ZEBRA MUSSELS IN LAKES: IS THERE ANY HOPE TO CONTROL THEM IN AN ENVIRONMENTALLY SAFE WAY?

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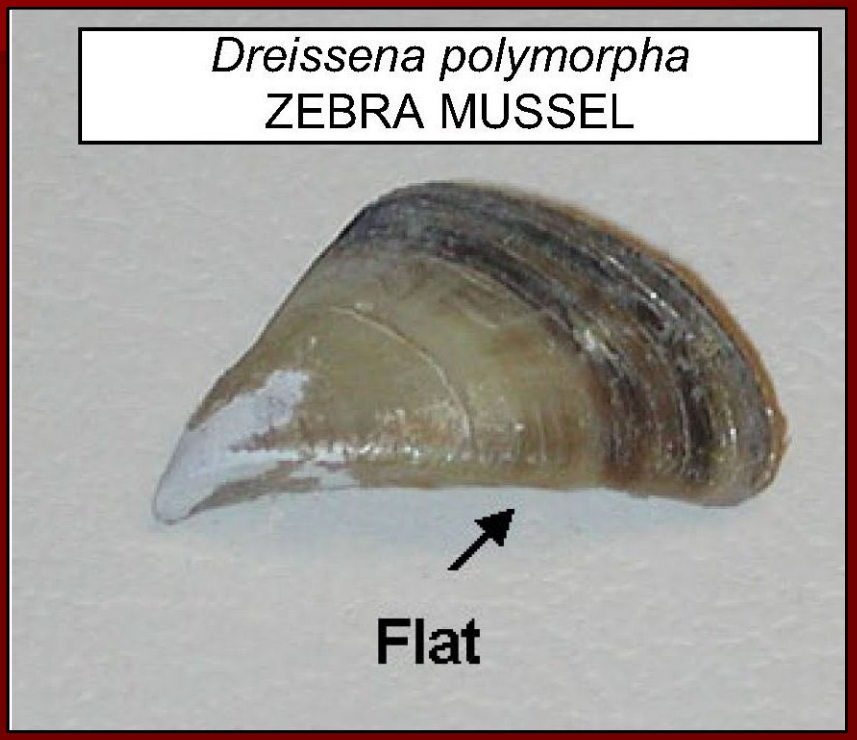
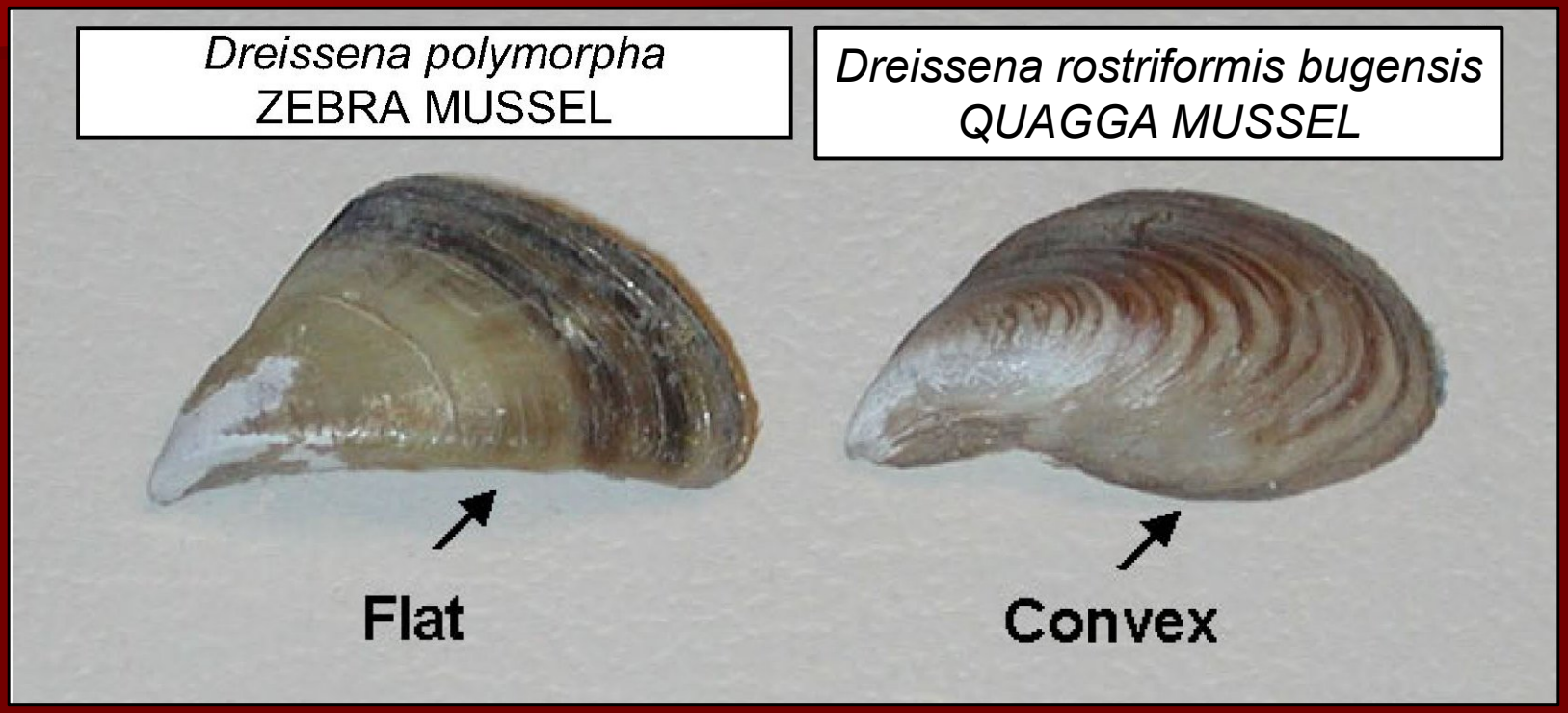
Project Funding Acknowledgement



They are fingernail in size

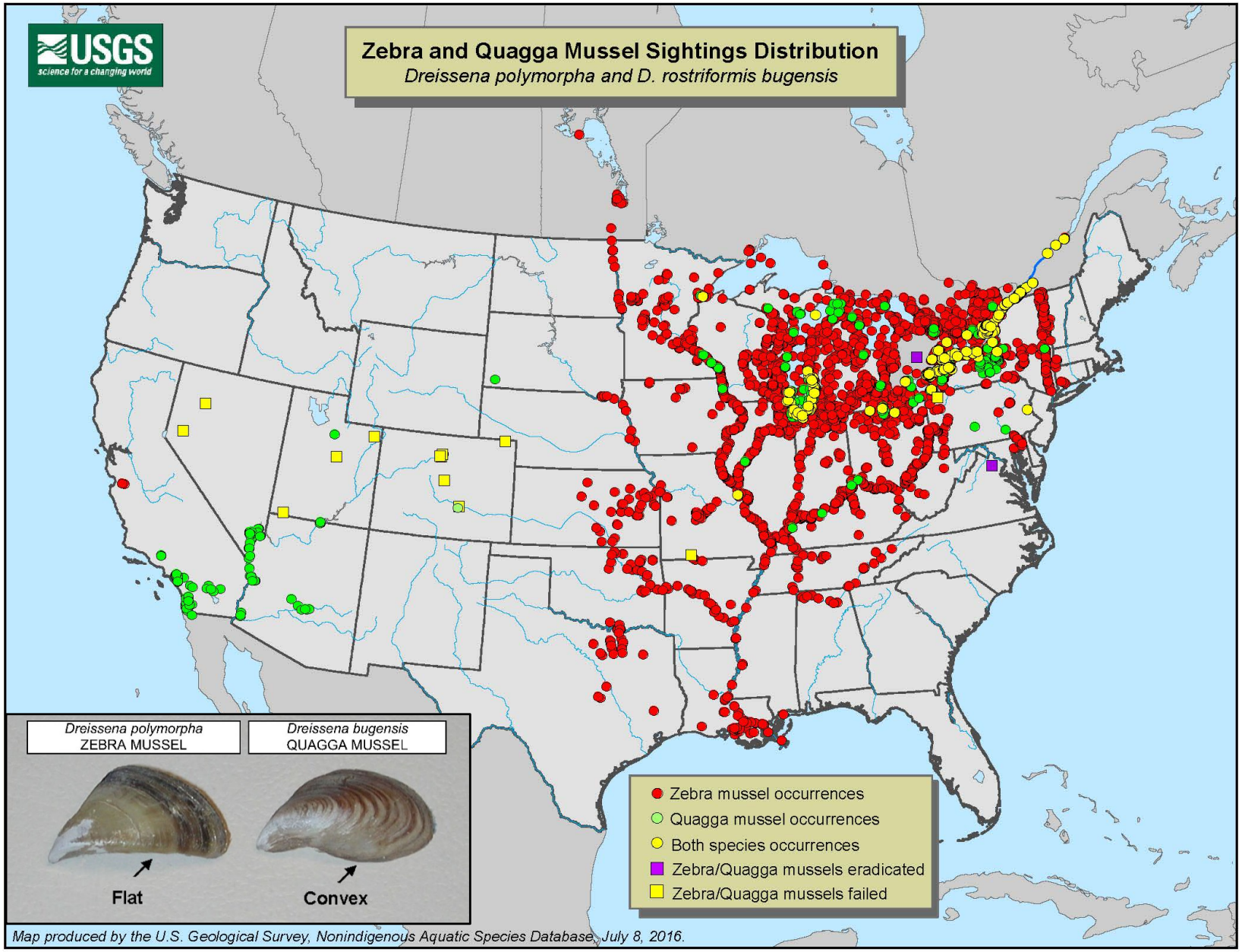
Zebra mussels are the poster child of high-impact aquatic invasive species



There are actually two *Dreissena* species in North America….
the zebra mussel and the quagga mussel

Both arrived in North America in mid-1980s in Great Lakes

…and they have spread coast to coast during the last 3 decades



They are the only freshwater mussels now in North America with byssal threads enabling them to attach to any underwater hard surface

Attaching to surfaces such as……

What are the negative impacts of these invasive mussels?

