evropský sociální fond v ČR
EVROPSKÁ UNIE
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OP Vzdělávání pro konkurenceschopnost
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Inovace studia hydrobiologických disciplín s důrazem na rozšíření možností uplatnění absolventů biologických oborů PřF UP v praxi.

reg. číslo: CZ.1.07/2.2.00/28.0173

Experimental studies on the interactions among invasive aquatic species of Ponto-Caspian origin

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Our team

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1
Invasive organisms in European waters

2
Land-water ecotones

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Invasive Ponto-Caspian species in European waters

zebra mussel
Dreissena polymorpha

Pontogammaridae - 5 species

Goby fish - 4 species

- Common invasions in Europe in recent years
- Strong impact on local communities
- Complex interactions with one another and with local taxa

Invasive Ponto-Caspian species in European waters

Research topics

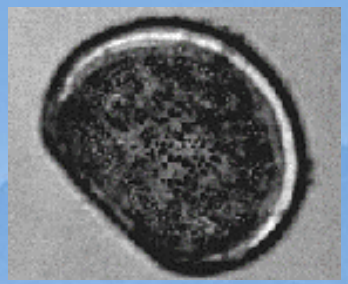
- Behaviour
- Habitat preferences
- Interactions with other organisms
    - Responses to predator cues
    - Interspecific competition

Invasive Ponto-Caspian species in European waters

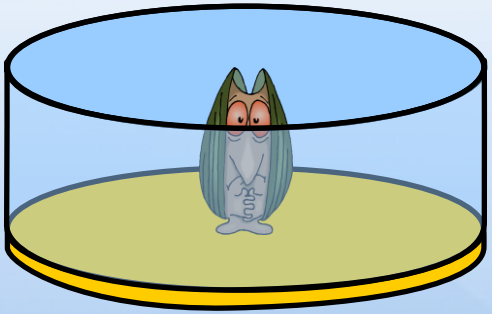
Dreissena polymorpha

- Byssally attached to solid substrata
- Planktonic larva: veliger
- Large densities (several th. per m^2)
- Ecosystem engineer:
  - Filtration
  - Habitat forming
  - Food for detritivores
- Economic impact: fouling

The hypothesis:
The behaviour of settled individuals affects the distribution and survival of mussels

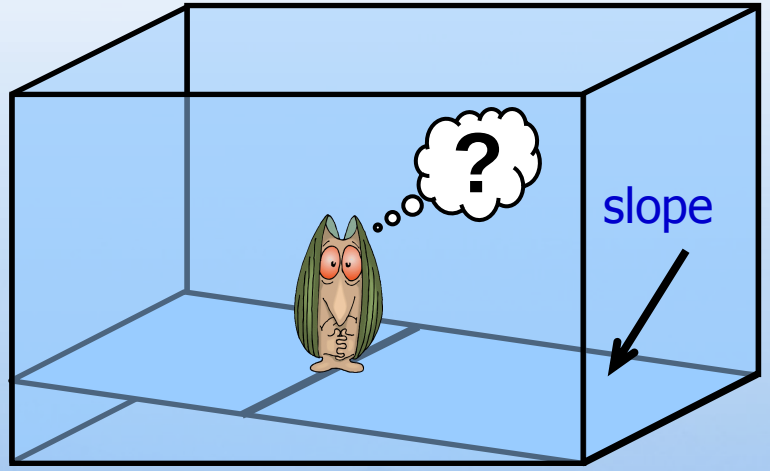


Horizontal movement



ImageJ software

Vertical movement

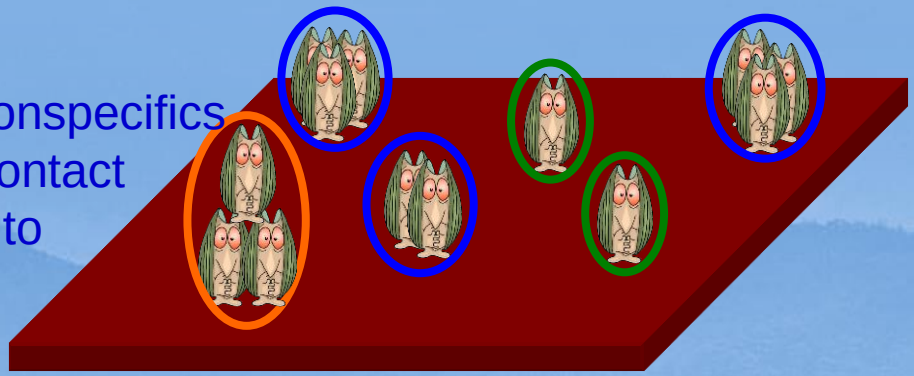


Attachment strength

Digital dynamometer

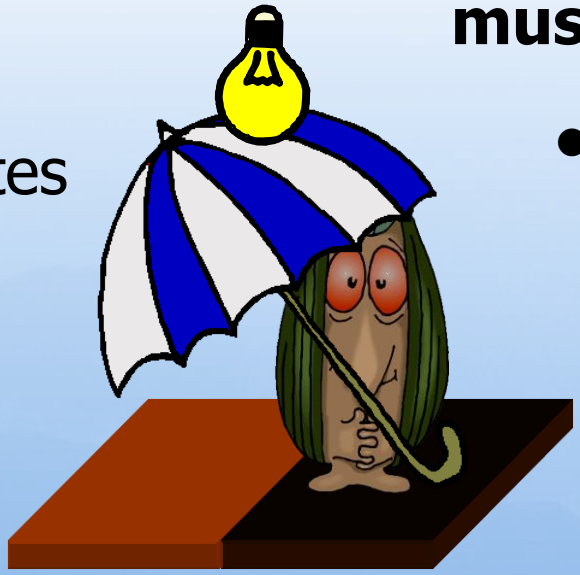
Aggregation

- **Druzes**: mussels attached to conspecifics
- **Monolayer aggregations**: in contact with conspecifics, but attached to the other substratum
- **Singletons**



Previous research

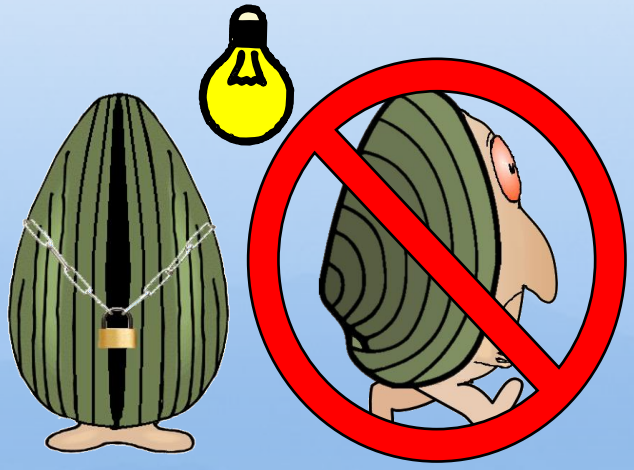
- Mussels avoid illuminated sites



- In darkness, small mussels move upwards
- This movement is inhibited by light

Impact of abiotic factors on mussel behaviour

- Light reduces mussel activity



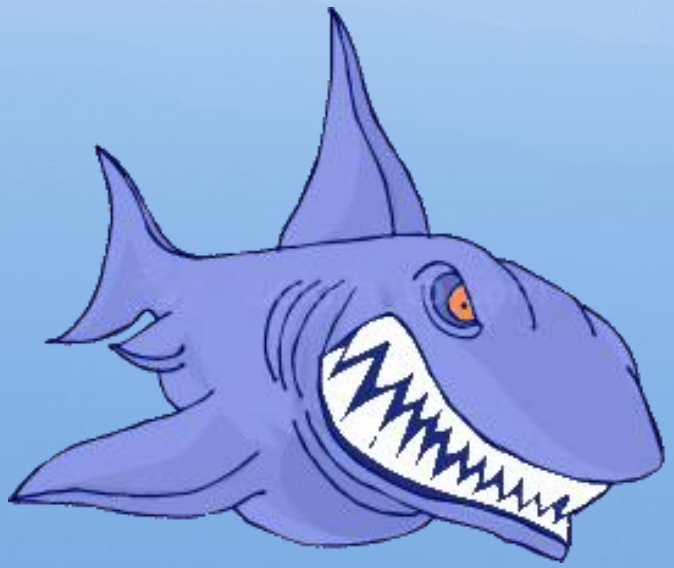
- Kobak J 2006. Geotactic behaviour of *D. polymorpha*. Malacologia 48: 305-308
- Kobak J 2006. Factors influencing the attachment strength of *D. polymorpha*. Biofouling 22: 153-162
- Kobak J, Nowacki P 2007. Light-related behaviour of zebra mussel. Fundam Appl Limnol 169: 341-352
- Kobak J, Poznańska M, Kakareko T 2009. Effect of attachment status and aggregation on behaviour of the zebra mussel, Bivalvia. J Mollus Stud 75: 109-117
- Kobak J 2013. Behavior of juvenile and adult zebra mussels. In: Nalepa TF, Schloesser DW (Eds) Quagga and Zebra Mussels: Biology, Impacts, and Control. 2nd Edition. Boca Raton: CRC Press: 331-334

Light=danger?

