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EU Water Framework Directive, its ecological quality indicators and alien species



Sergej Olenin, Darius Daunys & Dan Minchin



Coastal Research and Planning Institute
Klaipeda University, Lithuania

Marine Organism Investigations
Ireland

EU Water Framework Directive (WFD)

launched in December 2001

- aims to improve the water quality of rivers, lakes, transitional and coastal waters
 - at the latest 15 years after the date of entry into force of the Directive.
- requires development and harmonization of ecological quality status assessment systems, *inter alia* - a common definition of the 'good' ecological quality status..

WFD Ecological Quality Indicators

BIOLOGICAL

- Phytoplankton
- Phytobenthos
- Macrofauna
- Fish

- Species composition, abundance and biomass of natural communities;
- Presence of indicator (sensitive) species and values of relevant indices

PHYSICO-CHEMICAL

- Nutrients
- Salinity
- Transparency
- Oxygen
- Synthetic pollutants
- pH
- Temperature

- Concentrations of chemicals must meet environmental quality standards;
- Both physico-chemical and hydro-morphological parameters should be in the ranges which ensure proper functioning of the water type specific ecosystem and the achievement of the values specified for the relevant biological quality elements.

HYDRO-MORPHOLOGICAL

- Changes in sediment transport
- Water flow
- Channel patterns
- Conditions of the shore zones
- Substrate conditions

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**All
parameters
may be
changed by
invasive
alien
species!**

How alien species can change the water quality?

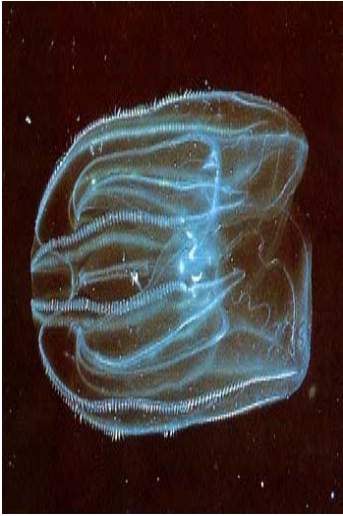
Database created:

~300 case studies screened

~120 alien species showed clear impact on various WFD Ecological Quality indicators

WFD Quality element	Water body type	Trend	Abstract	Region	Reference
Macrofauna	River	DEC	In Irish rivers, the native amphipod <i>Gammarus duebeni celticus</i> has become locally extinct, ostensibly through differential predation by the more aggressive and introduced <i>G. pulex</i> . This mechanism	Europe, Ireland	Kelly, Dick, 2005
Macrofauna	Lake	DEC	The crayfish plague, caused by infection with the fungi Aphanomyces astaci , was introduced to Europe from its native North America with imported American crayfish in 1860. It spread	Europe, Sweden	Josefsson and Andersson, 2001
Macrofauna	River	INC	A high turnover in macro invertebrate composition took place between 1993 and 2001 in the Upper and Middle Rhine because of successful invasion of exotic invertebrates. Dreissena provides	Europe, Rhine river	Haas et al. 2002
FISH	Lake	DEC	During this century up to 12 exotic species were introduced to the Lake Banyoles, the second largest lake of the Iberian Peninsula, leading to the apparent loss of two native species (threespined	Europe, Iberian Peninsula	Garcia-Berthou, Moreno-Amich, 2000
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FISH	River	DEC	The elimination of the Atlantic salmon <i>Salmo salar</i> in more than 30 rivers in Norway as a result of the introduction of the conspecific	Europe, Norway	McNeely and Schutyser, 2003

How alien species can change the water quality: examples



Caspian Sea:

The invasion of the comb jelly *Mnemiopsis leidyi* causes a 6-fold decrease in abundance of zooplankton, the only food source for the kilka (three species of *Clupeonella*). The white sturgeon (*Huso huso*) feeding on kilka, considered to be highly endangered.

(Shiganova et al. 2001)



Spain:

The alien Louisiana red swamp crayfish *Procambarus clarkii* destructs 90% of the aquatic vegetation in a lake, which switches to the turbid state. Concentration of TP rises by 800%, the water chlorophyll content increases by 100%. The trophic status of the lake become hypertrophic.

(Rodríguez et al., 2005)

How alien species can change the water quality: examples



Europe, North America:

The zebra mussel *Dreissena polymorpha*, multiple impacts: changes in benthic community structure, modification of bottom sediments, increase in water transparency, release of nutrients

(e.g. Karatayev et al., 2002)



California, USA:

The European green crab *Carcinus maenas*: dramatic declines in the abundances of native clams *Nutricula* spp. and shore crabs *Hemigrapsus oregonensis*

(Grosholz, 2002)

WFD Ecological Quality Indicators and alien species

- **AS may cause both worsening and “improving” of the ecological quality**
 - (i.e. through increasing of water transparency).
- **There are no rules (within the WFD) on how to take into account **Biological pollution** which is effecting the ecological quality of the water bodies.**

Biological pollution

- **The impacts of alien invasive species sufficient to disturb ecological quality by effects on:**
 - **an individual (internal biological pollution by parasites or pathogens),**
 - **a population (by genetic change, i.e. hybridization),**
 - **a community (by structural shift),**
 - **a habitat (by modification of physical-chemical conditions),**
 - **an ecosystem (by alteration of energy and organic material flow).**
- **The biological and ecological effects of biopollution may also cause adverse economic consequences.**

Based on:

Elliott, M., (2003). Biological pollutants and biological pollution – an increasing cause for concern. Mar Pol Bull 46: 275-280.

Olenin S, Minchin D, Daunys D (2007). Assessment of biopollution in aquatic ecosystems. Mar Pol Bull , 55 (7-9), 379-394

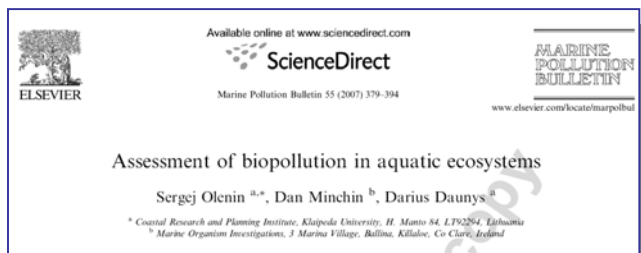
A method to assess *biological pollution*

Postulates

- Abundance, distribution range and magnitude of AS impact can vary over time
- AS produce measurable effects only after they have attained a particular level of abundance and then occupying sufficiently large area

Prerequisites for Biopollution assessment:

- Data on AS abundance and distribution range
- Good ecological and biological knowledge of AS, including magnitude of AS impacts.



**Ranking Abundance (*Low, Moderate, High*) and
Distribution (*One, Few, Many, All localities*)
Range of alien species (5 Classes)**

<u>Class</u>	<u>An AS occurs</u>
A	in <i>low</i> numbers in <i>one or several</i> localities
B	in <i>low</i> numbers in <i>many</i> localities in moderate numbers in one or several localities
C	in <i>low</i> numbers in <i>all</i> localities, in <i>moderate</i> numbers in <i>many</i> localities, in <i>high</i> numbers in <i>several</i> localities
D	in <i>moderate</i> numbers in <i>all</i> localities in <i>high</i> numbers in <i>many</i> localities
E	in <i>high</i> numbers in <i>all</i> localities

Ranking the impacts

- We consider separately the impacts on:
- Community
 - the changes caused in native species composition and abundance, including shifts in type-specific communities,
- Habitat
 - Degree of habitat modification, and
- Ecosystem
 - The level of impact on ecosystem process.

The magnitude of impacts is interrelated

Dividing into three separate groups facilitates an assessment

Assessing impact on communities

Categories used:

- **Changes in native species ranking according to quantitative parameters**

(abundance, biomass, coverage, etc)

- **Shift in community dominant species,**
- **Loss of a type-specific community**
- **Displacement of a native species**
- **Loss of a native keystone species**

(i.e. resource providers and ecosystem engineers, sensu Jones et al., 1994; Payton et al., 2002)

Classification of alien species impact on communities

<u>Code</u>	<u>Impact</u>	<u>Description</u>
C 0	No	<ul style="list-style-type: none"> •No displacement of native species •Ranking of native species unchanged •Type-specific communities are present.
C 1	Weak	<ul style="list-style-type: none"> •Local displacement of native species, but no extinction. •Change in ranking of native species, but dominant species remain the same. •Type-specific communities are present.
C 2	Moderate	<ul style="list-style-type: none"> •Large scale displacement of native spp, but no extinction •Shift in community dominant species •Type specific community noticeably changed
C 3	Strong	<ul style="list-style-type: none"> •Local population extinction •Native dominant species still present but highly reduced (AS dominant) •Loss of type specific community
C 4	Massive	<ul style="list-style-type: none"> •Population extinction of native keystone species. •Extinction of type-specific communities in more than one ecological group.

Assessing impact on habitats

Categories used:

- habitat alteration (change in the quality)
 - » e.g. reduction in the density of a sea grass meadow, addition of shell deposits to sandy or muddy bottoms, siltation, or, in general, the decline of existing or addition of a new habitat feature
- habitat fragmentation
 - » a habitat, once continuous, becomes divided into separate parts following an alien species invasion
- habitat loss
 - » reduction of the spatial extent of a habitat. In extreme cases this may lead to the elimination of a habitat within an assessment unit
- key habitats
 - » very important for the wider support of the ecological processes
 - » (*sensu* Hiscock et al., 2003), such as *Posidonia* meadows, biogenic reefs or spawning grounds.