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Basically there are three….

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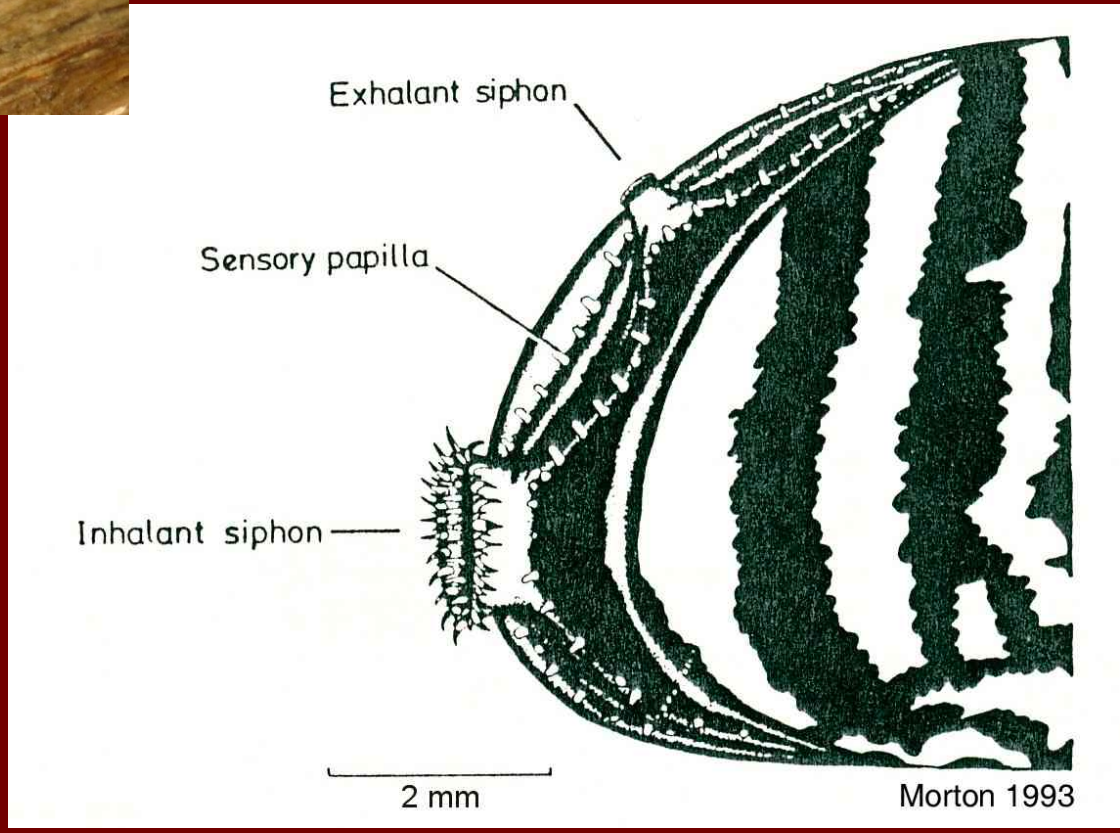
Basically there are three….

