What is biological pollution and how we can measure it?

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Klaipeda University, Lithuania
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:
Biopollution assessment rationale

Postulates:

• An alien species will produce measurable effects only after attaining a particular level of abundance and when occupying a sufficiently large area.

• At the largest level of population expansion an invader has the greatest impact.

• Consequently,
  – the relative abundance of an alien species,
  – its distribution range and
  – the magnitude of impact(s)
    should be considered when assessing biopollution.
## Ranking abundance (low, moderate, high) and distribution (one, several, many, all localities) range

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>• low numbers in one or several localities</td>
</tr>
</tbody>
</table>
| B    | • low numbers in many localities  
      |   • moderate numbers in one or several localities |
| C    | • low numbers in all localities  
      |   • moderate numbers in many localities  
      |   • high numbers in several localities |
| D    | • moderate numbers in all localities  
      |   • high numbers in many localities |
| E    | • high numbers in all localities |
The assessment unit (study area) should be defined

**One locality** for a Sea

**Several localities** for a coastal zone

**Many localities** for a lagoon within the coastal zone

**All localities** for a zone of a coastal lagoon

*Source: Savini, Occhipinti Ambrogi, 2007*
## Ranking bioinvasion impact on communities

<table>
<thead>
<tr>
<th>Code</th>
<th>Impact</th>
<th>Description</th>
</tr>
</thead>
</table>
| C 0  | No      | • No displacement of native sp in presence of AS  
|       |         | • Ranking of native sp quantitatively unchanged  
|       |         | • Type specific community present                                                |
| C 1  | Weak    | • Local displacement of native species  
|       |         | • Dominant species remain the same  
|       |         | • Type-specific communities are present                                        |
| C 2  | Moderate| • Large scale displacement of native species  
|       |         | • Type-specific communities are changed noticeably  
|       |         | • Shifts in community dominant species                                         |
| C 3  | Strong  | • Population extinctions within the ecosystem  
|       |         | • Alien species are dominant  
|       |         | • Loss of type-specific community within an ecological group                    |
| C 4  | Massive | • Population extinction of native keystone species  
|       |         | • Extinction of type-specific communities occurs within more than one ecological group |
**Ranking bioinvasion impact on native habitats**

<table>
<thead>
<tr>
<th>Code</th>
<th>Impact</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>H0</td>
<td>No</td>
<td>• No habitat alteration</td>
</tr>
<tr>
<td>H1</td>
<td>Weak</td>
<td>• Alteration of a habitat(s), but</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• No reduction of spatial extent of a habitat(s).</td>
</tr>
<tr>
<td>H2</td>
<td>Moderate</td>
<td>• Alteration and reduction of spatial extent of a habitat(s).</td>
</tr>
<tr>
<td>H3</td>
<td>Strong</td>
<td>• Alteration of a key habitat,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Severe reduction of spatial extent of habitat(s)</td>
</tr>
<tr>
<td>H4</td>
<td>Massive</td>
<td>• Loss of habitats in most of the assessment unit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Loss of a key habitat</td>
</tr>
</tbody>
</table>
### Ranking bioinvasion impact on ecosystem functioning

<table>
<thead>
<tr>
<th>Code</th>
<th>Impact</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>E0</td>
<td>No</td>
<td>• No measurable effect.</td>
</tr>
<tr>
<td>E1</td>
<td>Weak</td>
<td>• Measurable, but weak changes with no loss or addition of new ecosystem function(s).</td>
</tr>
<tr>
<td>E2</td>
<td>Moderate</td>
<td>• Moderate modification of ecosystem performance, changes in functional group(s).</td>
</tr>
<tr>
<td>E3</td>
<td>Strong</td>
<td>• Severe shifts in ecosystem functioning, reorganisation of the food web.</td>
</tr>
<tr>
<td>E4</td>
<td>Massive</td>
<td>• Extreme, ecosystem-wide shift in the food web and/or loss of the role of a functional group(s).</td>
</tr>
</tbody>
</table>
# Confidence level
applied for assessing the impacts

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>The impacts were documented by field and/or experimental studies for the given assessment unit.</td>
</tr>
<tr>
<td>Medium</td>
<td>The impacts were documented by field and/or experimental studies for a part of the assessment unit and extrapolated to the entire system by expert judgment.</td>
</tr>
<tr>
<td>Low</td>
<td>The impacts were not documented neither by field nor by experimental studies, expert knowledge of the species impact based on data from studies made elsewhere was applied.</td>
</tr>
</tbody>
</table>
Combined abundance and distribution range class and evaluation of impact of aliens on: native species and communities (C), invaded habitat (H) and ecosystem functioning (E).