(both benthic and pelagic habitats)

Classification of alien species impact on native habitats

<u>Code</u>	<u>Impact</u>	<u>Description</u>
H0	No	<ul style="list-style-type: none">•No habitat alteration
H1	Weak	<ul style="list-style-type: none">•Alteration of a habitat(s),•No reduction of spatial extent of a habitat(s).
H2	Moderate	<ul style="list-style-type: none">•Alteration and reduction of spatial extent of a habitat(s).
H3	Strong	<ul style="list-style-type: none">•Alteration of a key habitat,•Severe reduction of spatial extent of habitat(s);•Loss of habitat(s) within a small area of the assessment unit.
H4	Massive	<ul style="list-style-type: none">•Loss of habitats in most or the entire assessment unit,•Loss of a key habitat

Classification of alien species impact on ecosystem functioning

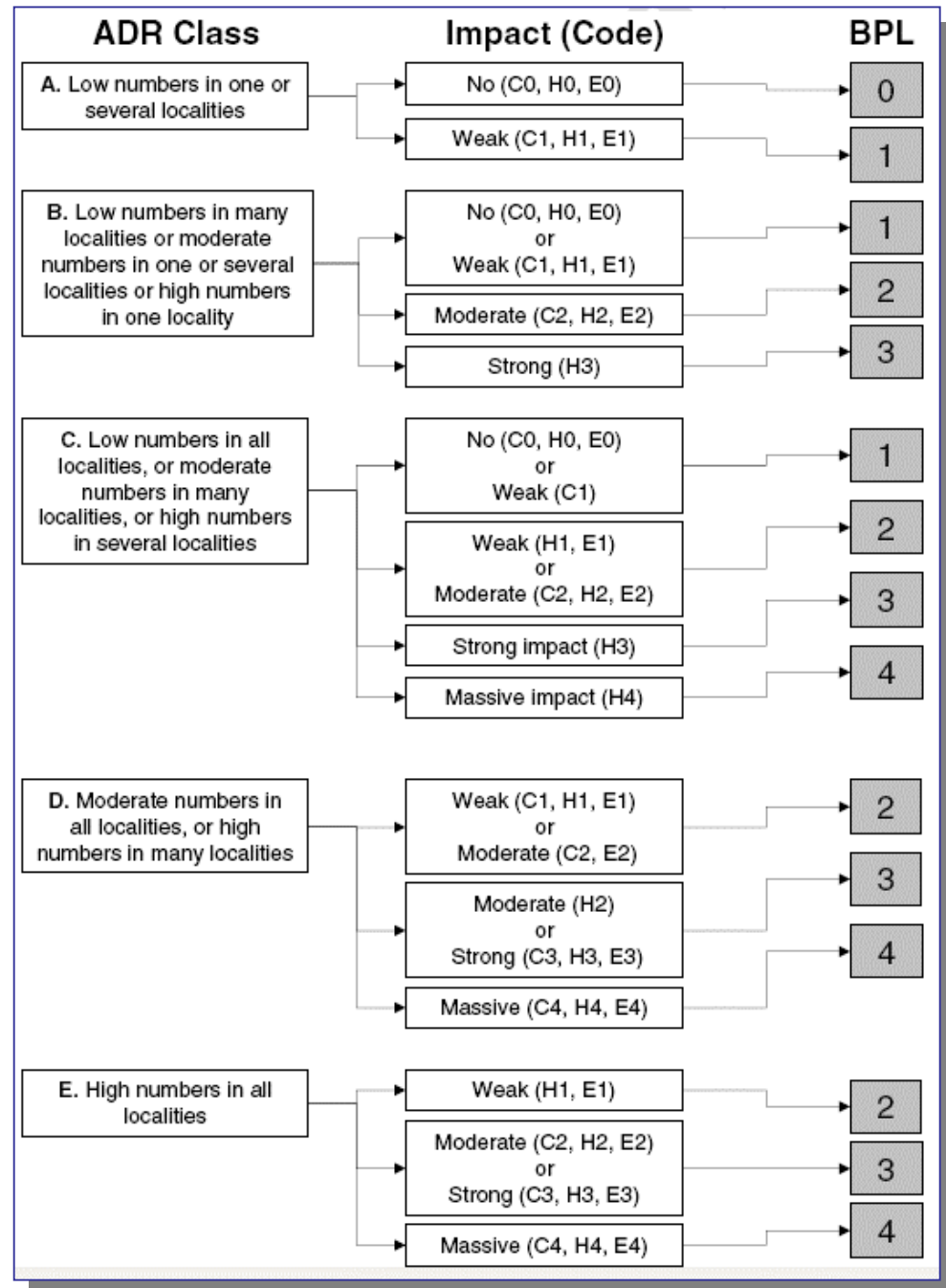
<u>Code</u>	<u>Impact</u>	<u>Description</u>
E0	No	<ul style="list-style-type: none"> •No measurable effect.
E1	Weak	<ul style="list-style-type: none"> •Measurable changes with no loss or addition of new ecosystem function(s).
E2	Moderate	<ul style="list-style-type: none"> •Moderate modification of ecosystem performance and/or •Addition of a new, or reduction of existing, functional group(s) in part of the assessment unit
E3	Strong	<ul style="list-style-type: none"> •Severe shifts in ecosystem functioning in part of the assessment unit. •Reorganisation of the food web as a result of addition or reduction of functional groups within trophic levels
E4	Massive	<ul style="list-style-type: none"> •Extreme, ecosystem-wide shift in the food web and/or •Loss of the role of a functional group(s).

Combined abundance and distribution range (ADR) class and magnitude of the impacts on:

native species and communities (C), invaded habitat (H) and ecosystem functioning (E).

ADR	species and communities					habitat					ecosystem functioning				
	C0	C1	C2	C3	C4	H0	H1	H2	H3	H4	E0	E1	E2	E3	E4
A	0	1	-	-	-	0	1	-	-	-	0	1	-	-	-
B	1	1	2	-	-	1	1	2	3	-	1	1	2	-	-
C	1	1	2	-	-	1	2	2	3	4	1	2	2	-	-
D	-	2	2	3	4	-	2	3	3	4	-	2	2	3	4
E	-	-	3	3	4	-	2	3	3	4	-	2	3	3	4

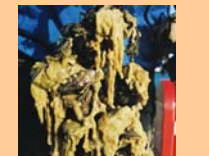
The decision support scheme for assessment of Biopollution Level (BPL)



Computerised biopollution assessment system

is being developed

Biopollution assessment system



For registered users:

[Create new species account](#)

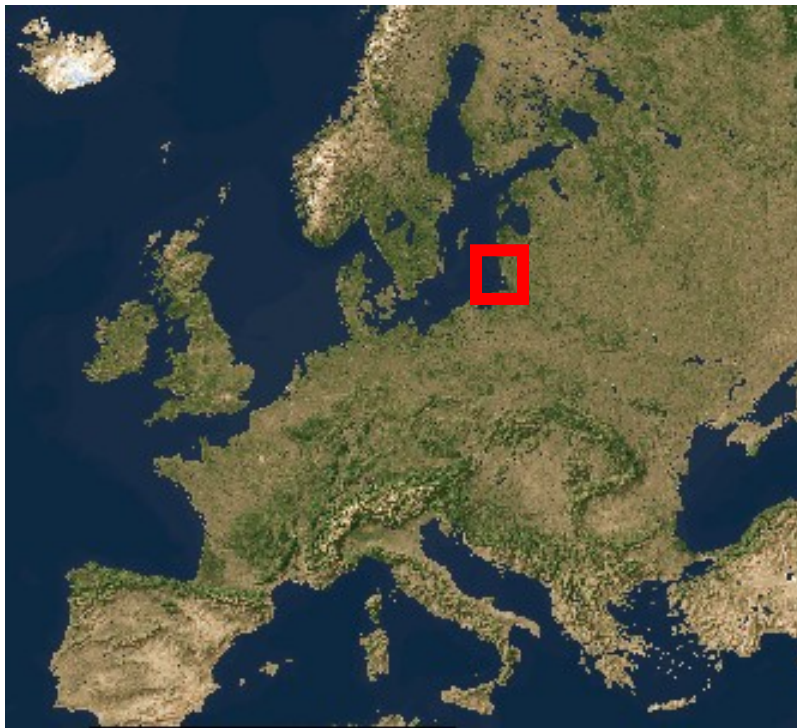
[Create new regional account](#)

[Edit existing species accounts](#)

[Edit existing regional accounts](#)

Regional account

Example: Curonian lagoon, Baltic Sea



Create new regional account

Define the assessment unit

Country Lithuania and/or

Region Baltic Sea

Assessment unit Curonian Lagoon

Assessment unit is a defined water body or territory, for example: Gulf of Finland, Venice Lagoon, Lake Balaton, small pond Kairiai; Lower Alps, Valley of river Glenn

Define the assessment period

From 1950 to 2007

Regional account

Assessment unit: *Curonian Lagoon (Lithuania, Baltic Sea)*

Assessment period: 1950-2007

Species: *Dreissena polymorpha*

Step 1/5: define relative abundance - species occurs in [low, moderate, high] numbers