1. Ecological Impacts

2. Recreational Impacts

3. Industrial Impacts

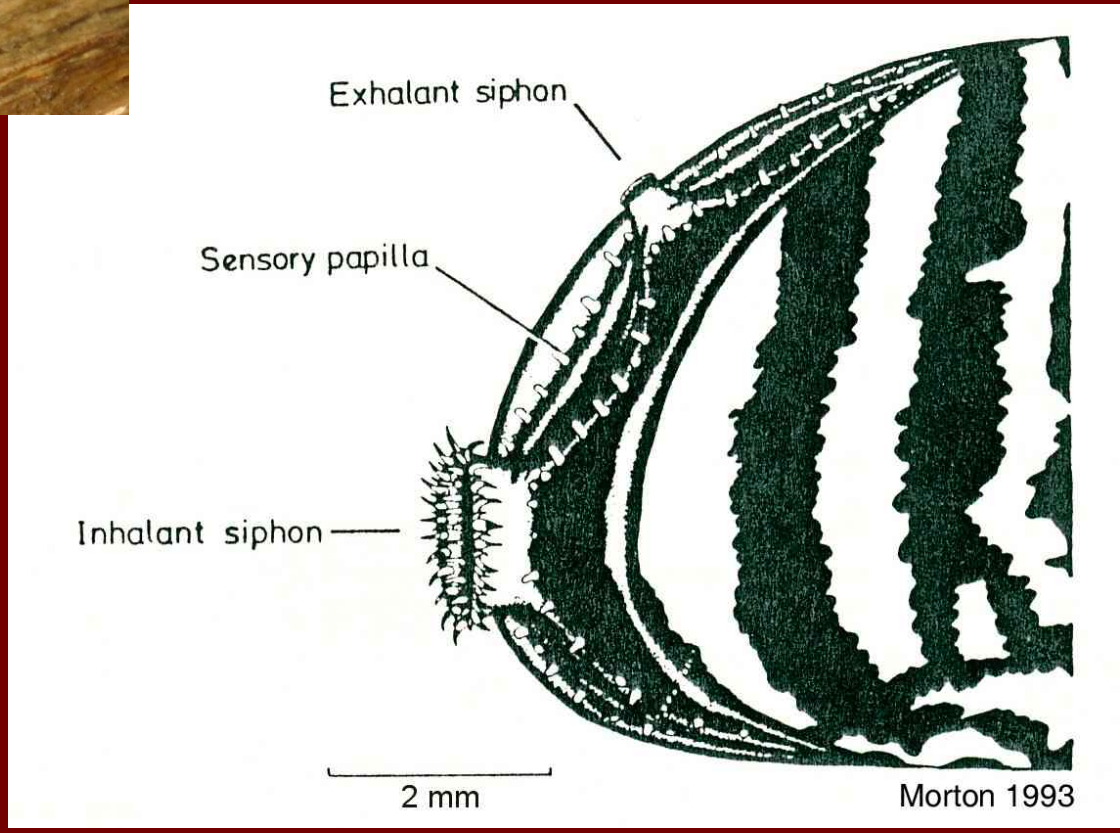
Ecological Impacts



Ecological Impacts

Each large mussel can filter 1 liter of water per day

So… millions of filtering mussels in a water body do clear the water

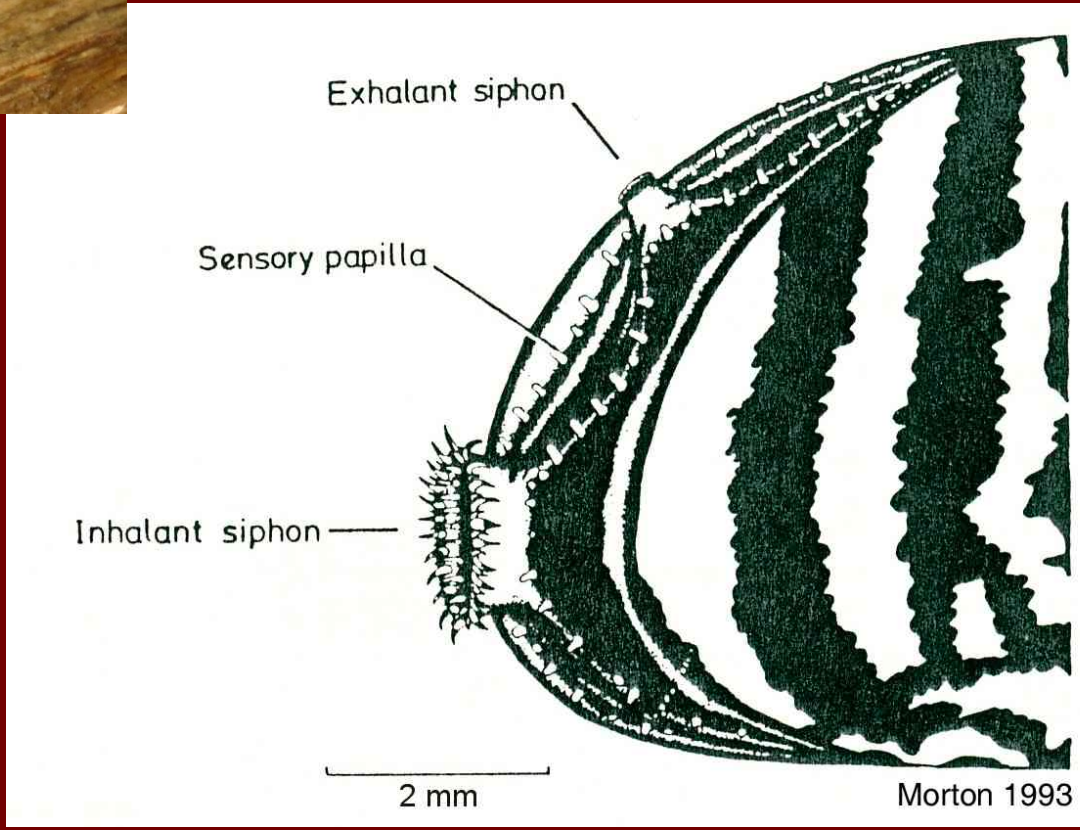


Ecological Impacts

Each large mussel can filter 1 liter of water per day

So… millions of filtering mussels in a water body do clear the water

So, yes, the water gets clearer, but that can have serious ecological consequences such as changes in fish populations & more weeds growing from the bottom



…. and also their infestations kill our native unionid clams

…but why no zebra mussels here?

In these photos, zebra mussels were only able to attach to the tops of these native clams since these clams live in mud…

…but even such a limited clump of zebra mussels can kill a clam within one year

Recreational Impacts

Fouling of recreation equipment…. boats, docks, boat lifts, etc.

Some recreational water bodies are completely closed off to the public for fear of the mussels spreading to other water bodies

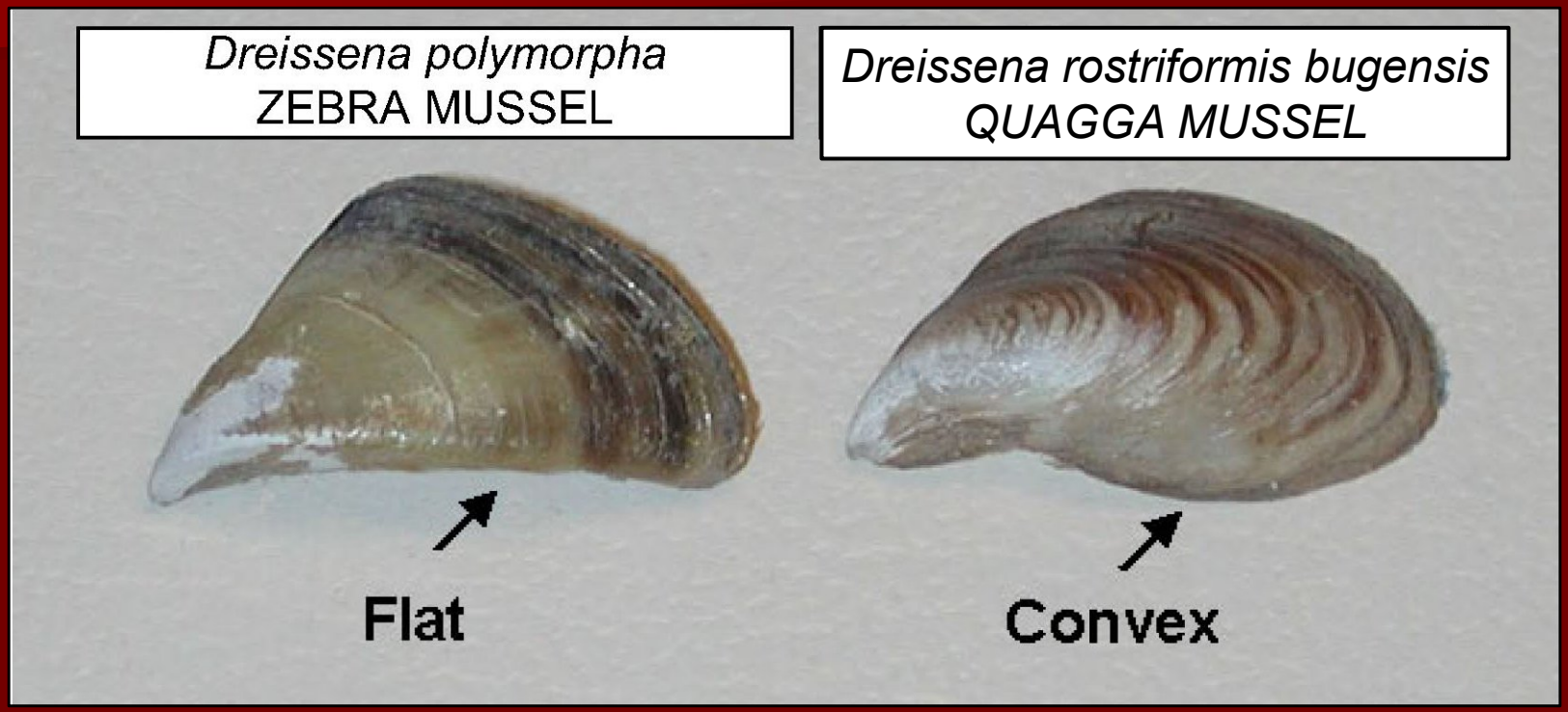
San Justo Reservoir (California) has been closed since 2008

Industrial Impacts

Harsh chemicals put into the pipes do clean out the zebra mussels, but then the chemicals are discharged back out into the water body where they represent a pollution threat

….and now the topic of this presentation…..

How to control them throughout entire lakes *!!*



….and I will now be discussing my lab's research on an "outside the box" approach for controlling them lake-wide

We envision a control approach that will work not only in small lakes…..

….but also even throughout the Great Lakes *!!*

….but also even throughout the Great Lakes *!!*

Yes, if our research is successful, its impact could be that huge

Did you ever wonder …

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“Why aren’t lake associations across North America treating their lakes for Dreissena mussel control ?”

Did you ever wonder …

“Why aren’t lake associations across North America treating their lakes for Dreissena mussel control ?”

Here’s why…..

Treating an entire large water body is currently:

- Too expensive

and/or

- Too environmentally degrading

Currently available control agents lack target specificity and kill far more than just the zebra or quagga mussels

To be economically feasible a control agent ideally must be:

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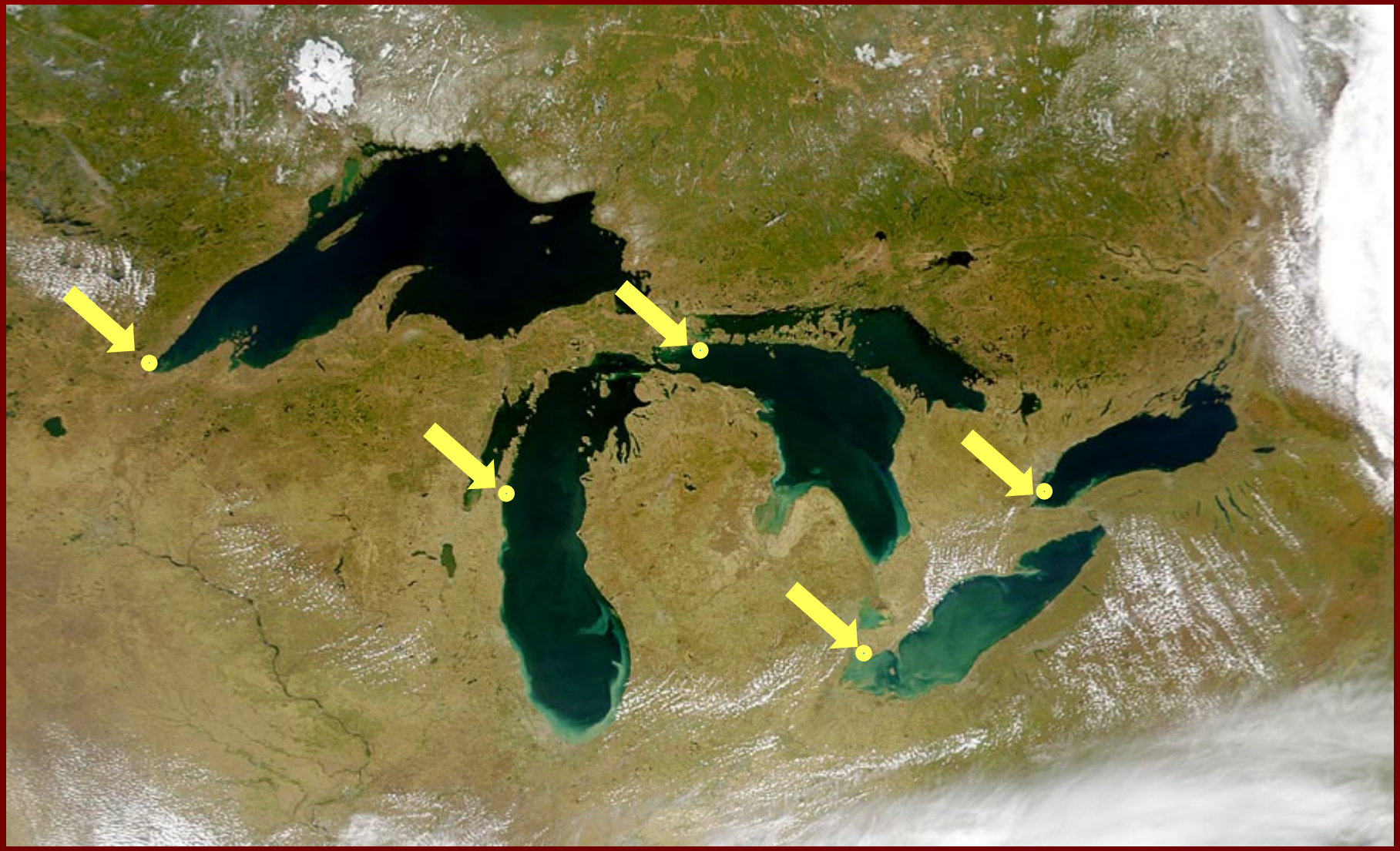
-- applied only in a small part of the water body