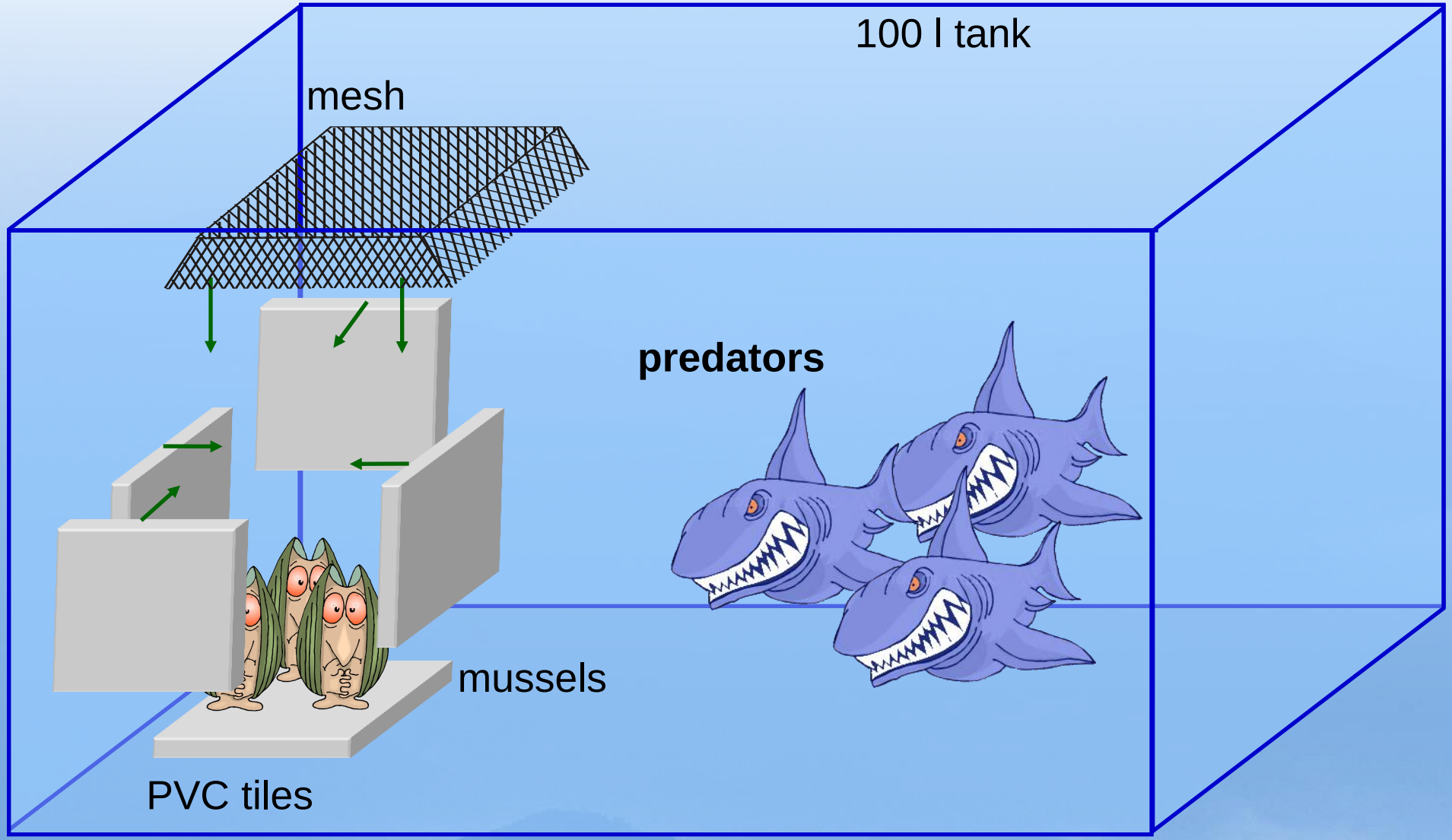
- No shelters
- Exposure to predators

Perhaps, mussels avoid open sites, exposed to predators?

Do mussels respond directly to predator cues?



Responses of mussels to predator cues

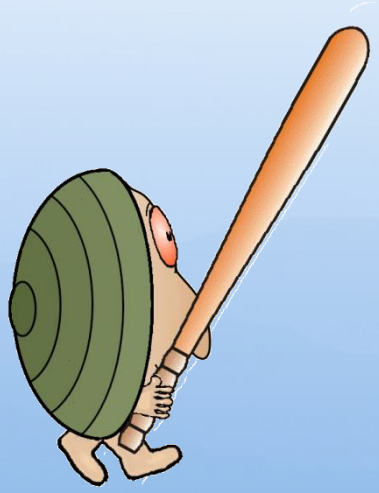


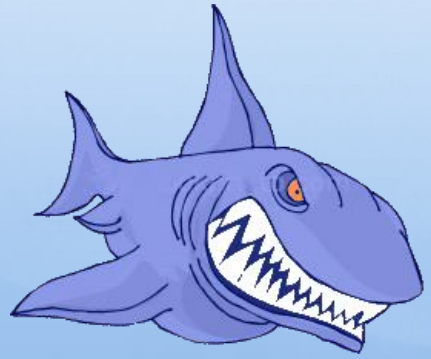
- Kobak J, Kakareko T 2009. Attachment strength, aggregation and movement of the zebra mussel in the presence of potential predators. Fundam Appl Limnol 174: 193-204
- Kobak J, Kakareko T, Poznańska M 2010. Changes in attachment strength and aggregation of zebra mussel in the presence of potential fish predators of various species and size. Hydrobiologia 644: 195-206.

Predators:	roach 	spiny-cheek crayfish 	racer goby 	perch 
Mussels:				
small (<10 mm) 	• Increased attachment (100%) • Increased aggregation (46%) • Reduced upward movement (44%)	No response	No response	No response
medium (10-17 mm) 	• Increased attachment (66%) • Increased aggregation (50%)	No response	No response	No response
large (>17 mm) 	No response	No response	No response	No response

- Kobak J, Kakareko T 2009. Attachment strength, aggregation and movement of the zebra mussel in the presence of potential predators. Fundam Appl Limnol 174: 193-204
- Kobak J, Kakareko T, Poznańska M 2010. Changes in attachment strength and aggregation of zebra mussel in the presence of potential fish predators of various species and size. Hydrobiologia 644: 195-206.

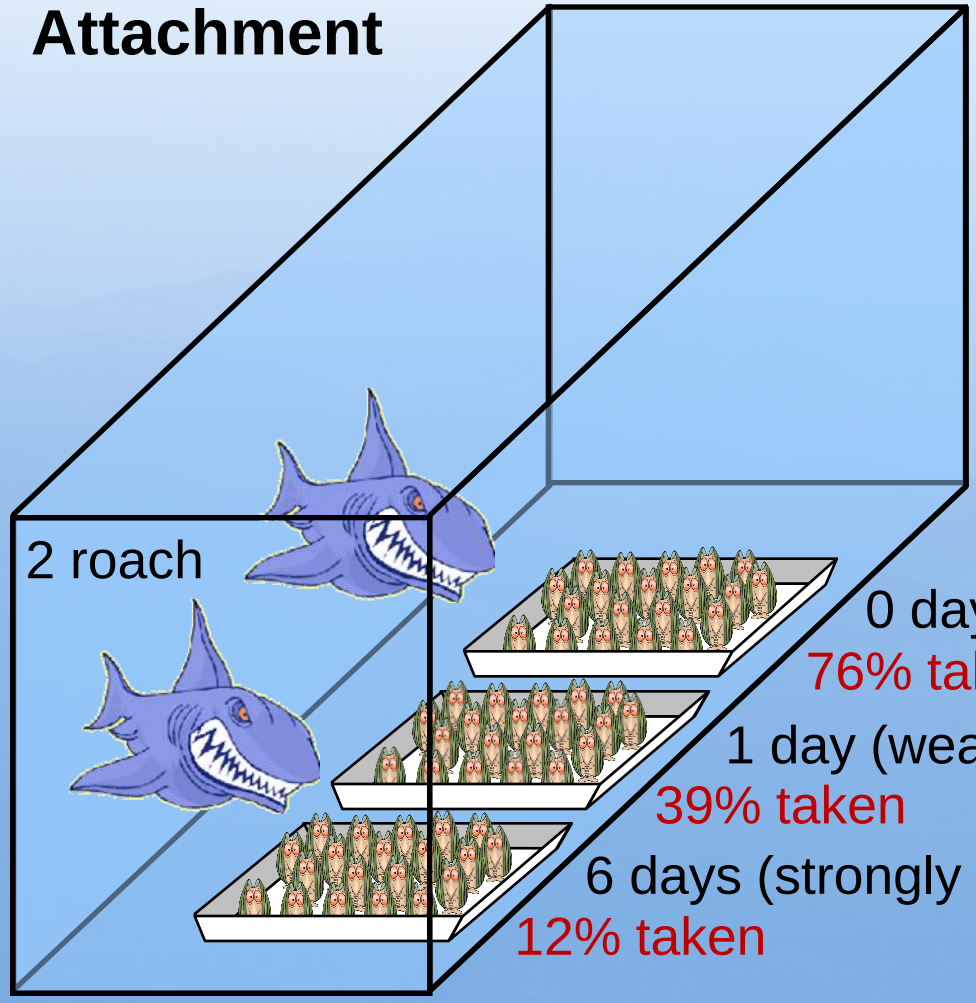
Efficiency of anti-predator responses of mussels