Step 2/5: define distribution range – species occurs in [one, few, many, all] localities

Step 3/5: define impact on NATIVE SPECIES AND COMMUNITIES [C0, C1, C2, C3, C4]

Step 4/5: define impact on HABITATS [H0, H1, H2, H3, H4]

Step 5/5: define impact on ECOSYSTEMS [E0, E1, E2, E3, E4]

Next step: Get assessment of Biopollution Level (BPL) for this species

Enter data for the next species from the same assessment unit

Get the regional account

Regional account

Account for assessment unit:
Curonian Lagoon
(Baltic Sea, Lithuania)

Assessment period:
1950-2007

Author:
D. Daunys

Summary

Species	Abundance & Distribution Range	Impact on Community	Impact on Habitat	Impact on Ecosystem	Biopollution Level
<u>1. Balanus improvisus</u>	<u>A</u>	<u>1</u>	<u>1</u>	<u>0</u>	<u>1</u>
<u>2. Chaetogammarus warpachowskyi</u>	<u>B</u>	<u>1</u>	<u>1</u>	<u>1</u>	<u>1</u>
<u>3. Cordylophora caspia</u>	<u>B</u>	<u>2</u>	<u>2</u>	<u>1</u>	<u>2</u>
<u>4. Chelicorophium curvispinum</u>	<u>B</u>	<u>1</u>	<u>1</u>	<u>1</u>	<u>1</u>
<u>5. Dreissena polymorpha</u>	<u>D</u>	<u>2</u>	<u>3</u>	<u>2</u>	<u>3</u>
<u>6. Limnomysis benedeni</u>	<u>B</u>	<u>2</u>	<u>1</u>	<u>2</u>	<u>2</u>
<u>7. Obesogammarus crassus</u>	<u>C</u>	<u>2</u>	<u>2</u>	<u>2</u>	<u>2</u>
<u>8. Paramysis lacustris</u>	<u>C</u>	<u>2</u>	<u>1</u>	<u>2</u>	<u>2</u>
<u>9. Pontogammarus robustoides</u>	<u>C</u>	<u>2</u>	<u>2</u>	<u>2</u>	<u>2</u>
<u>10. Cercopagis pengoi</u>	<u>B</u>	<u>2</u>	<u>1</u>	<u>1</u>	<u>2</u>
<u>11. Gammarus tigrinus</u>	<u>B</u>	<u>1</u>	<u>1</u>	<u>1</u>	<u>1</u>
<u>12. Marenzelleria neglecta</u>	<u>C</u>	<u>2</u>	<u>2</u>	<u>2</u>	<u>2</u>
...
<u>27. Neogobius melanostomus</u>	<u>A</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
<u>28. Prorocentrum minimum</u>	<u>A</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>

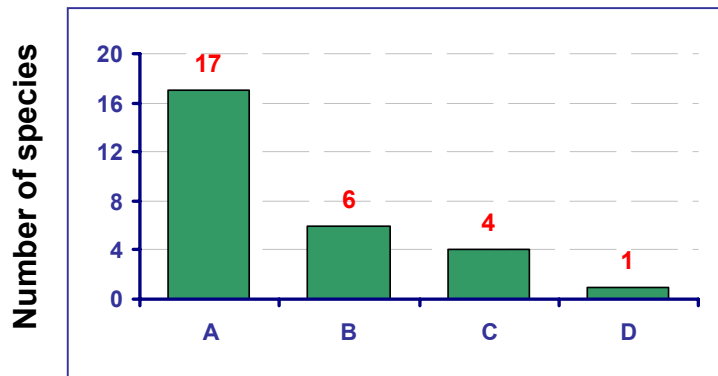
Biopollution assessment summary

Summary for assessment unit:
Curonian Lagoon
(Europe, Lithuania)

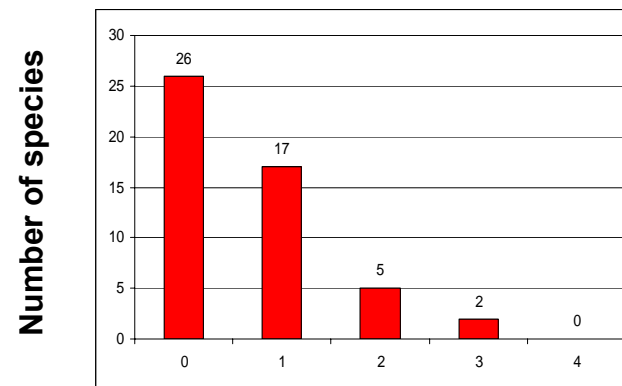
Assessment period:
1800-2007

Author:
D. Daunys

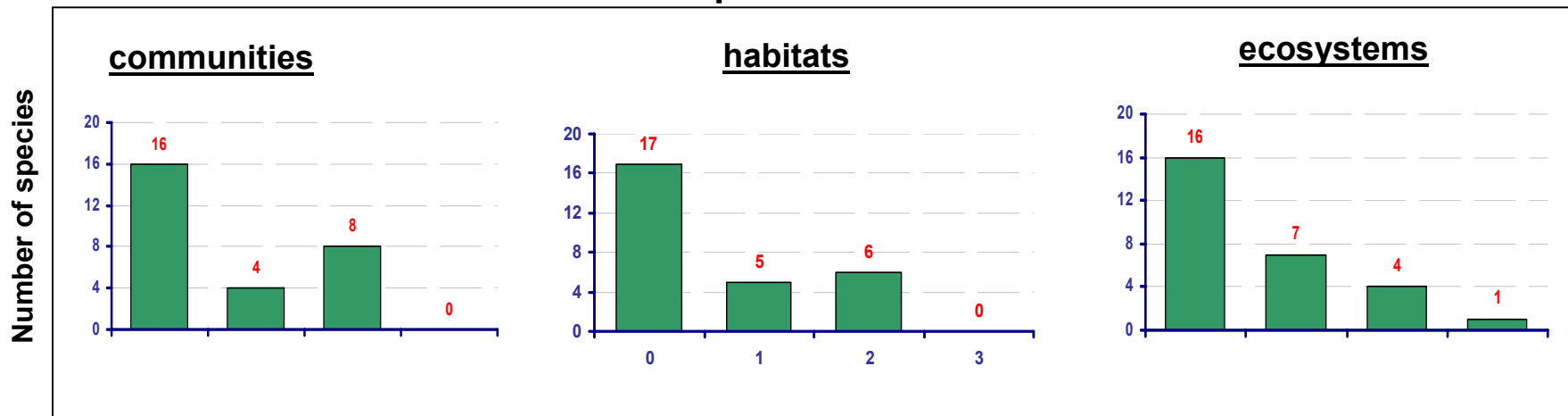
Abundance & Distribution Range



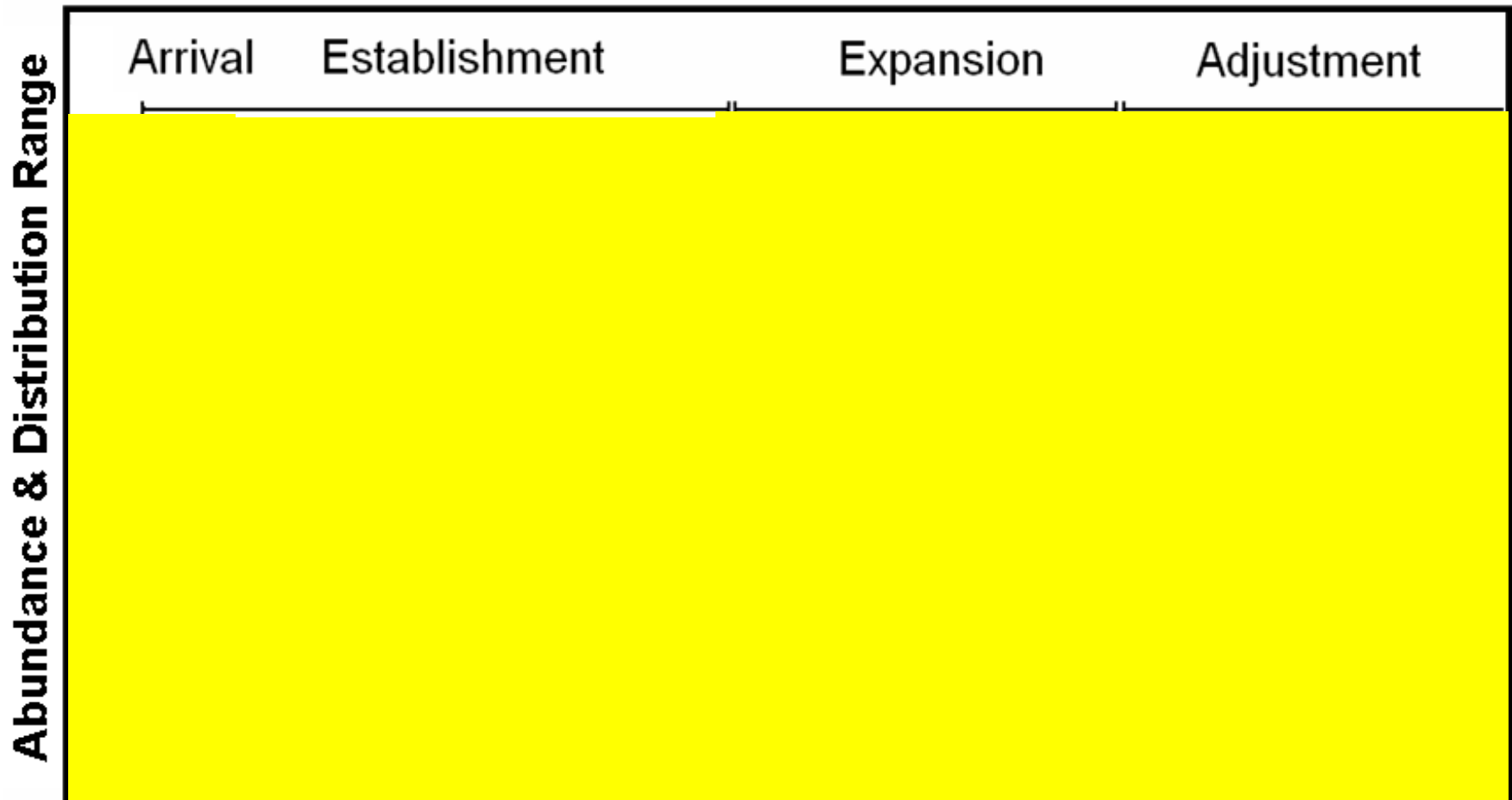
Biopollution level



Impacts on:

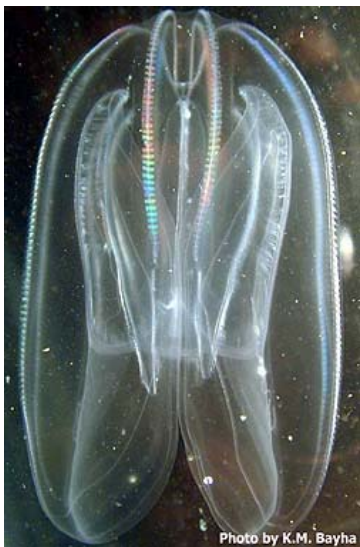


Invasion history in terms of Biopollution

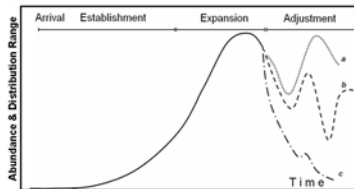


Modified from: Reise, Olenin, Thielges (2006). Helgoland Marine Research, 60 (2): 106–112

Example: invasion of the ctenophore *Mnemiopsis leidyi* in the Black Sea in terms of Biopollution



Arrival
(or establishment?)



ADR = A (low numbers in one locality)

C0 - No impact (no displacement of native species)

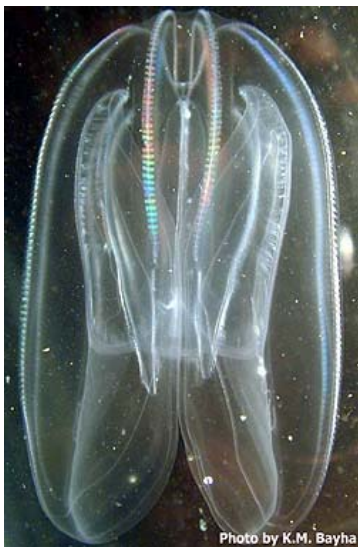
H? - Unknown (probably H0 - no habitat alteration)

E? - Unknown (probably = E0)

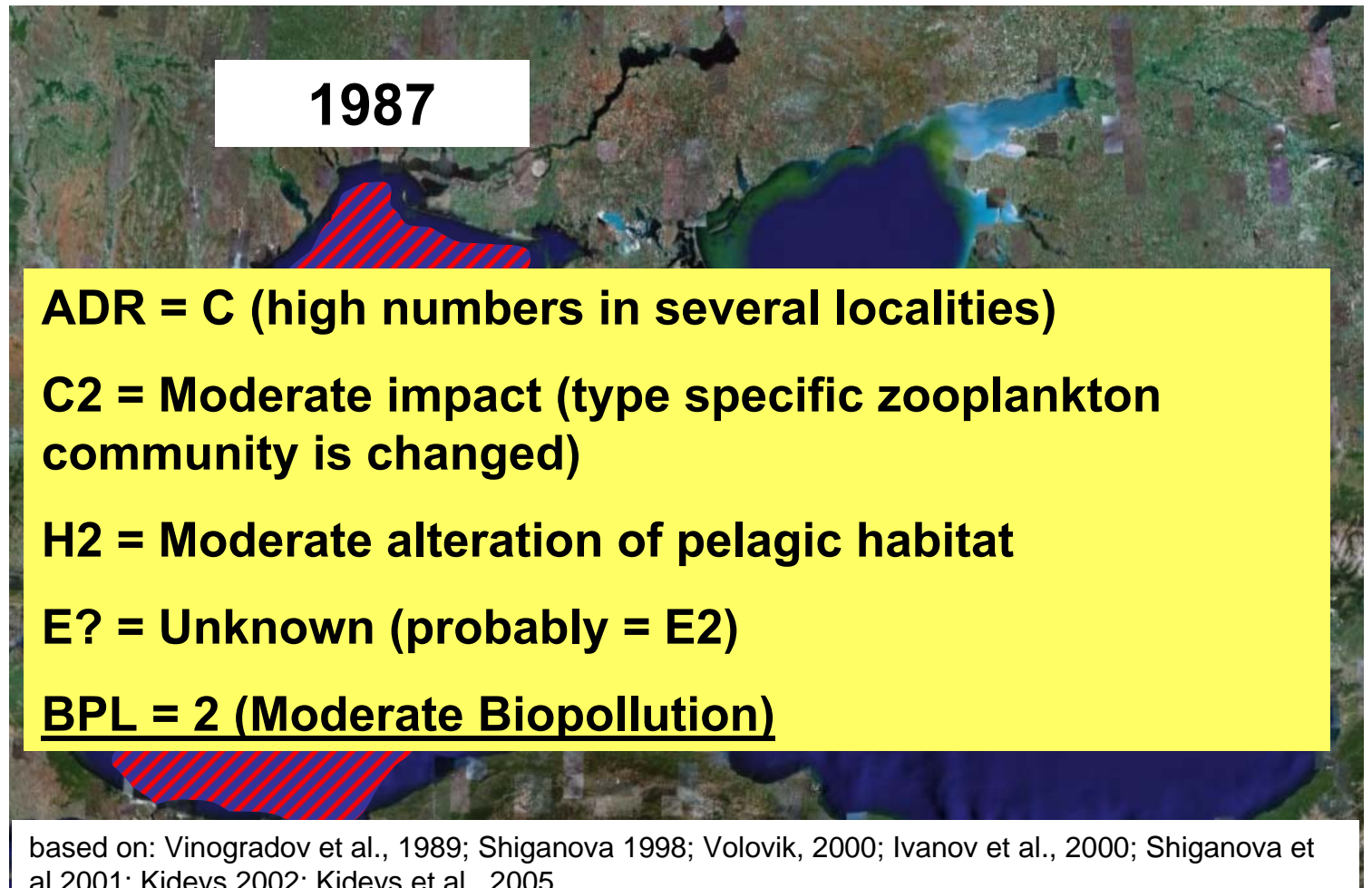
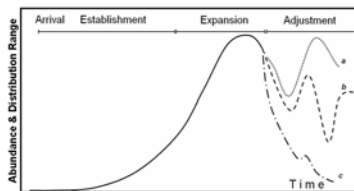
BPL = 0 (No biopollution)

based on: Vinogradov et al., 1989; Shiganova 1998; Volovik, 2000; Ivanov et al., 2000; Shiganova et al 2001; Kideys 2002; Kideys et al., 2005

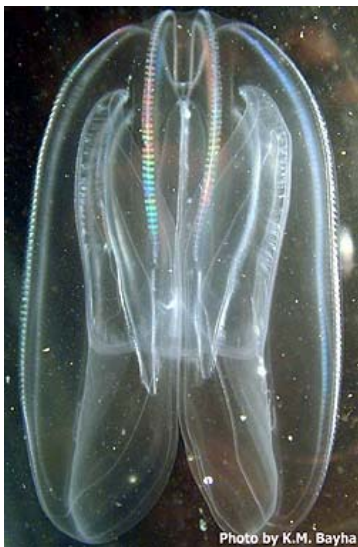
Invasion of the ctenophore *Mnemiopsis leidyi* in the Black Sea in terms of Biopollution