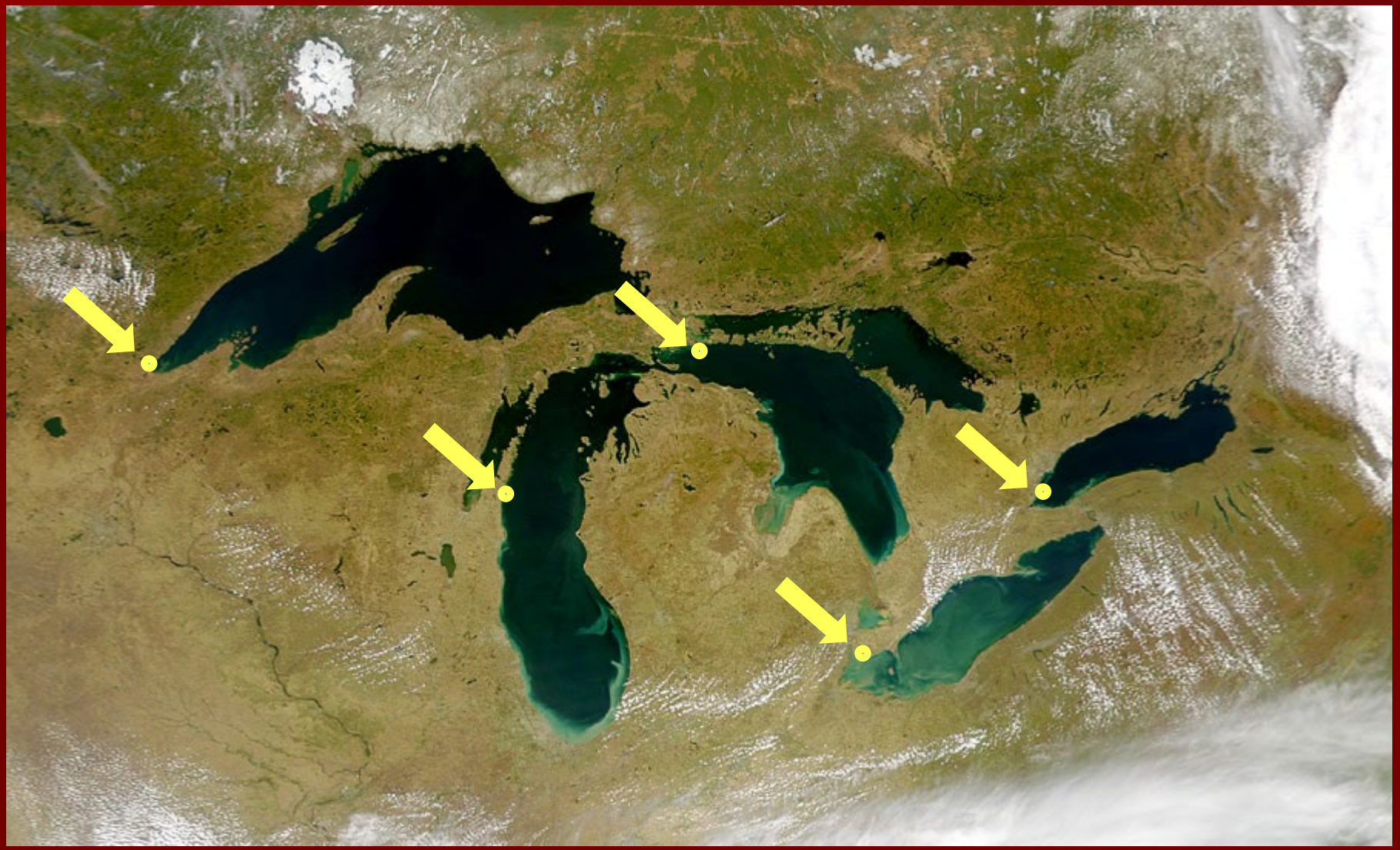


Our control agent will be applied to only a **small** part of a (not the entire) water body, resulting in significant savings

To be economically feasible a control agent ideally must be:

-- applied only in a small part of the water body

-- self-perpetuating



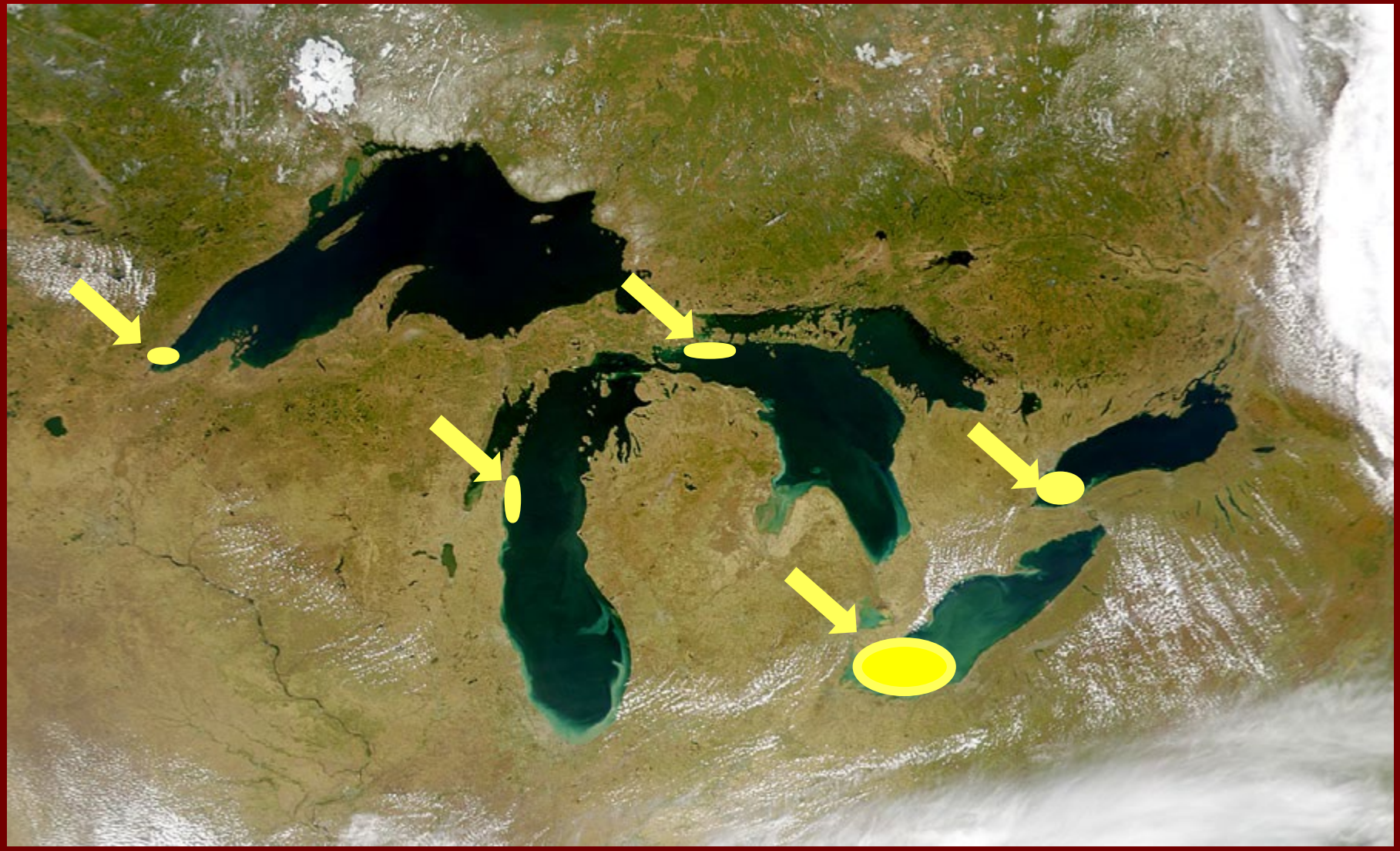
Our control agent will be **self-perpetuating** -- killing mussels from year to year and not requiring reapplications, resulting in significant savings

To be economically feasible a control agent ideally must be:

-- applied only in a **small part of the water body**

-- **self-perpetuating**

-- self-spreading



Our control agent will be **self-spreading** -- killing mussels elsewhere throughout the lake on its own, resulting in significant savings

To be economically feasible a control agent ideally must be:

-- applied only in a small part of the water body

-- self-perpetuating

-- self-spreading

Our control agent will be **LIVE** – the only kind of control agent capable of self-perpetuating and self-spreading

To be economically feasible a control agent ideally must be:
-- applied only in a small part of the water body
-- self-perpetuating
-- self-spreading

Our control agent will be **LIVE** – the only kind of control agent capable of self-perpetuating and self-spreading

Since it's **LIVE**, it's a **BIOCONTROL** agent…
……but what kind of biocontrol agent…???