Kobak J, Kakareko T 2011. The effectiveness of the induced anti-predator behaviour of zebra mussel in the presence of molluscivorous roach. Aquatic Ecology 45: 357-366

Efficiency of anti-predator responses of mussels

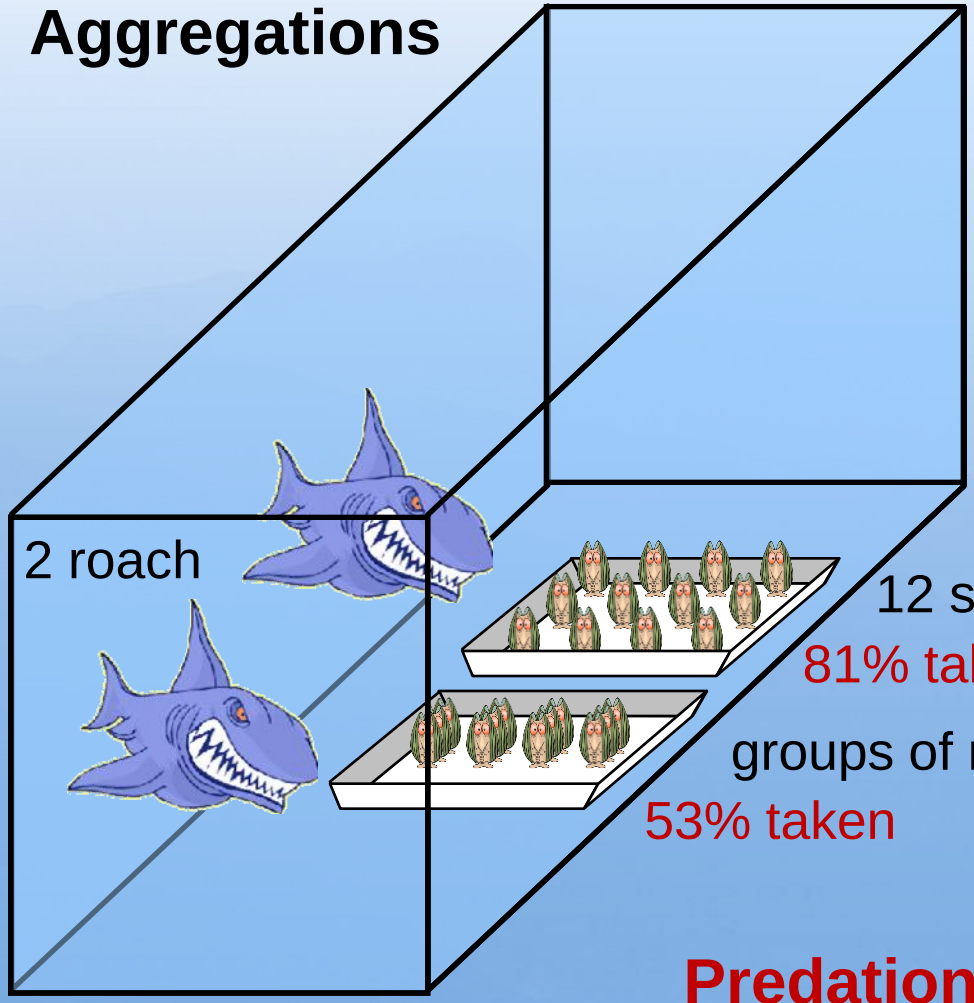


Predation efficiency decreases with the increased attachment strength

Kobak J, Kakareko T 2011. The effectiveness of the induced anti-predator behaviour of zebra mussel in the presence of molluscivorous roach. Aquatic Ecology 45: 357-366

Efficiency of anti-predator responses of mussels

Aggregations



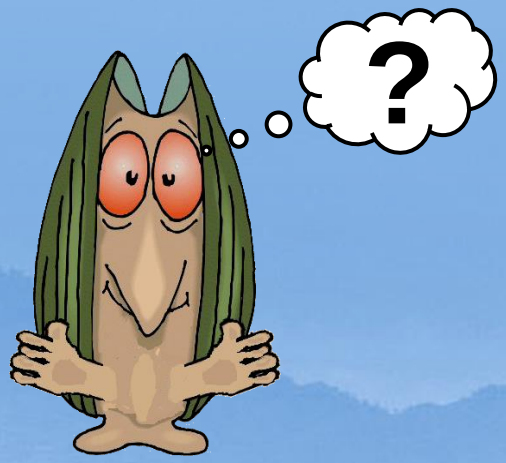
mussels glued with
the denture glue

Predation efficiency is lower if mussels are aggregated

Kobak J, Kakareko T 2011. The effectiveness of the induced anti-predator behaviour of zebra mussel in the presence of molluscivorous roach. Aquatic Ecology 45: 357-366

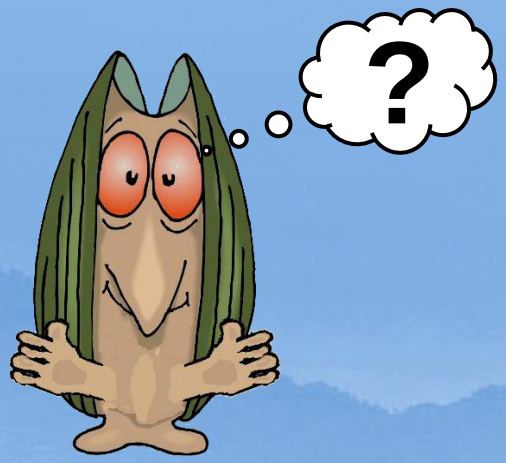
Summary

- In the absence of danger cues:
  - Mussels are more active and move upwards
  - In consequence, they occupy sites with optimum environmental conditions (on the colony surface, above the bottom)
    - lower intraspecific competition
    - more food
    - more oxygen
    - less metabolic wastes

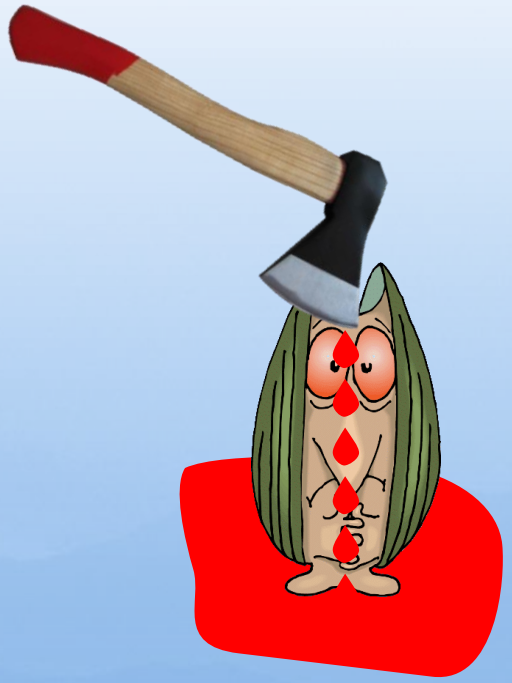


Summary

- In the presence of danger cues (light, predator kairomones):
  - Mussels are more strongly attached
  - Limit their activity
  - Reduce their upward movement
  - More often form aggregations
- In consequence, they occupy more protected sites, but of worse environmental quality
  - in shelters
  - in aggregations
  - stronger competition
  - less food and oxygen
  - more wastes