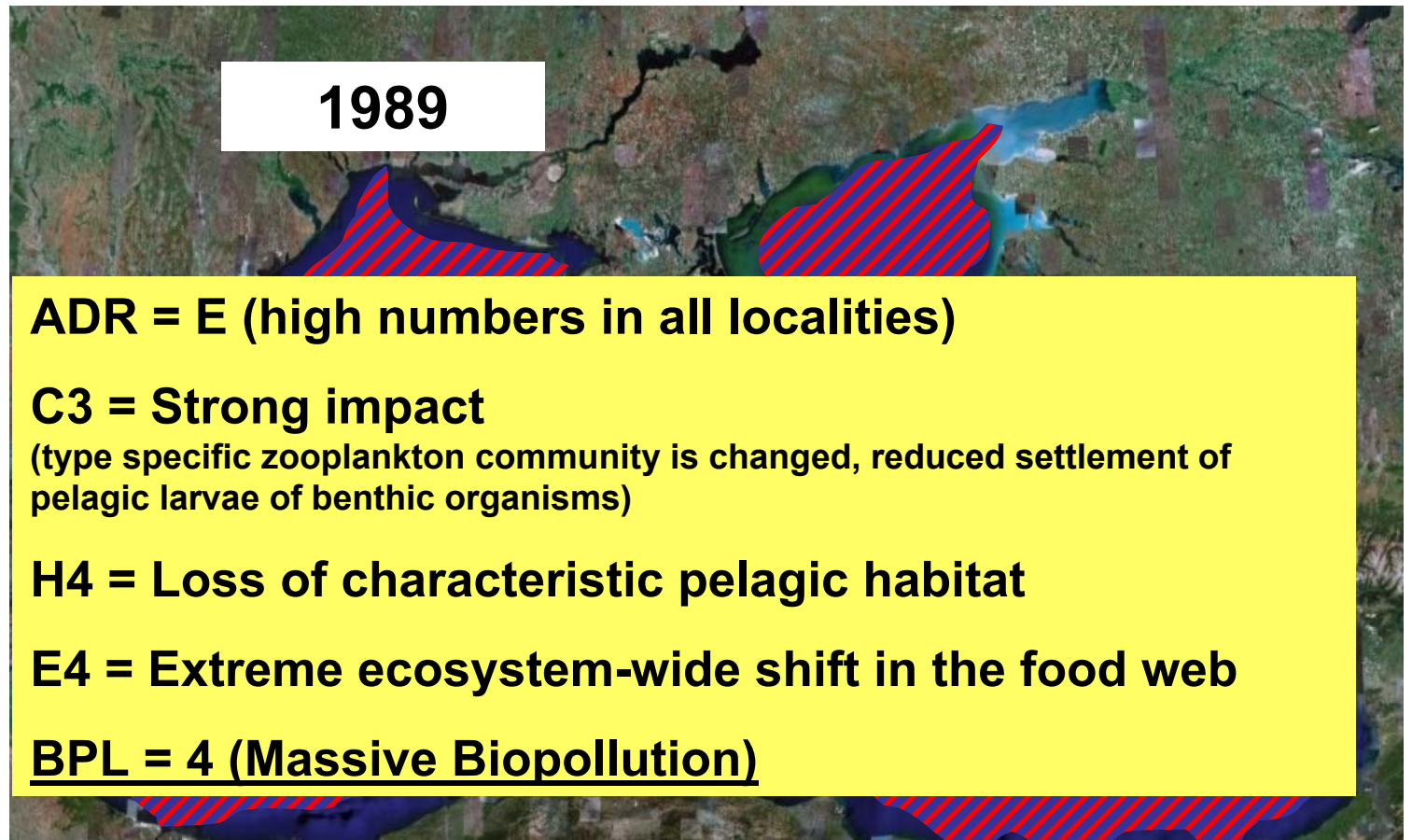
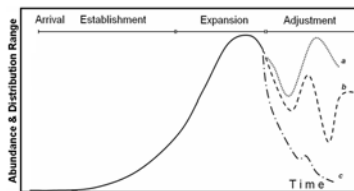
Expansion



Invasion of the ctenophore *Mnemiopsis leidyi* in the Black Sea in terms of Biopollution

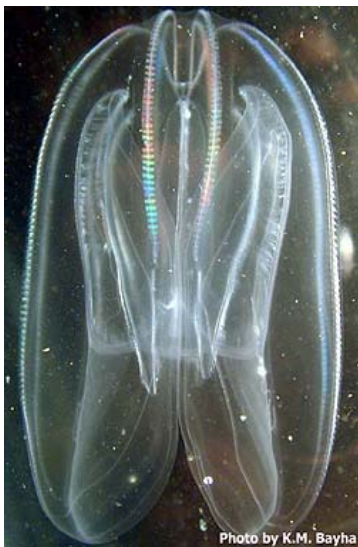


Expansion

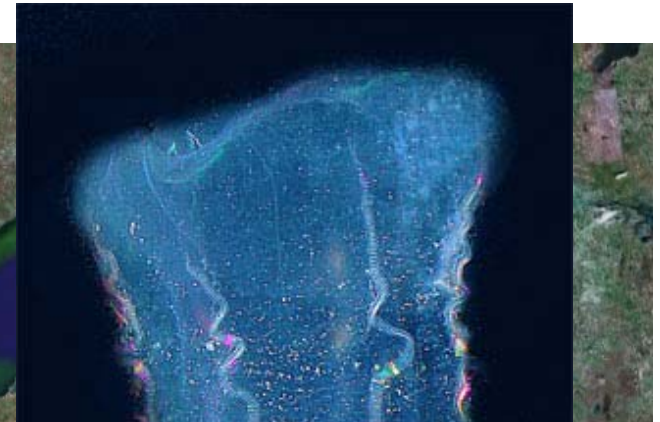
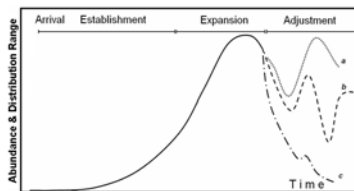


based on: Vinogradov et al., 1989; Shiganova 1998; Volovik, 2000; Ivanov et al., 2000; Shiganova et al 2001; Kideys 2002; Kideys et al., 2005

Invasion of the ctenophore *Mnemiopsis leidyi* in the Black Sea in terms of Biopollution



Adjustment



ADR = C (low numbers in all localities or moderate numbers in many localities)

C1 – C2 (Weak to moderate)

H1 – H2 (Weak to moderate)

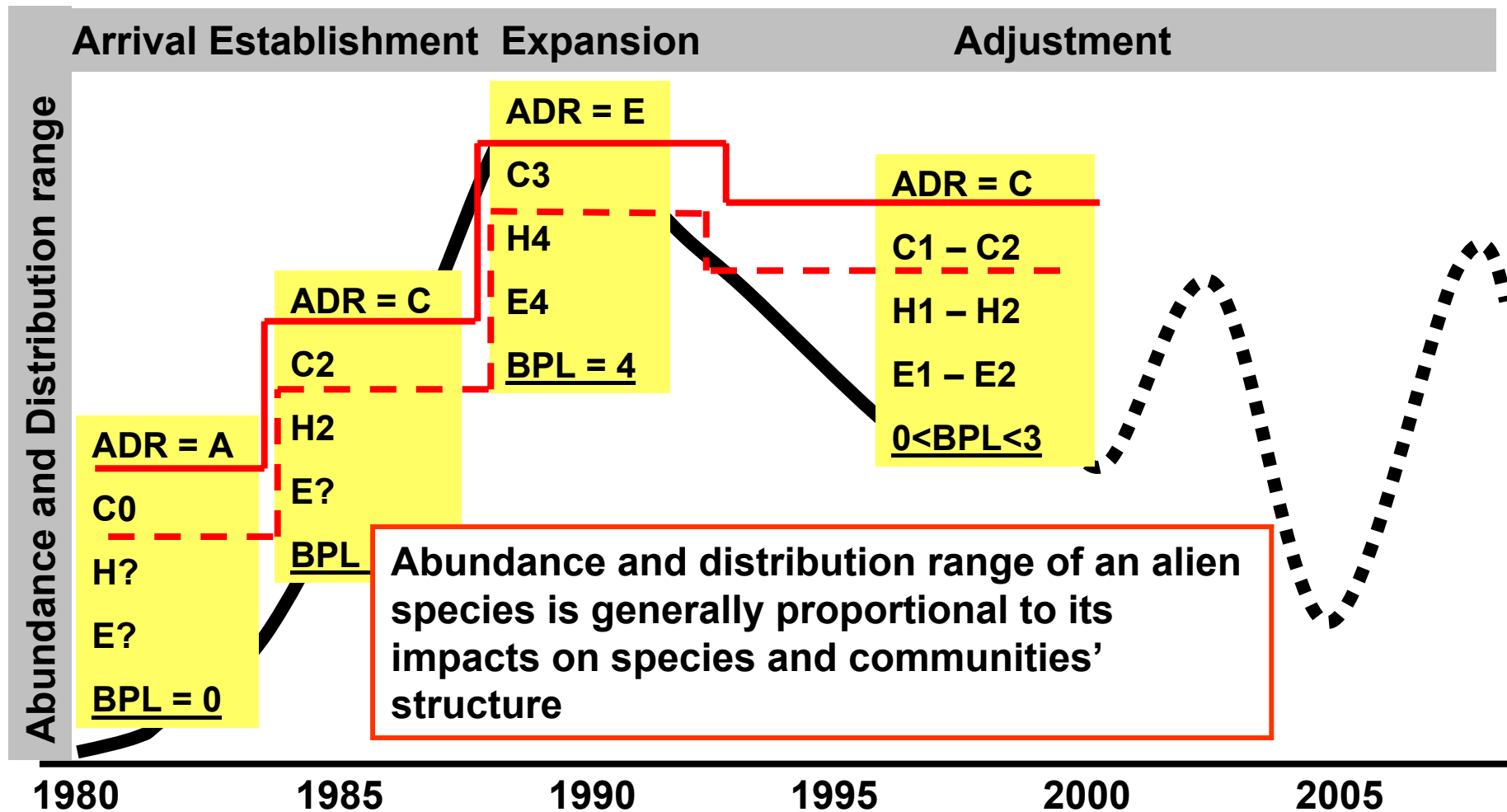
E1 – E2 (Weak to moderate)