The biocontrol agent will be a **PARASITE**

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…. because among all types of natural enemies,

parasites are the most host-specific killing agents

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…. because among all types of natural enemies,

parasites are the most host-specific killing agents

…. and HOST-SPECIFICITY is the MOST IMPORTANT

characteristic of any candidate biocontrol agent

This project is an extremely ambitious one

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This project is an extremely challenging one

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But I am confident there is a parasite already existing in nature that could be this future biocontrol agent

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This project is an extremely challenging one

But I am confident there is a parasite already existing in nature that could be this future biocontrol agent

But will we be able to find it?

That is our greatest challenge *!*

So where have we concentrated on looking to find this parasite…. this potentially extraordinary control agent?


Area in past that we have focused on looking for parasites in the same two *Dreissena* spp. as we have in North America:
- *D. polymorpha* (zebra)
- *D. rostriformis* (quagga)
Oslo
Stockholm
Helsinki
St Petersburg
Санкт-Петербург
Tallinn
Estonia
Riga
Latvia
Lithuania
Vilnius
Minsk
Минск
Belarus
Moscow
Москва
Edinburgh
United Kingdom
Isle of Man
Dublin
Ireland
Manchester
Liverpool
London
Denmark
Hamburg
Amsterdam
Netherlands
Berlin
Poland
Warsaw
Brussels
Cologne
Germany
Belgium
Frankfurt
Luxembourg
Prague
Czech Republic
Paris
Munich
Vienna
Slovakia
Austria
Budapest
Hungary
Switzerland
France
Milan
Slovenia
Zagreb
Croatia
Bosnia and Herzegovina
Sarajevo
Serbia
Belgrade
Београд
Romania
Bucharest
Moldova
Chisinau
Odessa
Одеса
Ukraine
Kiev
Київ
Kharkiv
Харків
Rostov
Ростов
Krasnodar
Краснодар
Monaco
Italy
Rome
Andorra
Barcelona
Porto
Madrid
Portugal
Lisbon
Spain
Valencia
Seville
Granada
Málaga
Gibraltar
Algiers
مدينة الجزائر
Tunis
تونس
Malta
Tunisia
Tripoli
طرابلس
Rabat
الرباط
Casablanca
الدار البيضاء
Morocco
Sofia
София
Bulgaria
Kosovo
Podgorica
Macedonia (FYROM)
Tirana
Albania
Greece
Athens
Αθήνα
Istanbul
Bursa
Ankara
Izmir
Turkey
Antalya
Adana
Cyprus
Syria
Lebanon
Beirut
Damascus
دمشق
Iraq
Baghdad
بغداد
Jordan
Alexandria
Jerusalem
Black Sea
Mediterranean Sea
Tyrrhenian Sea
Caspian Sea
Georgia
Tbilisi
Armenia
Azerbaijan
Baku
Makhachkala
Махачкала
Turkmenistan
Ashgabat
Uzbekistan
Shymkent
Tashkent
Dushanbe
Душанбе
Tajikistan
Tehran
تهران
Afghanistan
Kabul
کابل
Iran

… and we have found a variety of VERY HOST-SPECIFIC parasites in zebra and quagga populations…

… and we have found a variety of VERY HOST-SPECIFIC parasites in zebra and quagga populations… <u>but unfortunately none that are lethal (virulent) enough to be considered useful as a biocontrol agent</u>

… but in a way, this is not surprising. For example, the host-specific parasites we observed in *D. polymorpha* are likely to have been infecting them for millions of years, and such co-evolved parasites are typically not very virulent/lethal to their hosts – exactly what we found.


So here's the area we have now switched to… in our search for parasites……
An area where "cousins" of zebra and quagga mussels (other *Dreissena* species) live…
Oslo
Stockholm
Edinburgh
United Kingdom
Ireland
Denmark
Poland
Hamburg
Berlin
Amsterdam
Netherlands
London
Germany
Brussels
Belgium
Cologne
Frankfurt
Prague
Czech Republic
Paris
France
Switzerland
Munich
Vienna
Slovakia
Austria
Budapest
Hungary
Milan
Slovenia
Zagreb
Croatia
Belgrade
Bosnia and Herzegovina
Serbia
Sarajevo
Monaco
Italy
Rome
Andorra
Barcelona
Madrid
Spain
Portugal
Lisbon
Porto
Valencia
Seville
Granada
Málaga
Gibraltar
Algiers
Tunis
Malta
Tunisia
Rabat
Casablanca
Morocco
Tripoli
Mediterranean Sea
Tyrrhenian Sea
Ukraine
Moldova
Chisinau
Odessa
Romania
Bucharest
Sofia
Bulgaria
Kosovo
Macedonia (FYROM)
Albania
Greece
Athens
Izmir
Turkey
Istanbul
Bursa
Ankara
Antalya
Adana
Cyprus
Syria
Lebanon
Beirut
Damascus
Iraq
Baghdad
Jordan
Alexandria
Jerusalem
Iran
Afghanistan
Kazakhstan
Rostov-on-Don
Krasnodar
Georgia
Tbilisi
Armenia
Azerbaijan
Baku
Turkmenistan
Ashgabat
Uzbekistan
Tehran
Black Sea
Caspian Sea

… but why does looking at the parasites of "cousin" *Dreissena* species make sense?

Why might a parasite of a closely-related “cousin” species……

… be the ideal parasite we’re looking for to control zebra and quagga mussels?

… because a parasite of a “cousin” species might be so “NOVEL” …

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……and zebra and quagga mussels might be so “NAÏVE” to it…

… because a parasite of a “cousin” species might be so “NOVEL” …

……and zebra and quagga mussels might be so “NAÏVE” to it…

… that they can’t fight off the parasite and it kills them

“Sorry, but getting killed by a parasite of a “cousin” species sounds hard to believe !!”

“Does this ever happen in nature?”

“Sorry, but getting killed by a parasite of a “cousin” species sounds hard to believe !!”

“Does this ever happen in nature?”

Yes, all the time *!!*

….and here are some examples of

“NOVEL” parasites killing off

“NAÏVE” species

What happened to American chestnut trees?

What happened to American chestnut trees?

A fungus from an Asian “cousin” chestnut tree eliminated this tree species from North America

What happened to elm trees?

What happened to elm trees?

A fungus from an Asian “cousin” elm tree has devastated North American elm populations

What happened to eastern oysters?

Up until the 1950s, eastern oyster populations were abundant and the industry thrived

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Until a parasite killed 95% of these oysters

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Until a parasite killed 95% of these oysters
…and guess what?

Up until the 1950s, eastern oyster populations were abundant and the industry thrived

Until a parasite killed 95% of these oysters
…and guess what?