Mussel responses to alarm substances

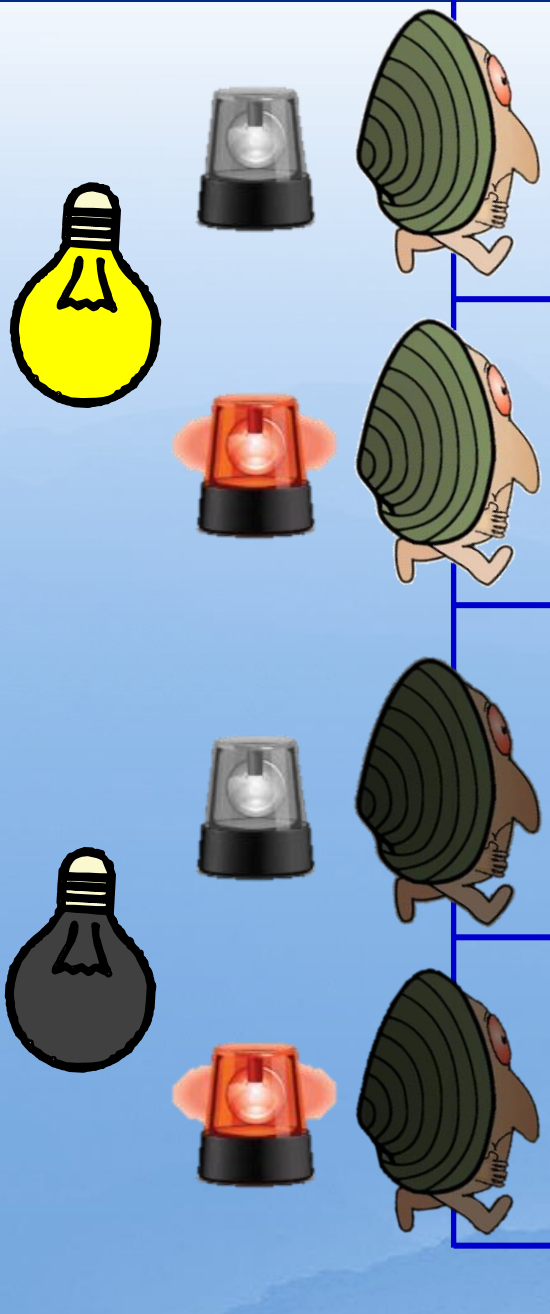


Conspecific alarm substances:

- reduce mussel activity
- including even attachment strength

- Czarnołęski M, Müller T, Adamus K, Ogorzelska G, Sog M 2010 Injured conspecifics alter mobility and byssus production in zebra mussels. Fundam Appl Limnol 176: 269-278
- Czarnołęski M, Müller T, Kierat J, Gryczkowski L, Chybowski Ł 2011 Anchor down or hunker down: an experimental study on zebra mussels' response to predation risk from crayfish. Anim Behav 82: 543-548
- Toomey MB, McCabe D, Marsden JE 2002 Factors affecting the movement of adult zebra mussels. J N Am Benthol Soc 21: 468-475

Horizontal movement



Alarm substance increased mussel movement in light...

...and reduced mussel movement in darkness

movement facilitates detection in darkness, in light a prey is visible anyway?

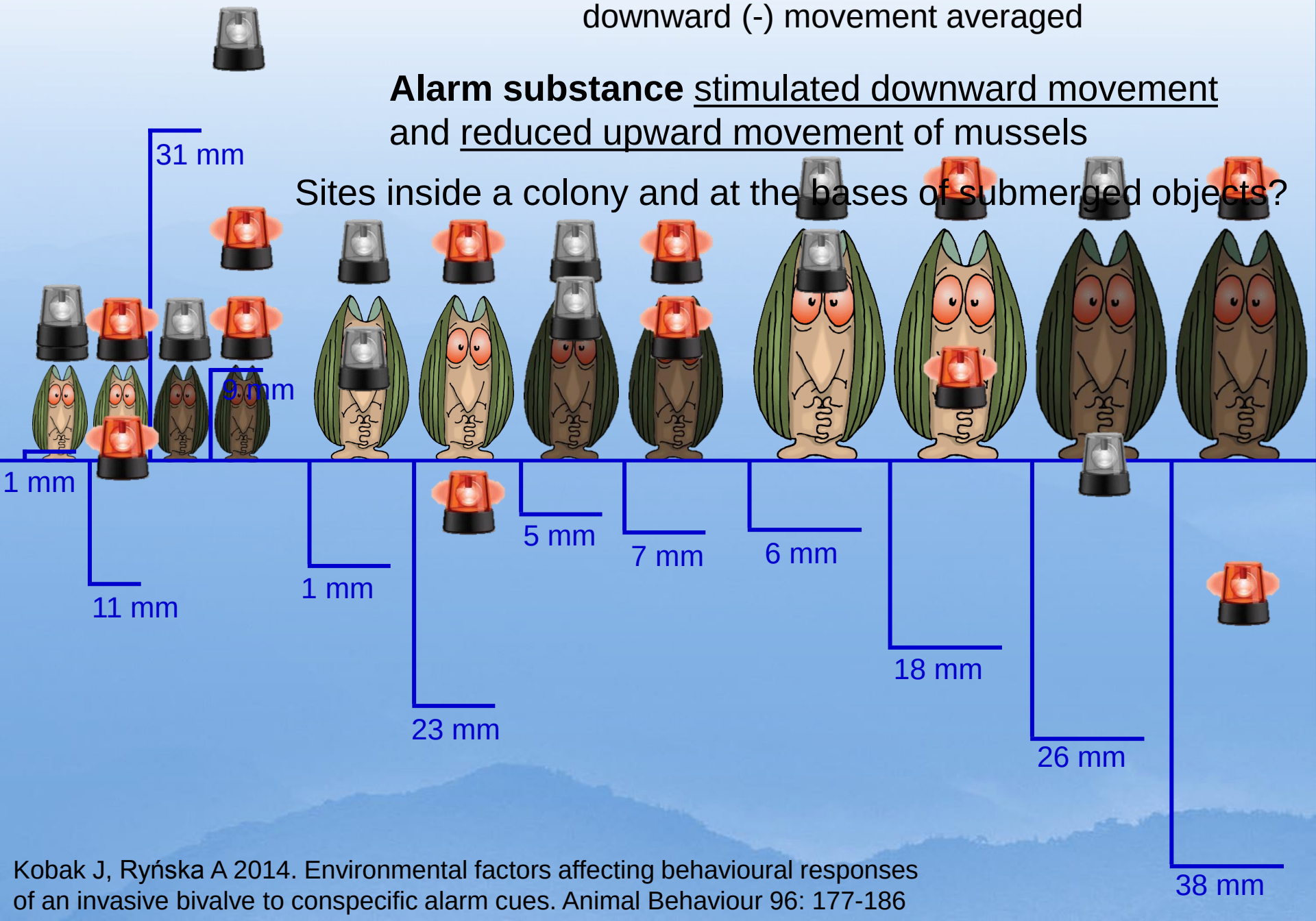
Kobak J, Ryńska A 2014. Environmental factors affecting behavioural responses of an invasive bivalve to conspecific alarm cues. Animal Behaviour 96: 177-186

Vertical movement

Net relocation: upward (+) and downward (-) movement averaged

Alarm substance stimulated downward movement and reduced upward movement of mussels

Sites inside a colony and at the bases of submerged objects?



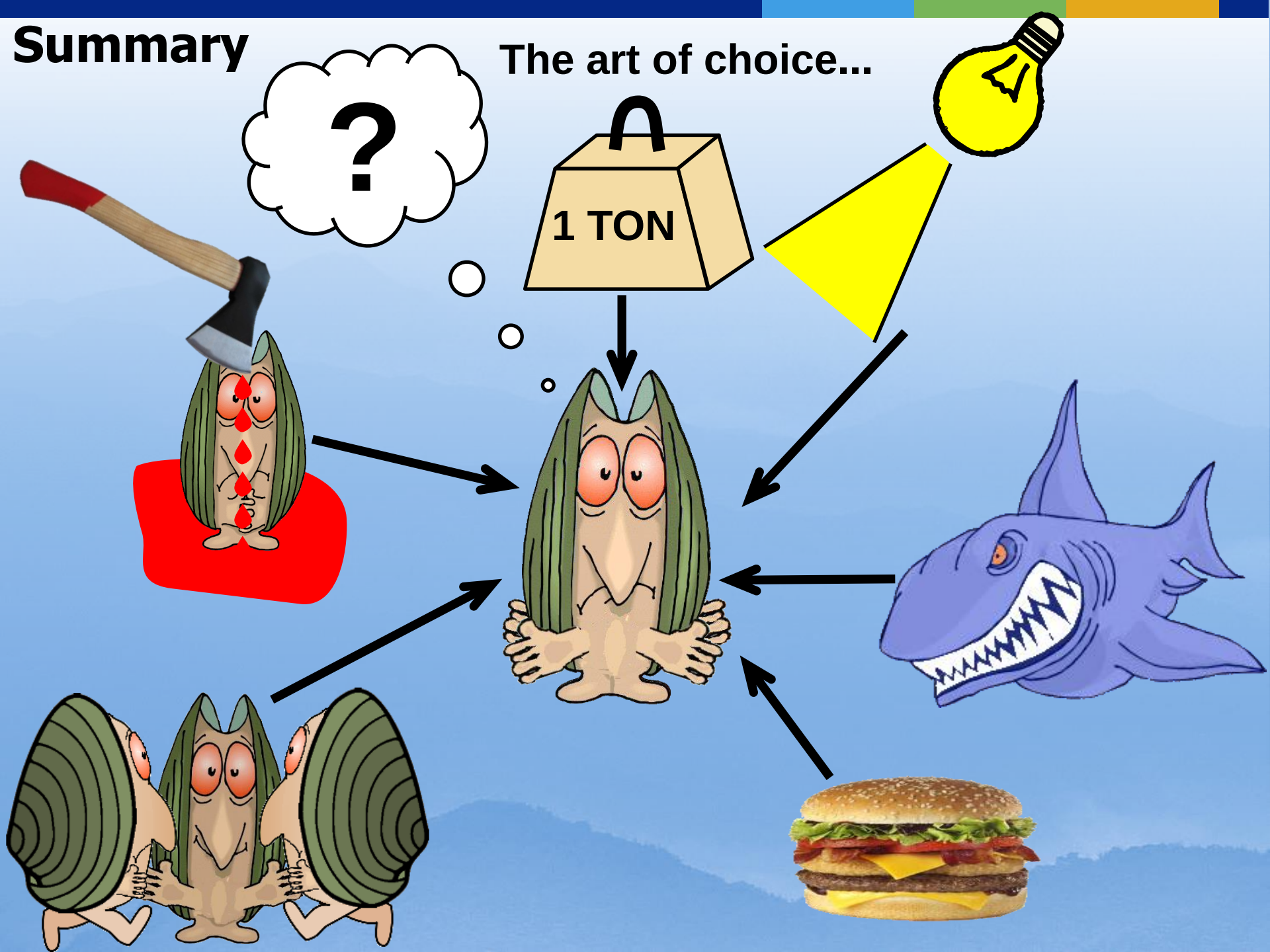
Kobak J, Ryńska A 2014. Environmental factors affecting behavioural responses of an invasive bivalve to conspecific alarm cues. Animal Behaviour 96: 177-186