BPL ≤ 2 (Weak or moderate)

based on: Vinogradov et al., 1989; Shiganova 1998; Volovik, 2000; Ivanov et al., 2000; Shiganova et al 2001; Kideys 2002; Kideys et al., 2005

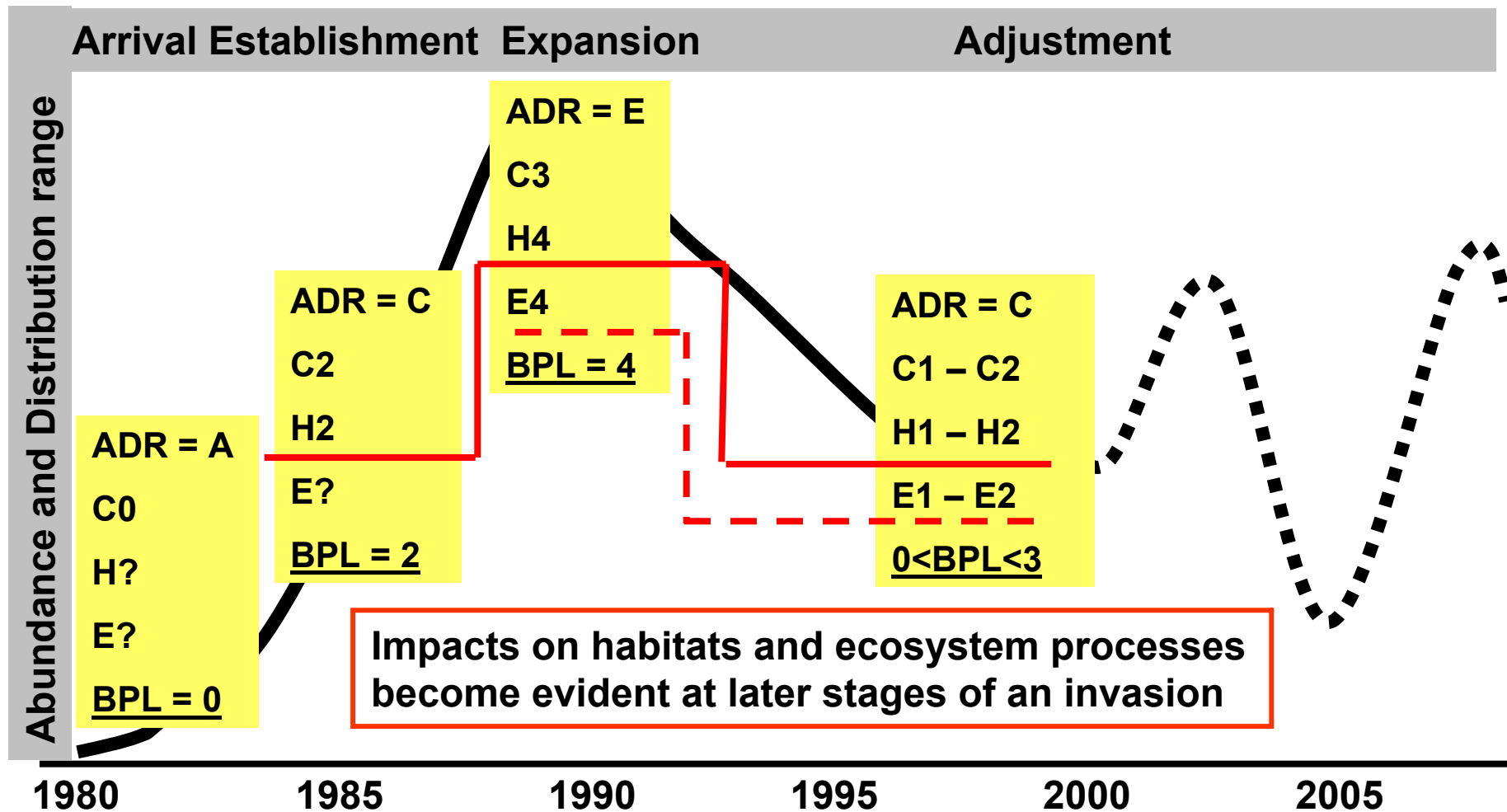
Invasion of the ctenophore *Mnemiopsis leidyi* in the Black Sea in terms of Biopollution

SUMMARY:



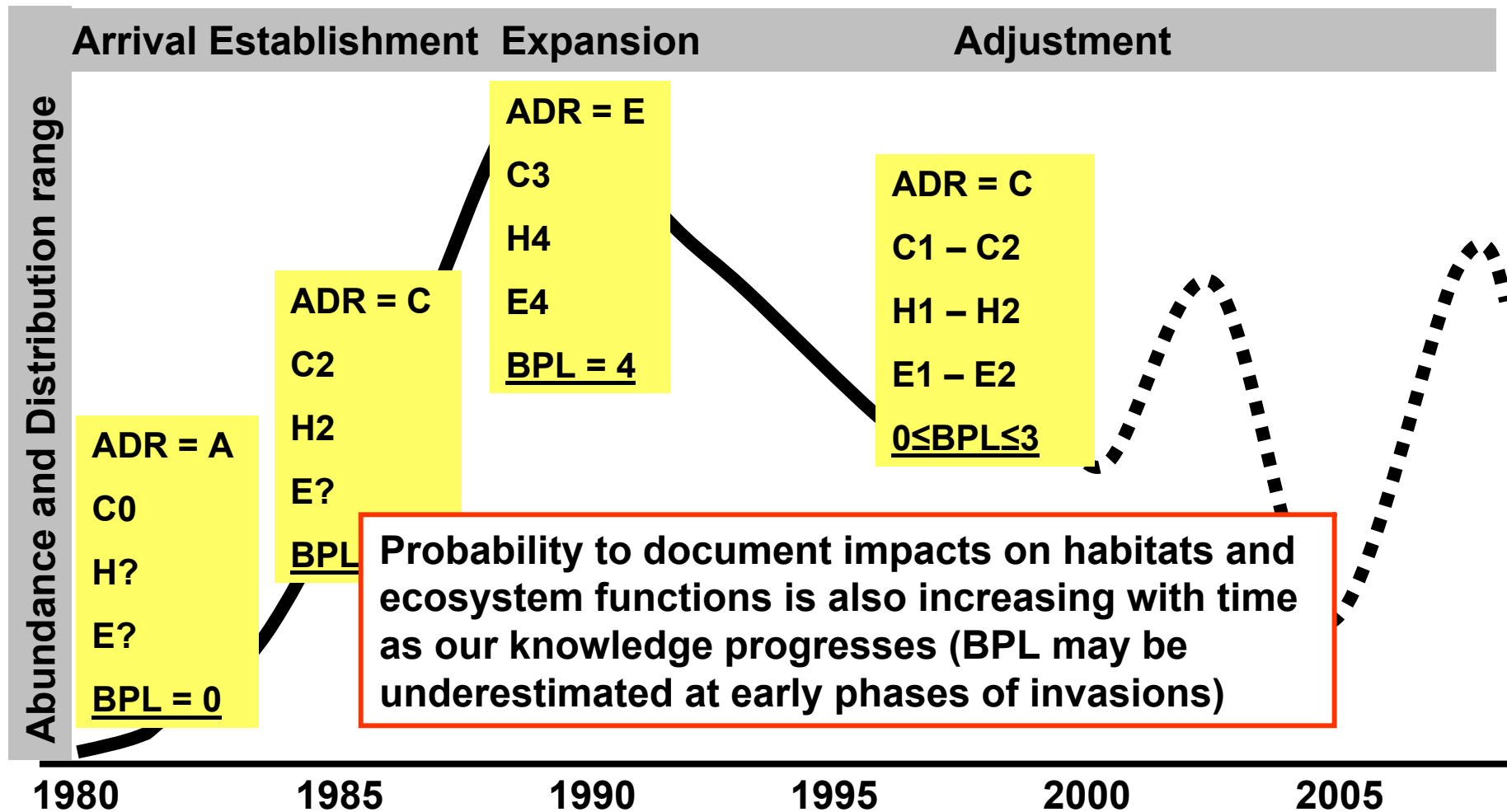
Invasion of the ctenophore *Mnemiopsis leidyi* in the Black Sea in terms of Biopollution

SUMMARY:



Invasion of the ctenophore *Mnemiopsis leidyi* in the Black Sea in terms of Biopollution

SUMMARY:





Invasion of *Mnemiopsis leidyi* in the Black, Caspian and Baltic Seas in terms of Biopollution

Baltic Sea

Recorded in 2006

Establishment phase

ADR = A

(low numbers in several localities)

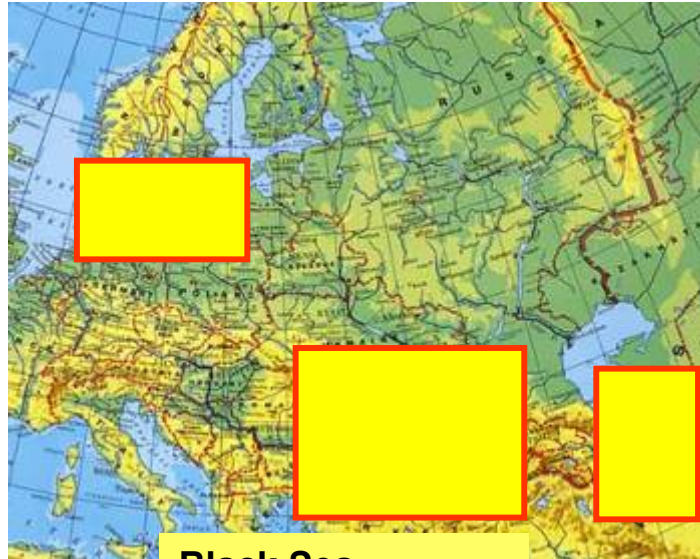
C0

H?