That killer parasite was from a “cousin” species, the Pacific oyster *!!*

So that's a few examples of "novel" parasites from "cousins" killing off "naïve" species

…and there are many other such "bad news" examples as those I've given you *!*

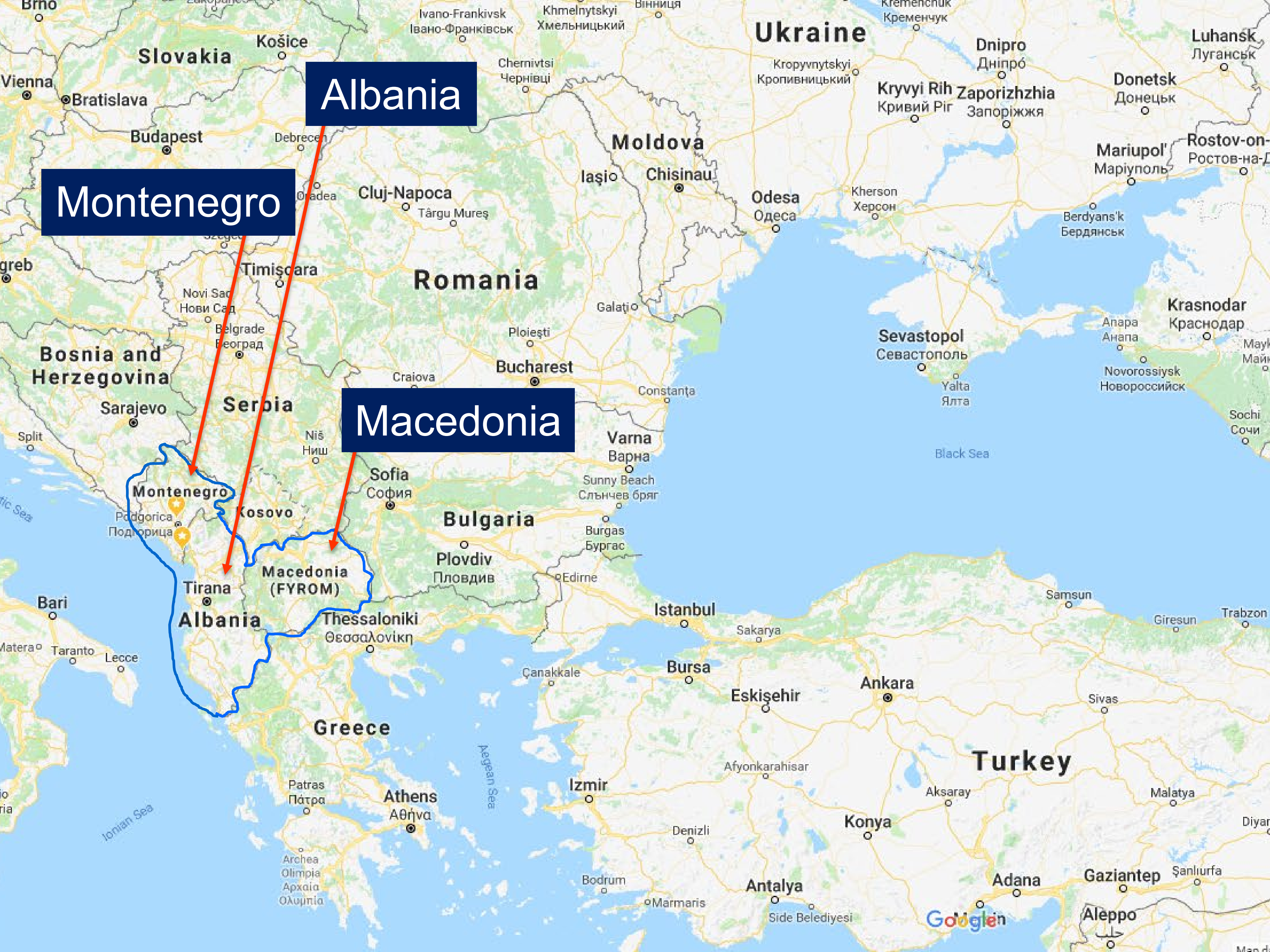
But what if we took advantage of this novel-naïve phenomenon and used it to our advantage?

But what if we took advantage of this novel-naïve phenomenon and used it to our advantage?

What if we used it to control zebra and quagga mussels *!*


So here again is the area we have now switched to… in our search for parasites……
An area where “cousin” *Dreissena* species live…
Oslo
Stockholm
Edinburgh
United Kingdom
Isle of Man
Dublin
Ireland
Manchester
Liverpool
London
North Sea
Denmark
Hamburg
Berlin
Poland
Amsterdam
Netherlands
Brussels
Belgium
Cologne
Germany
Frankfurt
Luxembourg
Paris
Prague
Czech Republic
Munich
Vienna
Slovakia
Austria
Budapest
Hungary
Switzerland
France
Milan
Slovenia
Zagreb
Croatia
Bosnia and Herzegovina
Serbia
Sarajevo
Belgrade
Romania
Bucharest
Ukraine
Moldova
Chisinau
Odessa
Одеса
Волгоград
Rostov-on-Don
Ростов-на-Дону
Kazakhstan
Krasnodar
Краснодар
Black Sea
Makhachkala
Махачкала
Georgia
Tbilisi
Caspian Sea
Uzbekistan
Shymkent
Шымкент
Tashke
Monaco
Italy
Rome
Andorra
Barcelona
Porto
Madrid
Portugal
Lisbon
Spain
Valencia
Seville
Granada
Málaga
Gibraltar
Algiers
Tunis
Malta
Tyrrhenian Sea
Bay of Biscay
Sofia
София
Bulgaria
Kosovo
Macedonia (FYROM)
Tirana
Albania
Greece
Athens
Αθήνα
Izmir
Istanbul
Bursa
Ankara
Turkey
Armenia
Azerbaijan
Baku
Turkmenistan
Ashgabat
Dushanbe
Душанбе
Tajiki
Antalya
Adana
Tehran
تهران
Cyprus
Syria
Lebanon
Beirut
Damascus
دمشق
Baghdad
بغداد
Iraq
Afghanistan
Kabul
کابل
Iran
Jordan
Jerusalem
Alexandria
الإسكندرية
Mediterranean Sea
Tripoli
طرابلس
Tunisia
Rabat
الرباط
Casablanca
الدار البيضاء
Morocco

… and in 2019 we concentrated on examining “cousin” species in the <u>Balkans and Turkey</u>