Additional factors affect mussel responses to danger cues

- Light
- Size
- Substratum inclination

Kobak J, Ryńska A 2014. Environmental factors affecting behavioural responses of an invasive bivalve to conspecific alarm cues. Animal Behaviour 96: 177-186

Summary



Interactions between Ponto-Caspian gammarids and the zebra mussel *Dreissena polymorpha*

Dikerogammarus villosus
„the killer shrimp”

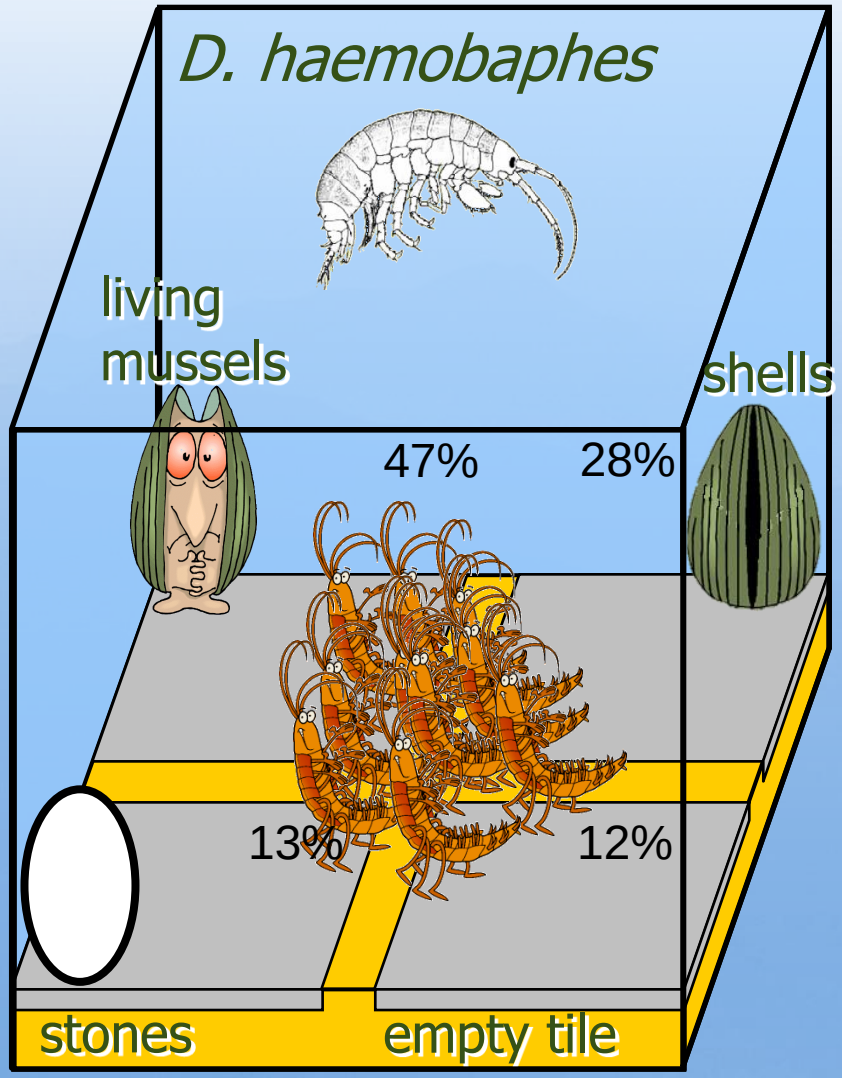
Dikerogammarus haemobaphes
„the demon shrimp”

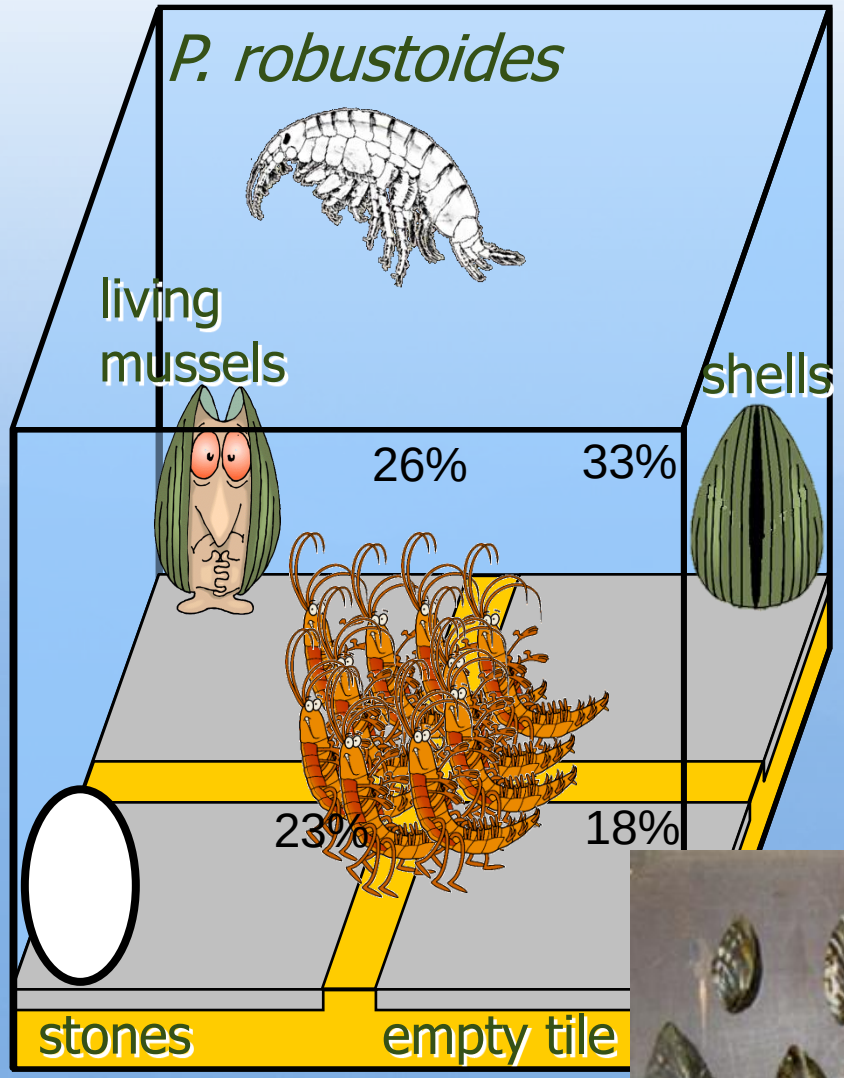
Pontogammarus robustoides

- Predatory, affect local communities, displace native species
- May use zebra mussels as habitats (shelters, food sources)

Do gammarids actively select mussel habitats?