E?

BPL=0

Based on: Hansson, 2006; Javidpour et al., 2006



Caspian Sea

Recorded in 1999

Adjustment phase?

ADR < D

(high numbers in many localities, but - never occupied the entire sea)

C3

H0-H4

E0-E4

(multiple ecosystem effects)

BPL < 4

Based on: Ivanov et al, 2004

Black Sea

Recorded in 1982

Adjustment phase

ADR = C (A-E)

C0-C3

H0-H4

E0-E4

0 ≤ BPL ≤ 4

Concluding remarks

- Biopollution Index (BPI) provides a uniform approach for assessment of alien species impacts, enabling comparison between different alien species and different areas, *inter alia* for WFD purposes.
- BPI may be used for:
 - acquiring baseline information on alien species,
 - monitoring of biopollution effects,
 - prioritizing impacting species (target species lists),
 - **evaluation of effectiveness of bioinvasion management.**
- Robustness of the biopollution assessment method should be tested in other regions, and for different species.

Support:

EU FP6
Strategic Targeted Research
Project
DAISIE



Delivering
Alien
Invasive
Species
Inventories
for Europe

SSPI-CT-2003-511202

DAISIE

Delivering Alien Invasive Species Inventories for Europe

Strategic Targeted Research Project

www.europe-aliens.org

EU FP6
Integrated Project
ALARM



ALARM
Assessing **L**arge scale environmental **R**isks
for biodiversity with tested **M**ethods



SIXTH FRAMEWORK PROGRAMME
SUB-PRIORITY 6.3
Sustainable Development, Global Change and Ecosystems



Conferences
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Poster competition
Jobs
Contact
News
Login ALARM
2003/03/01

Integrated Project
(Contract number: GOCE-CT-2003-506675)

www.alarmproject.net



sergej@corpi.ku.lt

darius@corpi.ku.lt

minchin@indigo.ie

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Marine Pollution Bulletin 55 (2007) 379–394

MARINE
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Assessment of biopollution in aquatic ecosystems

Sergej Olenin ^{a,*}, Dan Minchin ^b, Darius Daunys ^a

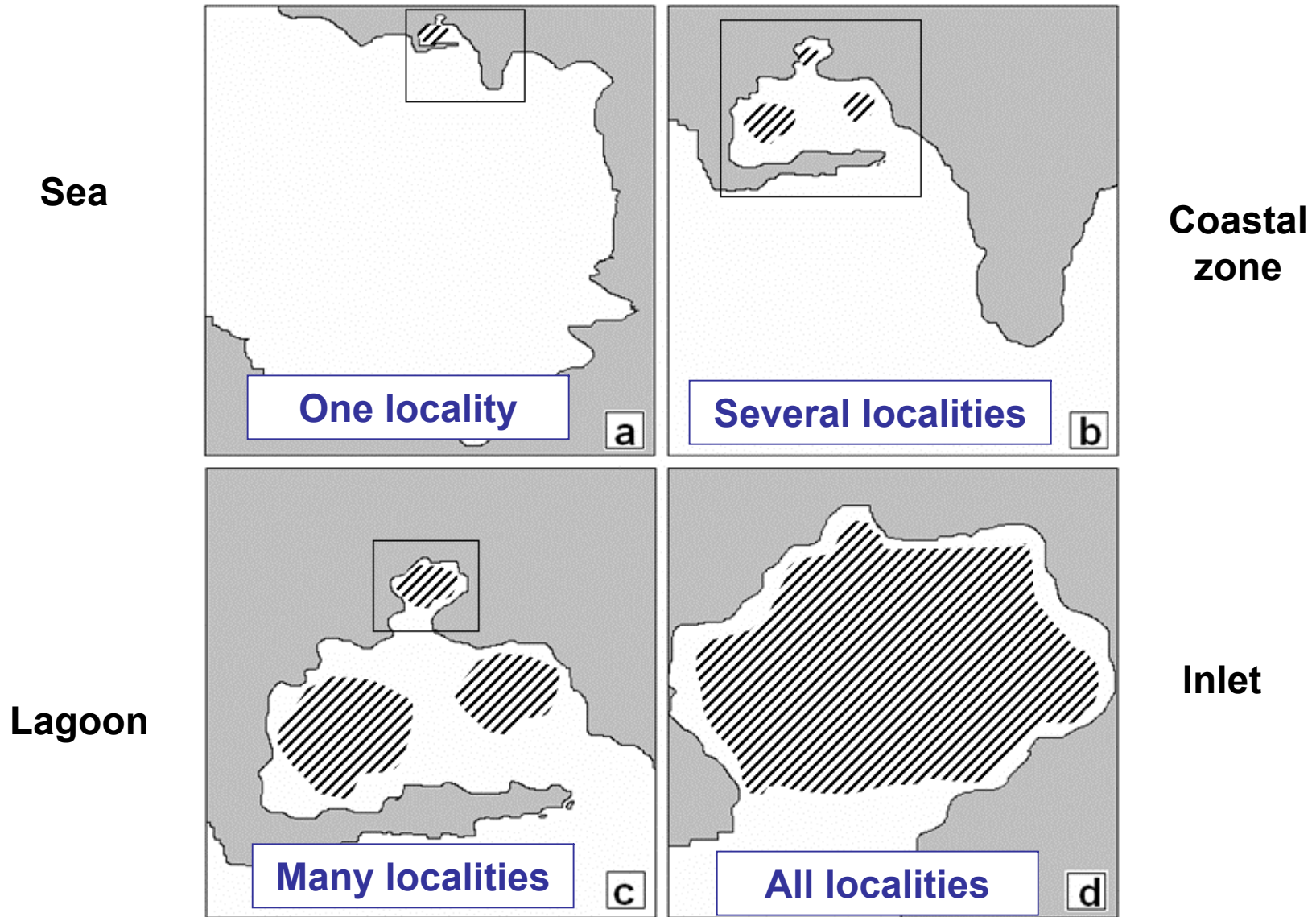
^a Coastal Research and Planning Institute, Klaipeda University, H. Manto 84, LT92294, Lithuania

^b Marine Organism Investigations, 3 Marina Village, Ballina, Killaloe, Co Clare, Ireland

Marine Pollution Bulletin , 55 (7-9), 379-394

Extras

“an alien species found in...”



The
biopollution
assessment
procedure:
step 2

Is the knowledge sufficient for the assessment?

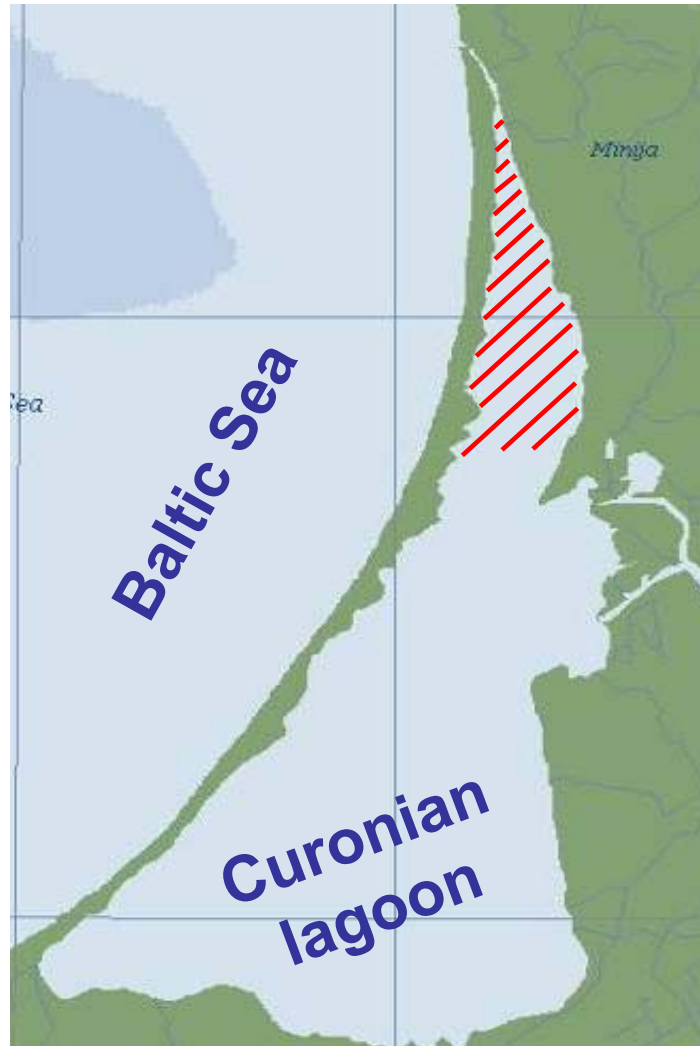
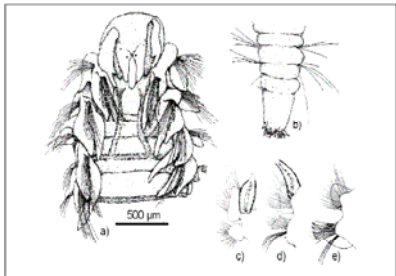
Yes