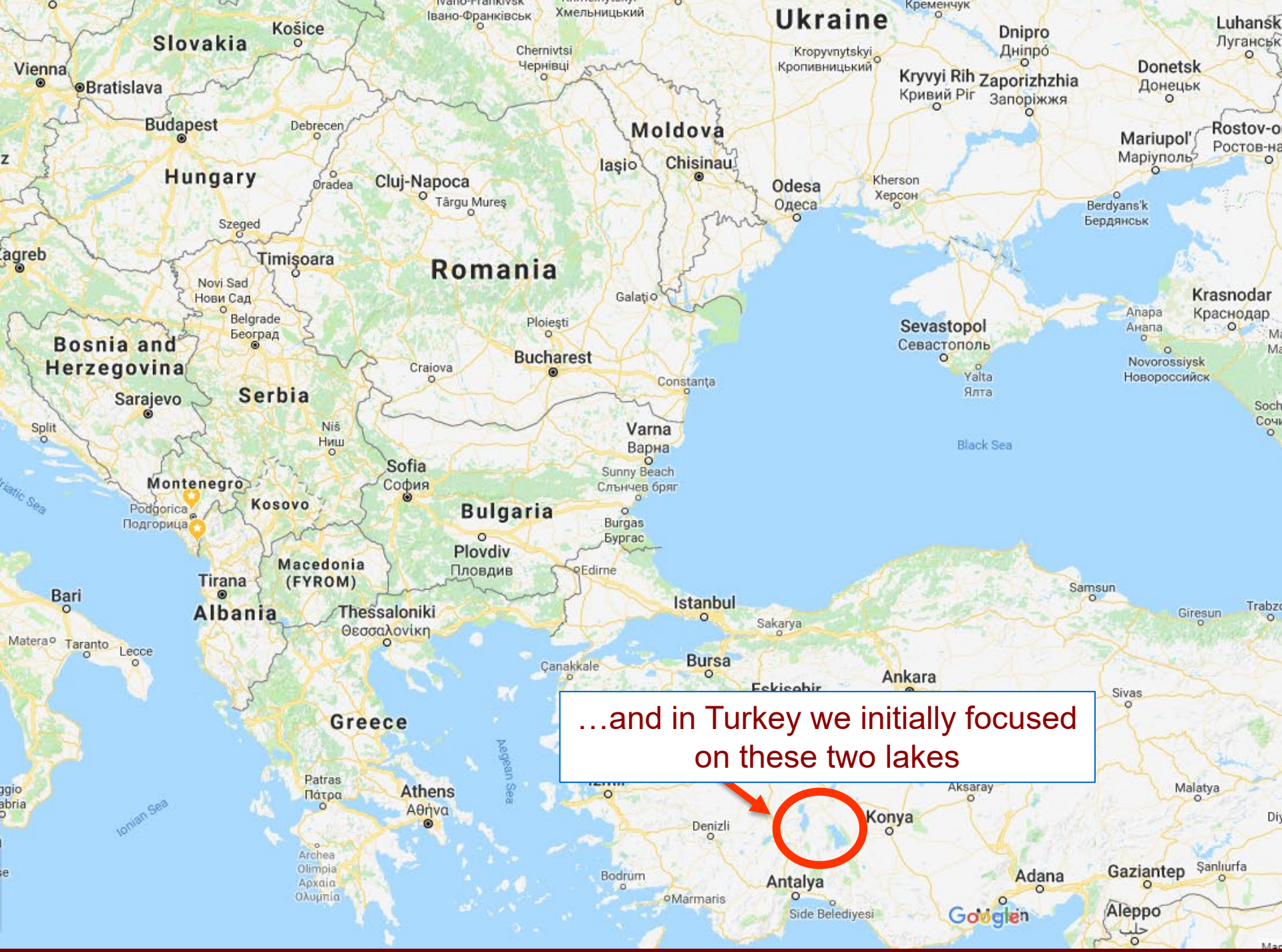

Albania
Montenegro
Macedonia
Ukraine
Slovakia
Romania
Moldova
Bosnia and Herzegovina
Serbia
Kosovo
Montenegro
Albania
Macedonia (FYROM)
Bulgaria
Greece
Turkey
Black Sea
Budapest
Bratislava
Vienna
Košice
Debrecen
Oradea
Cluj-Napoca
Târgu Mureș
Timișoara
Novi Sad
Belgrade
Sarajevo
Split
Podgorica
Tirana
Niš
Sofia
Craiova
Bucharest
Ploiești
Galați
Iași
Chisinau
Odesa
Kherson
Constanța
Varna
Sunny Beach
Burgas
Plovdiv
Edirne
Istanbul
Thessaloniki
Bari
Taranto
Lecce
Patras
Athens
Izmir
Bursa
Eskişehir
Ankara
Samsun
Sakarya
Çanakkale
Afyonkarahisar
Konya
Antalya
Denizli
Bodrum
Marmaris
Aksaray
Sivas
Malatya
Adana
Gaziantep
Şanlıurfa
Aleppo
Trabzon
Giresun
Sevastopol
Yalta
Novorossiysk
Anapa
Krasnodar
Sochi
Berdyans'k
Mariupol'
Rostov-on-
Donetsk
Luhansk
Dnipro
Zaporizhzhia
Kryvyi Rih
Kropyvnytskyi
Chernivtsi
Ivano-Frankivsk
Khmelnytskyi
Aegean Sea
Ionian Sea

Balkans
Montenegro, Albania & Macedonia

Lake Ohrid
Macedonia/Albania

Skadar Lake
Montenegro/Albania

…and we have focused on examining the parasites of the only *Dreissena* species that is in these two lakes:
"Cousin" *Dreissena carinata*

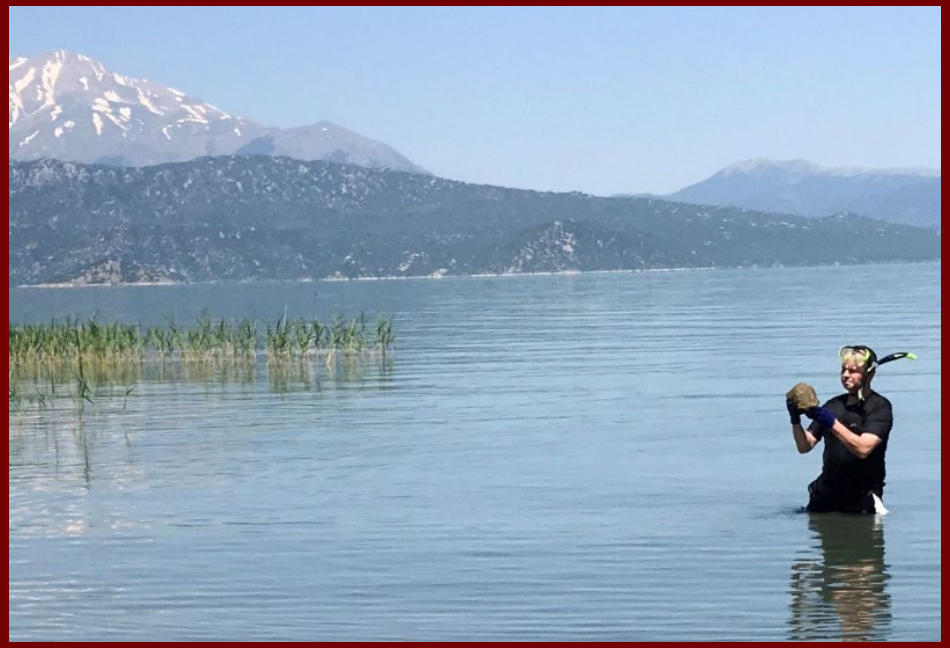

…and in Turkey we initially focused on these two lakes
Konya
Ukraine
Slovakia
Hungary
Romania
Moldova
Bulgaria
Serbia
Bosnia and Herzegovina
Montenegro
Kosovo
Albania
Macedonia (FYROM)
Greece
Black Sea
Aegean Sea
Ionian Sea
Vienna
Bratislava
Budapest
Košice
Debrecen
Oradea
Cluj-Napoca
Târgu Mureș
Szeged
Timișoara
Zagreb
Novi Sad
Нови Сад
Belgrade
Београд
Sarajevo
Split
Niš
Ниш
Sofia
София
Podgorica
Подгорица
Tirana
Bari
Matera
Taranto
Lecce
Thessaloniki
Θεσσαλονίκη
Patras
Πάτρα
Athens
Αθήνα
Archea Olimpia
Αρχαία Ολυμπία
Ploiești
Craiova
Bucharest
Galați
Iași
Chisinau
Chernivtsi
Чернівці
Івано-Франківськ
Хмельницький
Кременчук
Kropyvnytskyi
Кропивницький
Dnipro
Дніпро
Kryvyi Rih
Кривий Ріг
Zaporizhzhia
Запоріжжя
Donetsk
Донецьк
Luhansk
Луганськ
Mariupol'
Маріуполь
Rostov-on
Ростов-на
Odesa
Одеса
Kherson
Херсон
Berdyans'k
Бердянськ
Sevastopol
Севастополь
Yalta
Ялта
Anapa
Анапа
Krasnodar
Краснодар
Novorossiysk
Новороссийск
Constanța
Varna
Варна
Sunny Beach
Слънчев бряг
Burgas
Бургас
Edirne
Plovdiv
Пловдив
Istanbul
Çanakkale
Bursa
Sakarya
Samsun
Giresun
Trabzo
Ankara
Eskişehir
Sivas
Aksaray
Malatya
Denizli
Bodrum
Marmaris
Antalya
Side Belediyesi
Adana
Gaziantep
Şanlıurfa
Aleppo
حلب
Soch
Сочи
Google


Eğirdir Lake
&
Beyşehir Lake
Black Sea
Varna
Варна
Sunny Beach
Слънчев бряг
Bulgaria
Burgas
Бургас
Plovdiv
Пловдив
Edirne
Istanbul
Sakarya
Samsun
Giresun
Trabzon
Çanakkale
Bursa
Ankara
Eskişehir
Sivas
Turkey
Aegean Sea
İzmir
Aksaray
Malatya
Konya
Denizli
Bodrum
Antalya
Marmaris
Side Belediyesi
Adana
Gaziantep
Şanlıurfa
Aleppo
حلب
Google

Turkey

Eğirdir Lake
"Cousin" *Dreissena anatolica*

Beyşehir Lake
"Cousin" *Dreissena anatolica*

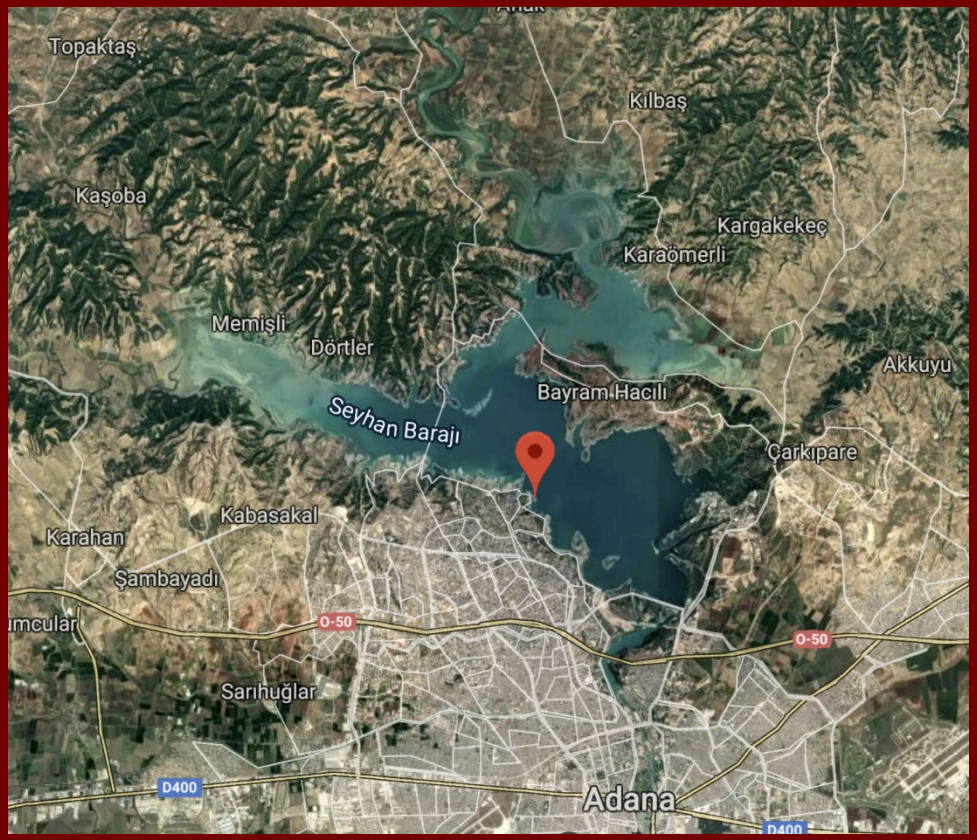



Black Sea
Сочи
Batumi
Samsun
Giresun
Trabzon
Rize
stanbul
Sakarya
Bursa
Ankara
Eskişehir
Sivas
Erzurum
Turkey
Afyonkarahisar
…and we also sampled at a dam reservoir at Adana
Malatya
Konya
Denizli
Diyarbakır
Batman
Mardin
Şanlıurfa
Gaziantep
Adana
Antalya
Marmaris
Side Belediyesi
Aleppo
Google

