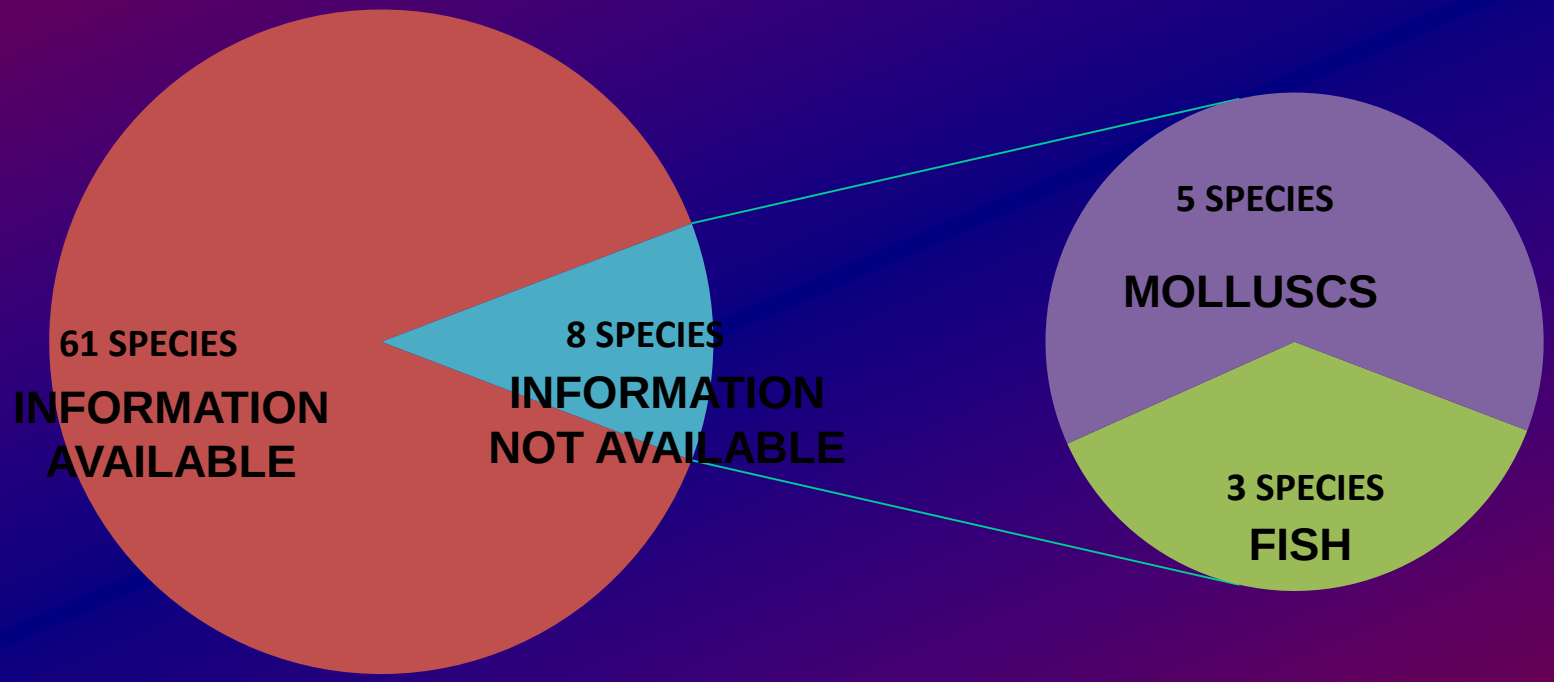
(if the conditions are not changed)