<table>
<thead>
<tr>
<th>ADR</th>
<th>species and communities</th>
<th>habitat</th>
<th>ecosystem function</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C0</td>
<td>C1</td>
<td>C2</td>
</tr>
<tr>
<td>A</td>
<td>0</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>D</td>
<td>-</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>E</td>
<td>-</td>
<td>-</td>
<td>3</td>
</tr>
</tbody>
</table>
The decision support scheme for assessment of Biopollution Level (BPL)

Used to develop the Computerized Biopollution Assessment System (COMBAT)
Biopollution assessment procedure
Define the assessment unit

Example: Curonian lagoon, Baltic Sea
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
Assess abundance & distribution range of a first alien species

The biopollution assessment procedure:
steps 3-4

e.g. *Marenzelleria neglecta*, a spionid polychaete

C
(occurs in high numbers in several localities)

Source: Daunys, 2001
Assess impact on native community

**Step 5**

**C2 moderate**

*Type-specific communities are changed noticeably due to shifts in community dominant species*

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

- Chironomids, Oligochaets (84%)
- Other taxa (16%)

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

- Chironomids, Oligochaets (9%)
- *M. neglecta* (90%)
- Other taxa (1%)

Source: Daunys, 2001
Assess impact on a habitat

H2 moderate

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

Source: Daunys, 2001
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)
### Biopollution Assessment Procedure: Step 6

<table>
<thead>
<tr>
<th>Abundance &amp; distribution range</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact on native species</td>
<td>C2</td>
</tr>
<tr>
<td>Impact on habitats</td>
<td>H2</td>
</tr>
<tr>
<td>Impact on ecosystem functioning</td>
<td>E2</td>
</tr>
</tbody>
</table>

**BPL = 2**

**Moderate**
### Assess biopollution level for all AS

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

**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
Most of alien species occur in low numbers in few localities (ADR=A)

Most of alien species have no measurable impacts (C0, H0, E0)

**Comparison of impacts**

- **Impact on native species / communities**
- **Impact on habitats**
- **Impact on ecosystem**
Monitoring of biopollution effects

(how Biopollution caused by the same species is changing over time?)
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)

1982 - first record, Sudak Bay, coast of Crimea

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

ADR = C (high numbers in several localities)

C2 = Moderate impact (type specific zooplankton community is changed)

H2 = Moderate alteration of pelagic habitat

E? = Unknown (probably = E2)

BPL = 2 (Moderate 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

Max. Biomass: 4.6 kg WW m\(^2\) (184 g m\(^3\))
Max. Abundance: 7,600 ind. m\(^2\) (304 ind. m\(^3\))

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

ADR = E (high numbers in all localities)

C3 = Strong impact
(type specific zooplankton community is changed, reduced settlement of pelagic larvae of benthic organisms)

H4 = Loss of the characteristic pelagic habitat

E4 = Extreme ecosystem-wide shifts in the food web

BPL = 4 (Massive Biopollution)
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:**

Abundance and distribution range of an alien species is generally proportional to its impacts on species and communities’ structure.
Invasion of the ctenophore *Mnemiopsis leidyi* in the Black Sea in terms of Biopollution

**SUMMARY:**

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrival</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Establishment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expansion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjustment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Abundance and Distribution range**

- **ADR = A**
  - C0
  - H?
  - E?
  - BPL = 0

- **ADR = C**
  - C2
  - H2
  - E?
  - BPL = 2

- **ADR = E**
  - C3
  - H4
  - E?
  - BPL = 4

- **Impacts on habitats and ecosystem processes**
  - become evident at later stages of an invasion

- **0 < BPL < 3**

**Notes:**

- ADR = Abundance and Distribution range
- BPL = Biological Pollutant Level
Invasion of the ctenophore *Mnemiopsis leidyi* in the Black Sea in terms of Biopollution

**SUMMARY:**

<table>
<thead>
<tr>
<th>Year</th>
<th>Arrival</th>
<th>Establishment</th>
<th>Expansion</th>
<th>Adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>A</td>
<td>C0 H? E?</td>
<td>ADR = C</td>
<td>BPL = 0</td>
</tr>
<tr>
<td>1985</td>
<td>C2 H2 E?</td>
<td></td>
<td>ADR = E</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td></td>
<td>C3 H4 E4</td>
<td>ADR = C C1 – C2 H1 – H2 E1 – E2</td>
<td>0 ≤ BPL ≤ 3</td>
</tr>
<tr>
<td>1995</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
<td></td>
<td>ADR = C</td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Probability to document impacts on habitats and ecosystem functions is also increasing with time as our knowledge progresses (BPL may be underestimated at early phases of invasions)
Comparison of the same species in different ecosystems
Invasion of *Mnemiopsis leidyi* in the Black, Caspian and Baltic Seas in terms of Biopollution

**Baltic Sea**
- Recorded in 2006 (SW Baltic)
- Establishment phase
- ADR = B (low numbers in many localities)
- C0
- H?
- E?
- BPL=0
- Based on: Hansson, 2006; Javidpour et al., 2006

**Black Sea**
- Recorded in 1982
- Adjustment phase
- ADR = C (A-E)
- C0-C3
- H0-H4
- E0-E4
- 0 ≤ BPL ≤ 4

**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
Assessing the risk of invasive species

- Most species show little or no impact
- BPL caused by the same species may greatly vary among different ecosystems
- Impacting species (BPL ≥ 2) not yet in Europe should be targeted ("black listed")
Bioinvasions and socio-economy

**Hypothesis:**

- Species with BPL<2 will not cause noticeable economic impacts
- Species with BPL=>3 can result in serious economic and social problems (i.e. zebra mussels in Ebro river reservoir, Spain)
Concluding remarks

• Biopollution Index (BPI) provides a uniform approach for assessment of alien species impacts, enabling comparison between different alien species and different areas.