Substratum selection by gammarids





1. Living mussels
2. Empty shells: the second choice

No preferences for mussel habitats

- Kobak J, Żytkowicz J 2007 Preferences of invasive Ponto-Caspian and native European gammarids for zebra mussel shell habitat. Hydrobiologia 589: 43-54

Substratum selection by gammarids

Biofilm removal

Periostracum removal

Surface modification

Gammarids respond to:

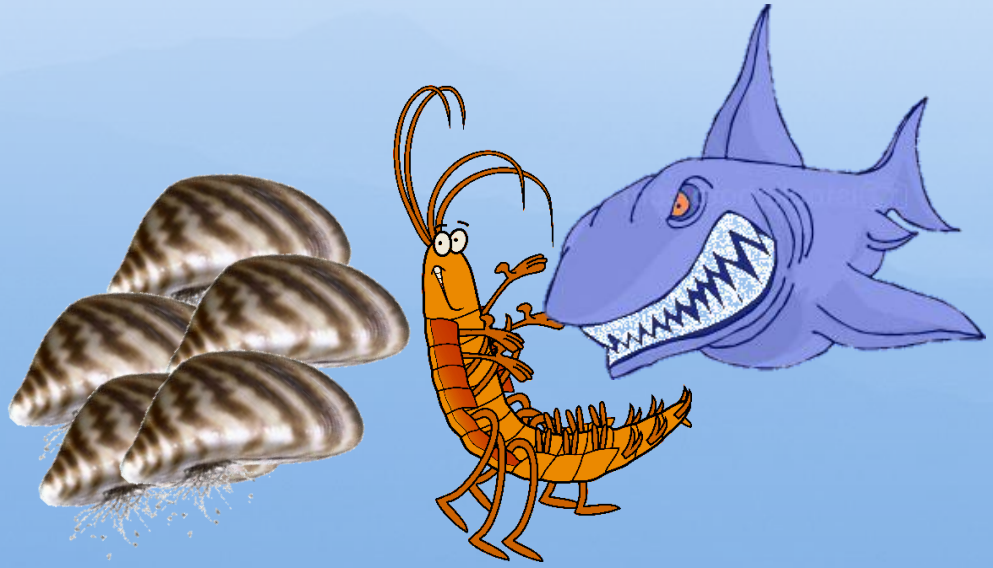
- mussel shape
- periostracum cue
- biofilm cue

They do not respond to:

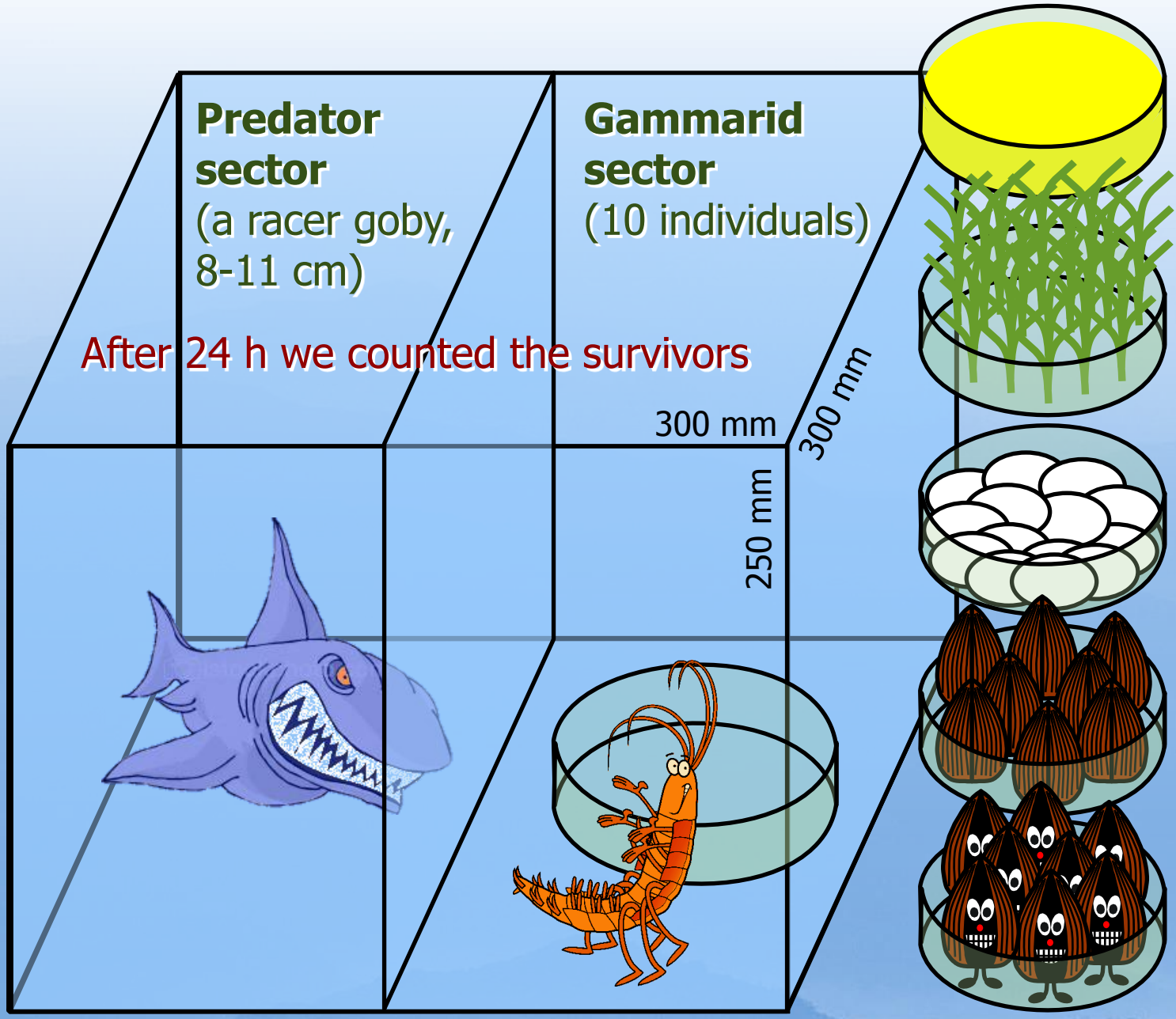
- mussel activity

- Kobak J, Żytkowicz J 2007 Preferences of invasive Ponto-Caspian and native European gammarids for zebra mussel shell habitat. Hydrobiologia 589: 43-54
- Kobak J, Kakareko T, Poznańska M, Żbikowski J 2009 Preferences of the Ponto-Caspian amphipod *D. haemobaphes* for living zebra mussels. Journal of Zoology 279: 229-235
- Kobak J, Kakareko T, Jermacz Ł, Poznańska M 2013 The impact of zebra mussel periostracum and biofilm cues on habitat selection by a Ponto-Caspian amphipod *D. haemobaphes*. Hydrobiologia 702: 215-226

Do gammarids use mussel colonies as anti-predator shelters?



racer goby
Babka gymnotrachelus
a Ponto-Caspian invasive predating on gammarids



Substrata:

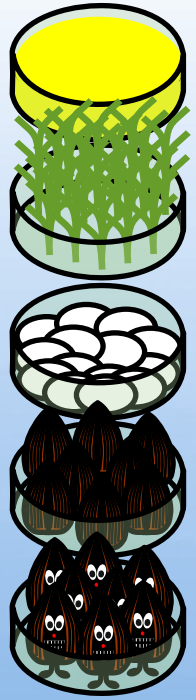
- sand
- plants (*Potamogeton perfoliatus*)
- stones
- empty mussel shells (single valves)
- living mussels

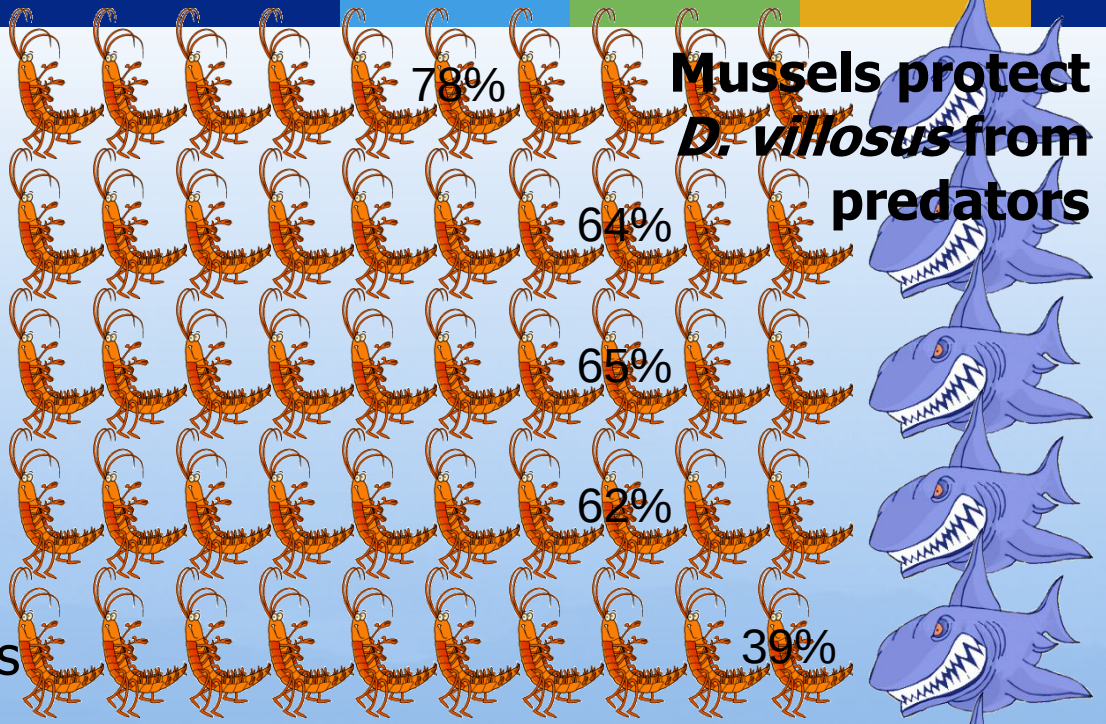
Kobak J, Jermacz Ł, Płąchocki D 2014. Effectiveness of zebra mussels to act as shelters from fish predators differs between native and invasive amphipod prey. Aquat Ecol 48: 397-408