- **Historical data – since 1920s**
- **Environmental monitoring, incl. biological parameters – since 1980**
- **Good knowledge of environmental conditions, local species diversity, ecosystem processes and invasion biology**

The
biopollution
assessment
procedure:
steps 3-4

Assess abundance & distribution range of a first alien species

e.g.
Marenzelleria neglecta,
a spionid polychaete



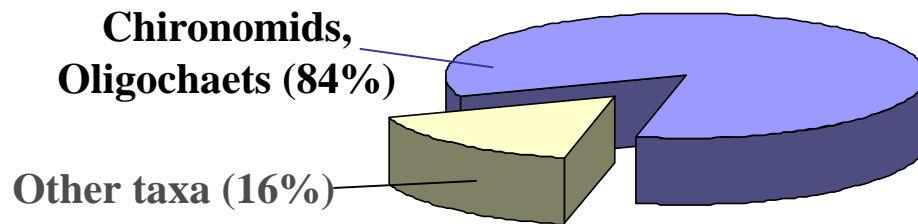
C
(occurs in
high numbers
in several
localities)

Source: Daunys, 2001

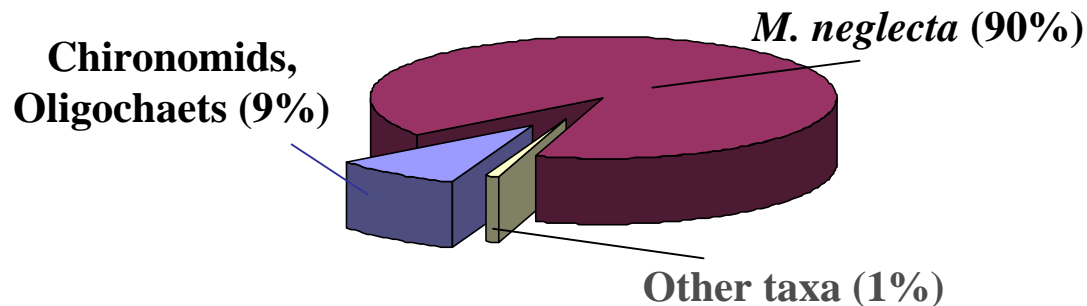
The
biopollution
assessment
procedure:
step 5

Assess impact on native community

Before invasion (total biomass $\sim 5 \pm 3.5 \text{ g m}^{-2}$)



After invasion (biomass $\sim 120 \pm 75 \text{ g m}^{-2}$)



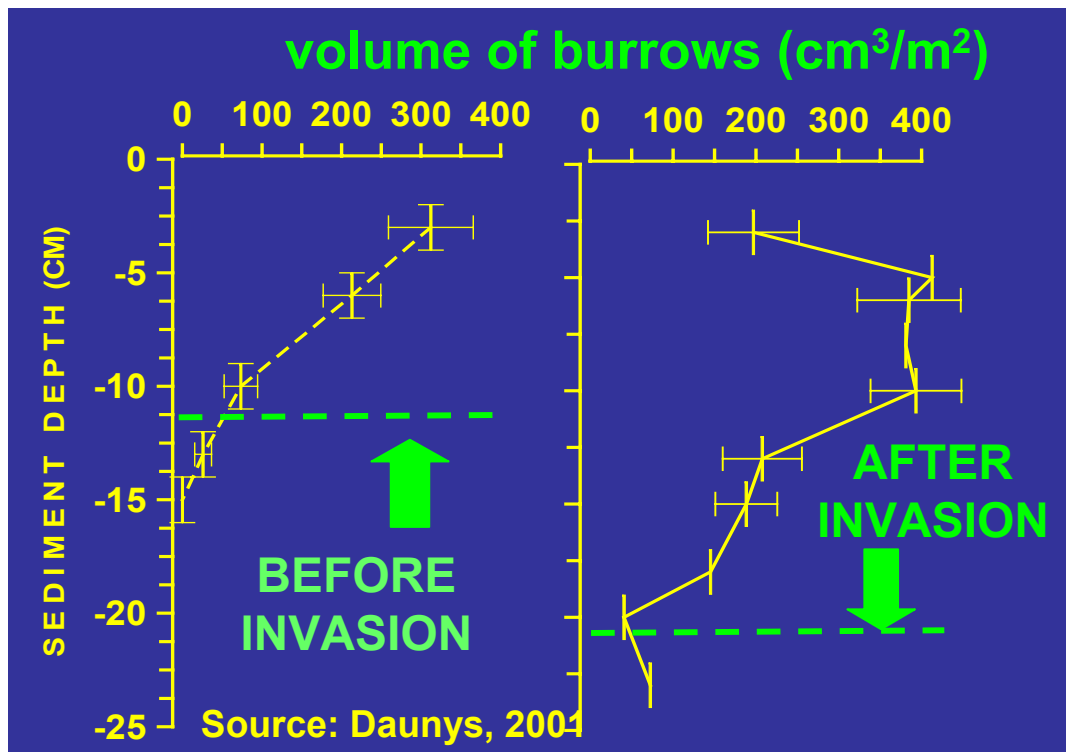
Source: Daunys, 2001

C2 moderate

(type-specific
communities are
changed noticeably
due to shifts in
community
dominant species)

The
biopollution
assessment
procedure:
step 5

Assess impact on a habitat



H2

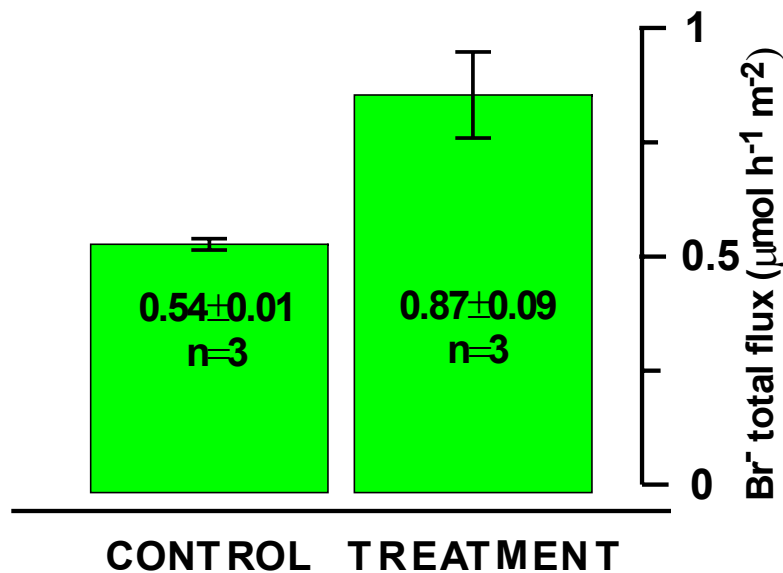
moderate

(Alteration of a
habitat, but no
reduction of its
spatial extent)

The
biopollution
assessment
procedure:
step 5

Assess impact on ecosystem function.

Increase in benthic-pelagic fluxes due to
bioturbation



From: Daunys, 2001

E2 moderate

(addition of a new
functional group in
part of the
assessment unit)

The
biopollution
assessment
procedure:
step 6

Assess biopollution level

Abundance & distribution range	C
Impact on native species	C2
Impact on habitats	H2
Impact on ecosystem functioning	E2

BPL = 2
moderate

The
biopollution
assessment
procedure:
step 7-n

Assess biopollution level for all AS

Species	ADR	C	H	E	BPL
1. <i>Balanus improvisus</i>	A	1	1	0	1
2. <i>Chaetogammarus warpachowskyi</i>	B	1	1	1	1
3. <i>Cordylophora caspia</i>	B	2	2	1	2
4. <i>Chelicorophium curvispinum</i>	B	1	1	1	1
5. <i>Dreissena polymorpha</i>	D	2	3	2	3
6. <i>Limnomysis benedeni</i>	B	2	1	2	2
7. <i>Obesogammarus crassus</i>	C	2	2	2	2
8. <i>Paramysis lacustris</i>	C	2	1	2	2
9. <i>Pontogammarus robustoides</i>	C	2	2	2	2
10. <i>Cercopagis pengoi</i>	B	2	1	1	2
11. <i>Gammarus tigrinus</i>	B	1	1	1	1
12. <i>Marenzelleria neglecta</i>	C	2	2	2	2
...
27. <i>Neogobius melanostomus</i>	A	0	0	0	0
28. <i>Prorocentrum minimum</i>	A	0	0	0	0

ADR – abundance and distribution range
C – impact on native species and communities
H – impact on habitat structure
E – impact on ecosystem
BPL – biopollution level

Only one species with
BPL=3, i.e. causing
strong biopollution

~ 30% of species cause
moderate biopollution
(BPL=2)

Most of species do not
cause biopollution
(BPL=0), i.e. are not
invasive