• 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.

• Computerised Biopollution assessment system - online since March 2008: www.corpi.lt/nemo/~biopollution
Support:

EU FP6 Strategic Targeted Research Project  
DAISIE

SSPI-CT-2003-511202  
DAISIE  
Delivering Alien Invasive Species Inventories for Europe

EU FP6 Integrated Project  
ALARM

www.alarmproject.net
Acknowledgement

Co-authors:
Dan Minchin and Darius Daunys

Working sessions 2004-2007:
Ireland, Lithuania, Slovakia, Spain, Austria
Thank you for your attendance!
EXTRAS
## Assessment Unit Accounts

<table>
<thead>
<tr>
<th>Assessment unit</th>
<th>Period</th>
<th>Type</th>
<th>Size (km²)</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curonian Lagoon</td>
<td>1980-2006</td>
<td>Coastal Waters</td>
<td>1584 km²</td>
<td>Darius Daunys</td>
</tr>
<tr>
<td>Dniiper</td>
<td>1958-2006</td>
<td>River</td>
<td>30 km²</td>
<td>Sergey Mastitsky</td>
</tr>
<tr>
<td>middle Danube</td>
<td>1975-2005</td>
<td>River</td>
<td>84 km²</td>
<td>Momir Paunovic</td>
</tr>
<tr>
<td>Sava</td>
<td>2006-2006</td>
<td>River</td>
<td>17 km²</td>
<td>Momir Paunovic</td>
</tr>
</tbody>
</table>
# Assessment unit account for river Sava, Serbia

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Dreissena polymorpha</em> (view report)</td>
<td>B</td>
<td>ə (C2)</td>
<td>ə (H2)</td>
<td>ə (E2)</td>
<td>ə</td>
<td>Momir Paunovic</td>
</tr>
<tr>
<td><em>Theodoxus danubialis</em> (view report)</td>
<td>A</td>
<td>ə (C1)</td>
<td>ə (H1)</td>
<td>ə (E1)</td>
<td>1</td>
<td>Momir Paunovic</td>
</tr>
<tr>
<td><em>Hypania invalida</em> (view report)</td>
<td>A</td>
<td>ə (C1)</td>
<td>ə (H1)</td>
<td>ə (E1)</td>
<td>1</td>
<td>Momir Paunovic</td>
</tr>
<tr>
<td><em>Corophium robustum</em> (view report)</td>
<td>A</td>
<td>ə (C1)</td>
<td>ə (H1)</td>
<td>ə (E1)</td>
<td>1</td>
<td>Momir Paunovic</td>
</tr>
<tr>
<td><em>Corophium curvispinum</em> (view report)</td>
<td>C</td>
<td>ə (C1)</td>
<td>ə (H1)</td>
<td>ə (E1)</td>
<td>ə</td>
<td>Momir Paunovic</td>
</tr>
<tr>
<td><em>Corbicula fluminea</em> (view report)</td>
<td>A</td>
<td>ə (C1)</td>
<td>ə (H1)</td>
<td>ə (E1)</td>
<td>1</td>
<td>Momir Paunovic</td>
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<tr>
<td><em>Corbicula fluminalis</em> (view report)</td>
<td>A</td>
<td>ə (C1)</td>
<td>ə (H1)</td>
<td>ə (E1)</td>
<td>1</td>
<td>Momir Paunovic</td>
</tr>
<tr>
<td><em>Branchyma sowerby</em> (view report)</td>
<td>C</td>
<td>ə (C2)</td>
<td>ə (H1)</td>
<td>ə (E2)</td>
<td>ə</td>
<td>Momir Paunovic</td>
</tr>
<tr>
<td><em>Anodonta woodiana</em> (view report)</td>
<td>C</td>
<td>ə (C2)</td>
<td>ə (H1)</td>
<td>ə (E2)</td>
<td>ə</td>
<td>Momir Paunovic</td>
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<td><em>Hypania invalida</em> (view report)</td>
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<td>Momir Paunovic</td>
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A European team of researchers has recently developed a groundbreaking method to determine the magnitude of the impacts from invasive alien aquatic species on marine, brackish and freshwater ecosystems. These species, introduced by humans from outside their natural geographic range, are one of the major causes of biodiversity loss in Europe. The method could serve as a basis for assessing temporal changes as well as the efficacy of management in the field of biological pollution.

1. The projects ALARM “Assessing LArge scale Risks for biodiversity with tested Methods” (http://www.alarmproject.net) and DAISIE “Delivering Alien Species Inventory for Europe” (http://www.europe-aliens.org) are supported by the European Commission under the 6th EU Framework programme.