Gammarid consumption

Dikerogammarus villosus

inhabitant of mussel colonies

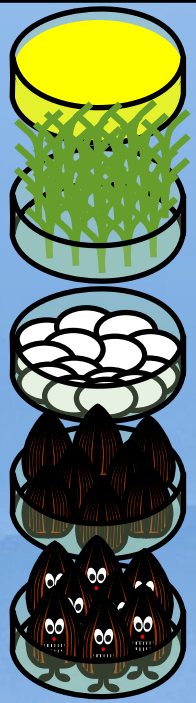


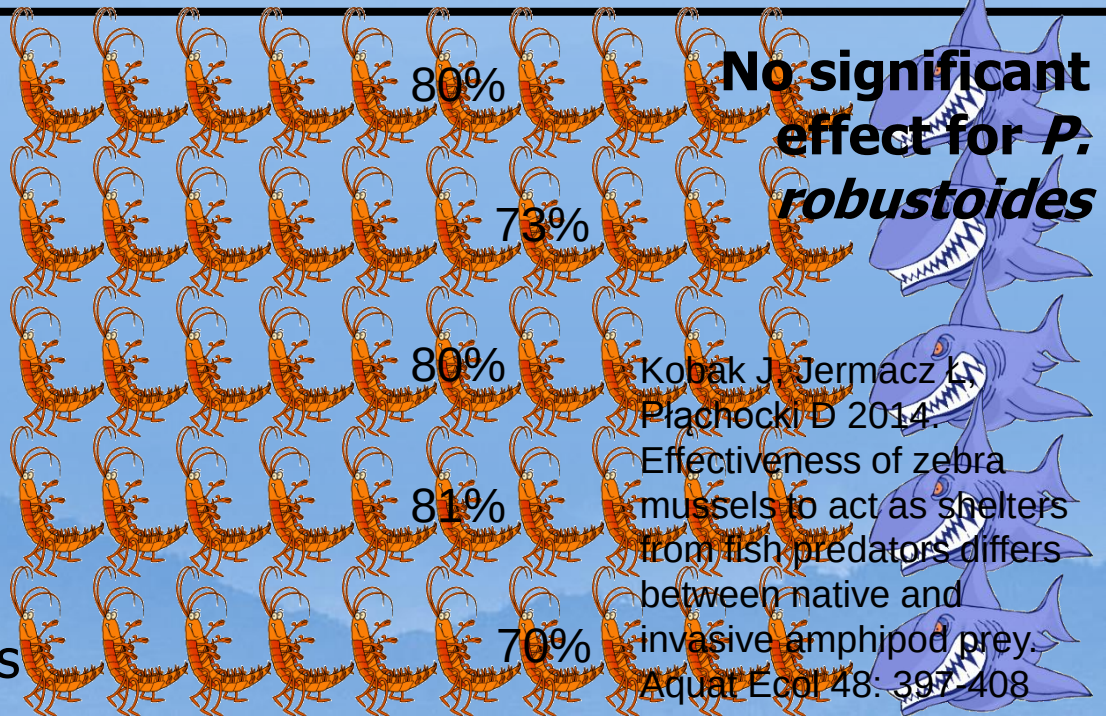


Mussels protect *D. villosus* from predators

Pontogammarus robustoides

not associated with mussels





No significant effect for *P. robustoides*

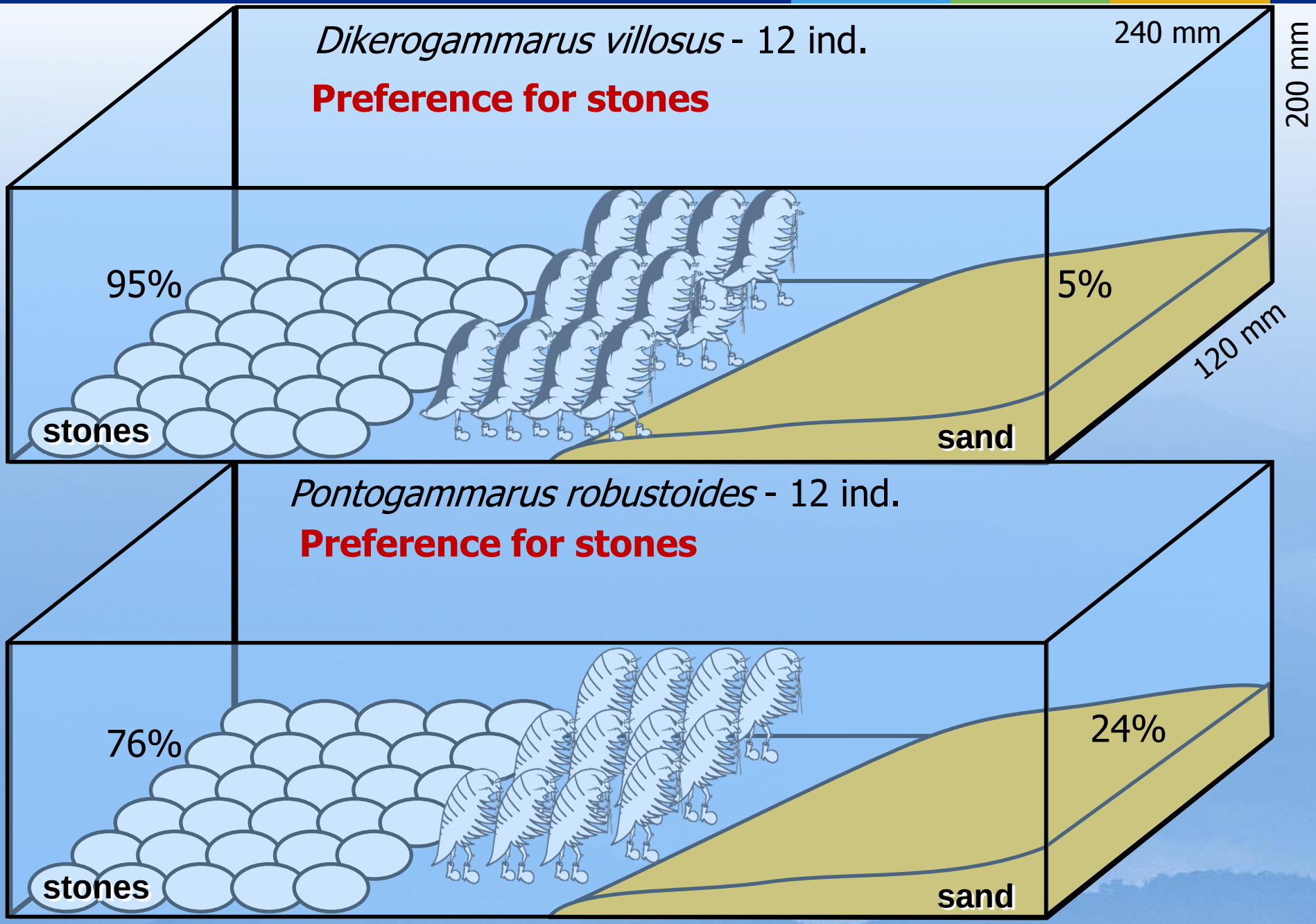
Kobak J, Jermacz Ł, Płachocki D 2014. Effectiveness of zebra mussels to act as shelters from fish predators differs between native and invasive amphipod prey. Aquat Ecol 48: 397-408