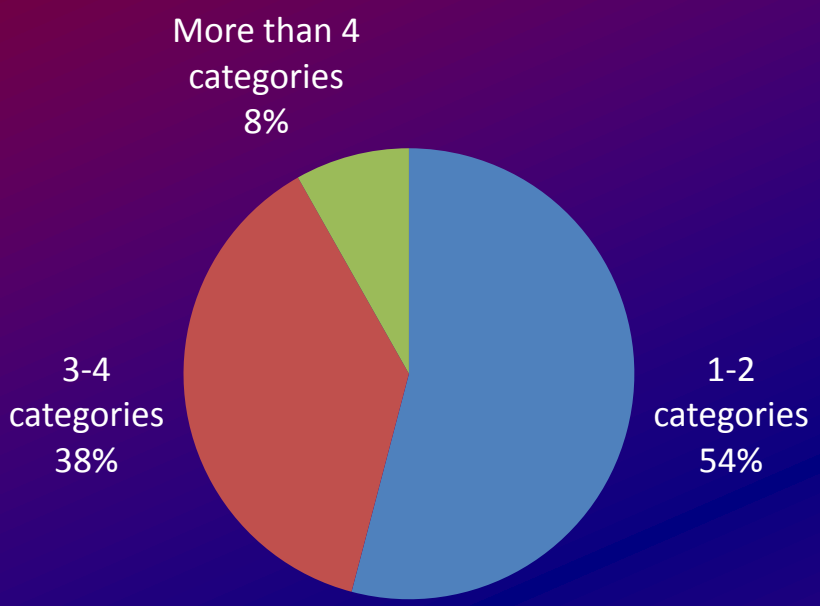
MW-NIS distribution in European Seas



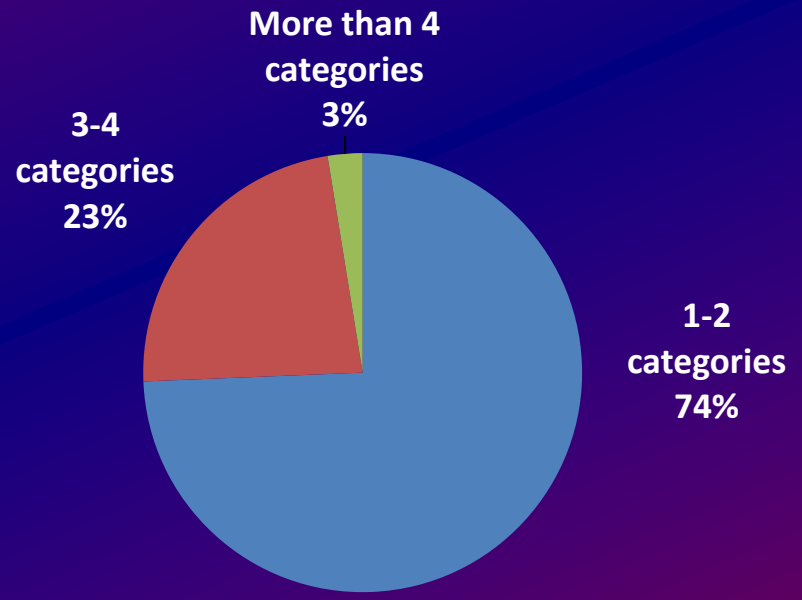
Available information on effects



For the majority of MW NIS, data is available only for 1-2 impact categories



All impact data
(61 species)



Only quantitative impact data
(39 species)

Widespread NIS with multiple impacts

Baltic Sea → 1 country
WEM → 10 countries
Mediterranean → 2 countries

It can directly inhibit indigenous floral assemblages recruitment and growth, even leading to eradication of some species (e.g. *Cystoseira barbata*)

May grow attached to oyster shells (e.g. *Crassostrea gigas*).

Sargassum muticum

Source: AquaNIS

Economical problems in Venice due to alteration of the canal vegetal landscape.

Dense stands of *S. muticum* may reduce light, dampen flow, increase sedimentation and reduce nutrient concentrations available for native species

It creates a habitat suitable for other NIS, such as caprellids

Widespread NIS with multiple impacts

Baltic Sea → 8 countries
WEM → 7 countries
Mediterranean → 3 countries

Alteration of food web: can act both as a predator and as a prey for native species

Can host white spot baculoviruses: potential vector for crustaceans diseases

Rhithropanopeus harrisii

Competition with native crabs and benthopelagos fishes

Source: Museo di Storia Naturale, Venezia

Economic loss to fishermen by spoiling fishes trapped in nets

When reaches high densities can cause possible pipe fouling