Interactions between Ponto-Caspian gammarid species and fish

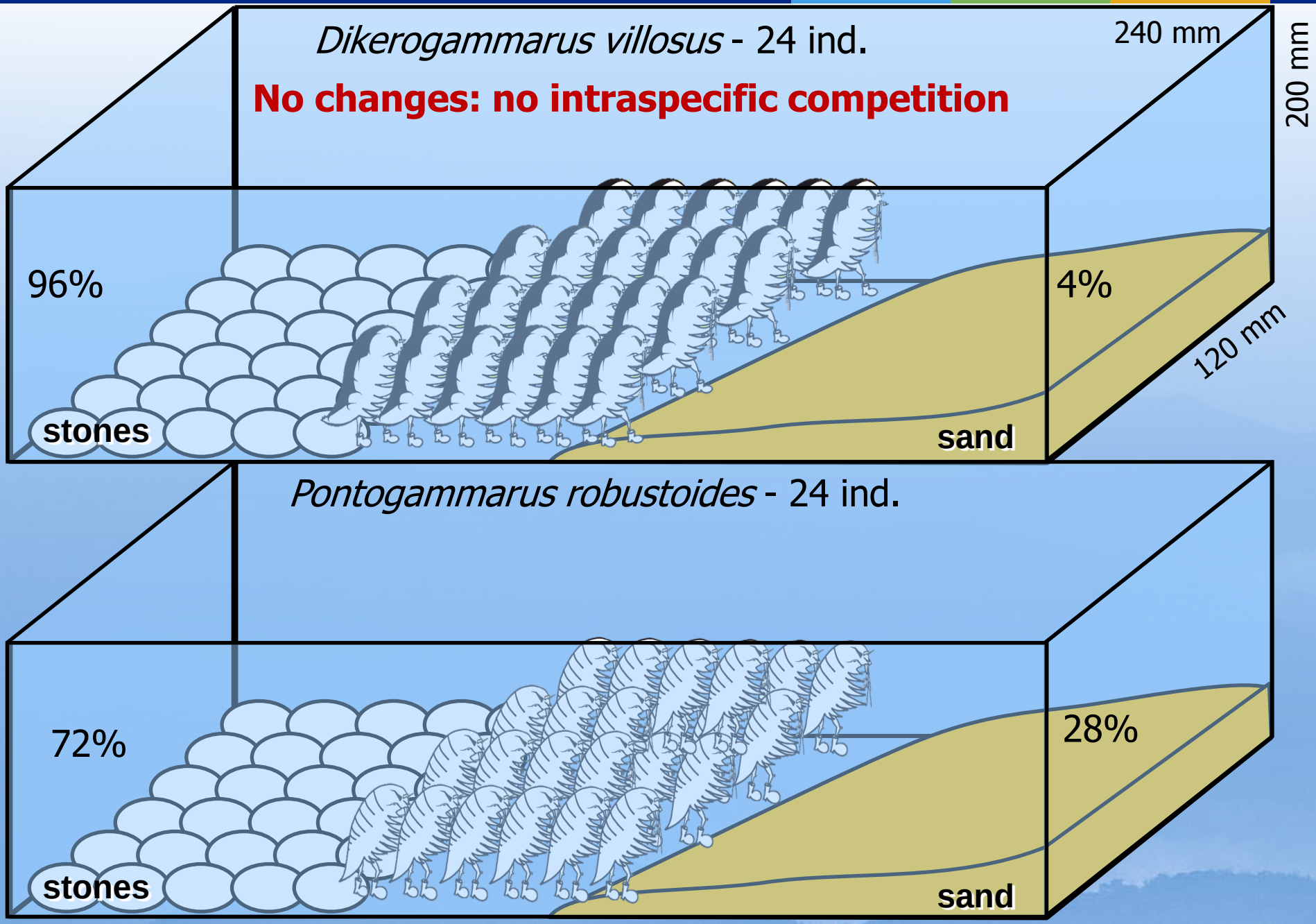
Pontogammarus robustoides

racer goby *Babka gymnotrachelus*

Dikerogammarus villosus „killer shrimp"



Jermacz Ł, Dzierżyńska A, Kakareko T, Poznańska M, Kobak J. submitted. Relation between interspecific competition and predation risk: invasive species' art of choice. Behavioral Ecology



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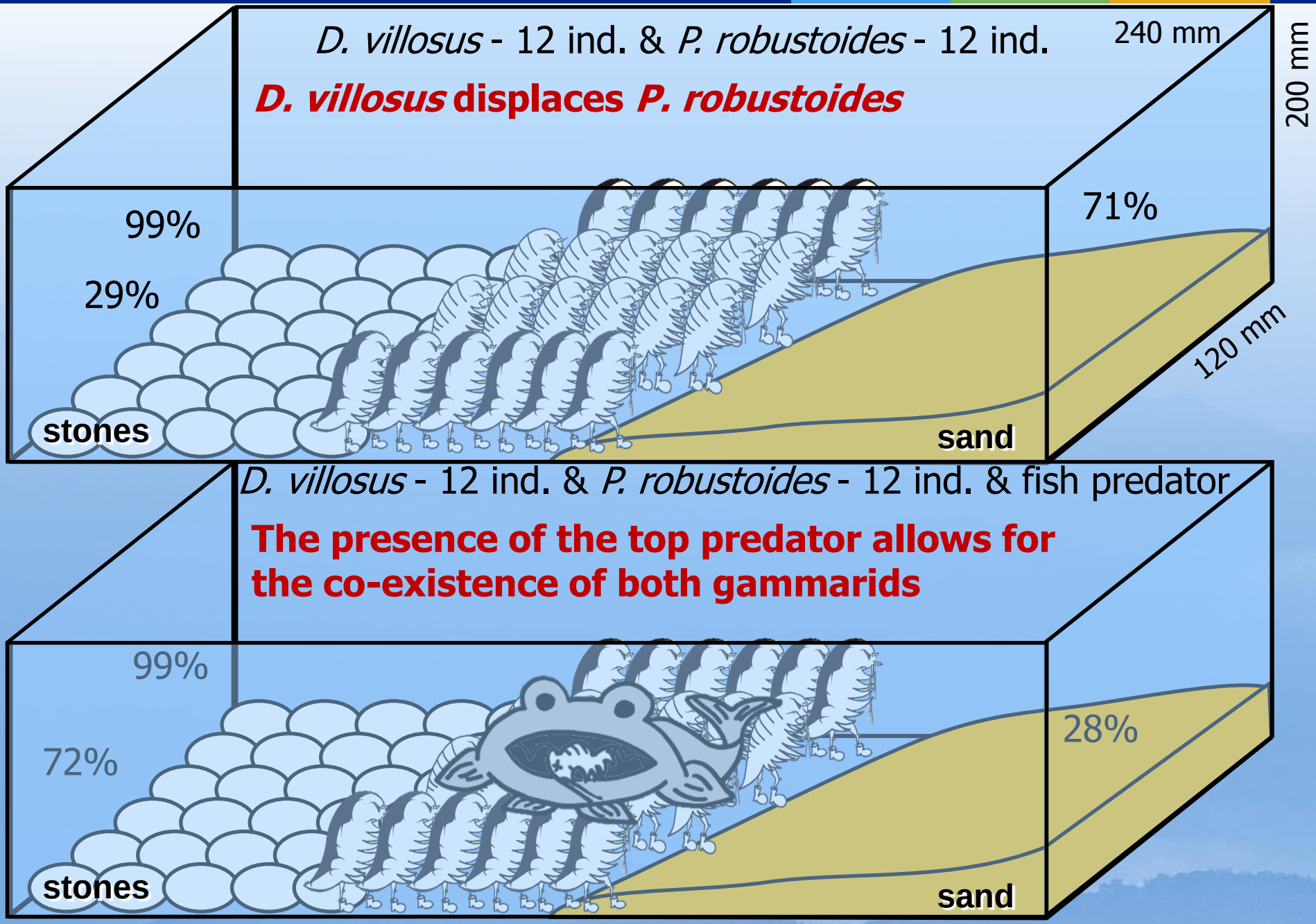
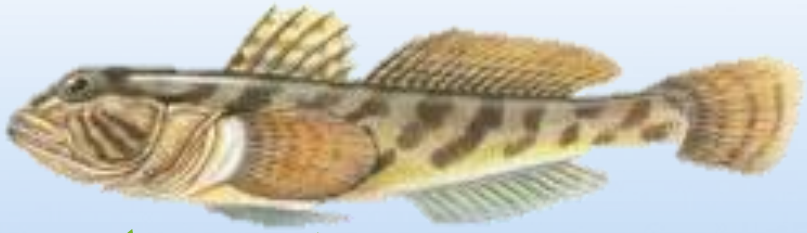


Jermacz Ł, Dzierżyńska A, Kakareko T, Poznańska M, Kobak J. submitted. Relation between interspecific competition and predation risk: invasive species' art of choice. Behavioral Ecology

Goby modify interactions between gammarids



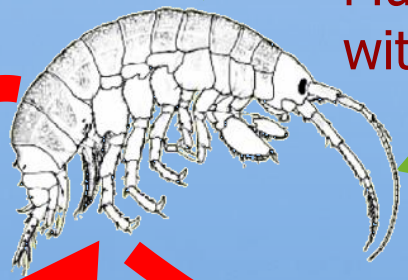
\+ −

− Goby predate on gammarids

\+

\+ Goby may find food in mussel colonies ?

Gammarids compete and displace each other



Mussels provide gammarids with anti-predator shelters

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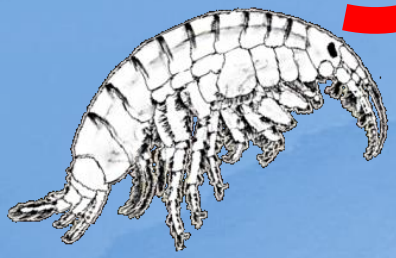

− Gammarids increase stress and induce defensive responses in mussels

Further topics

- Factors affecting valve movements and aggregation forming of zebra mussels
- Habitat selection by gammarids
- Anti-predator responses of gammarids
- Behavioural interactions among various gammarid species

Noldus Ethovision software

Thank you very much for your attention