Turkey

Seyhan Dam Reservoir at Adana

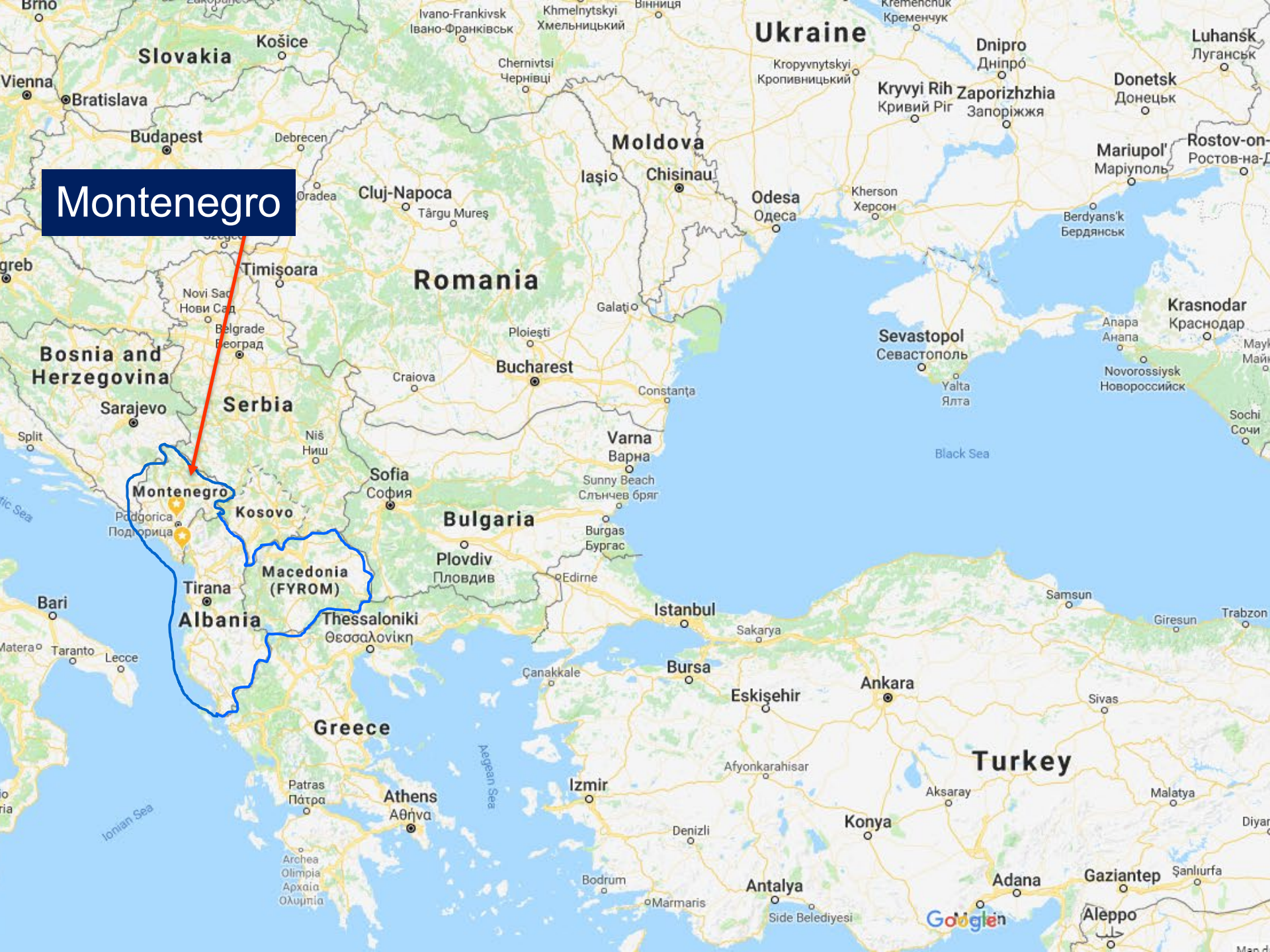
"Cousins" *Dreissena anatolica* and *Dreissena caputlacus*



OK, we collected these Balkan and Turkish mussels…

But what did we do next with them?

We brought them back to our field lab in Montenegro….


Montenegro
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Vienna
Bratislava
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Debrecen
Ivano-Frankivsk
Івано-Франківськ
Khmelnytskyi
Хмельницький
Ukraine
Chernivtsi
Чернівці
Kropyvnytskyi
Кропивницький
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Дніпро
Luhansk
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Kryvyi Rih
Кривий Ріг
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Донецьк
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Iaşi
Chisinau
Mariupol'
Маріуполь
Rostov-on-
Ростов-на-Д
Oradea
Cluj-Napoca
Târgu Mureş
Odesa
Одеса
Kherson
Херсон
Berdyans'k
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Анапа
Sevastopol
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Yalta
Ялта
Novorossiysk
Новороссийск
Sochi
Сочи
Bosnia and
Herzegovina
Sarajevo
Serbia
Split
Niš
Ниш
Varna
Варна
Sunny Beach
Слънчев бряг
Black Sea
Sofia
София
Montenegro
Podgorica
Подгорица
Kosovo
Bulgaria
Burgas
Бургас
Plovdiv
Пловдив
Edirne
Macedonia
(FYROM)
Tirana
Albania
Bari
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Θεσσαλονίκη
Istanbul
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Giresun
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Sakarya
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Çanakkale
Bursa
Eskişehir
Ankara
Sivas
Greece
Turkey
Afyonkarahisar
Aegean Sea
Patras
Πάτρα
Athens
Αθήνα
Izmir
Aksaray
Malatya
Konya
Denizli
Ionian Sea
Archea
Olimpia
Αρχαία
Ολυμπία
Bodrum
Marmaris
Antalya
Side Belediyesi
Adana
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…and although it's a just a relatively small trailer,…

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…with mussels held inside clear acrylic pipes in the aquaria

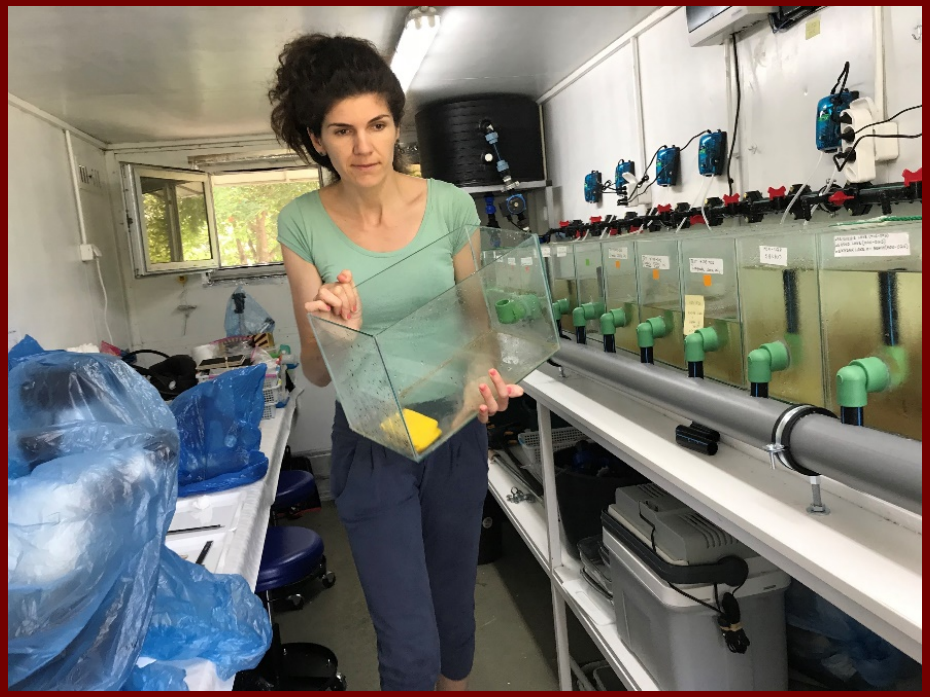
… and my research in the trailer is assisted by the following two key Montenegrin scientists…

Fieldwork

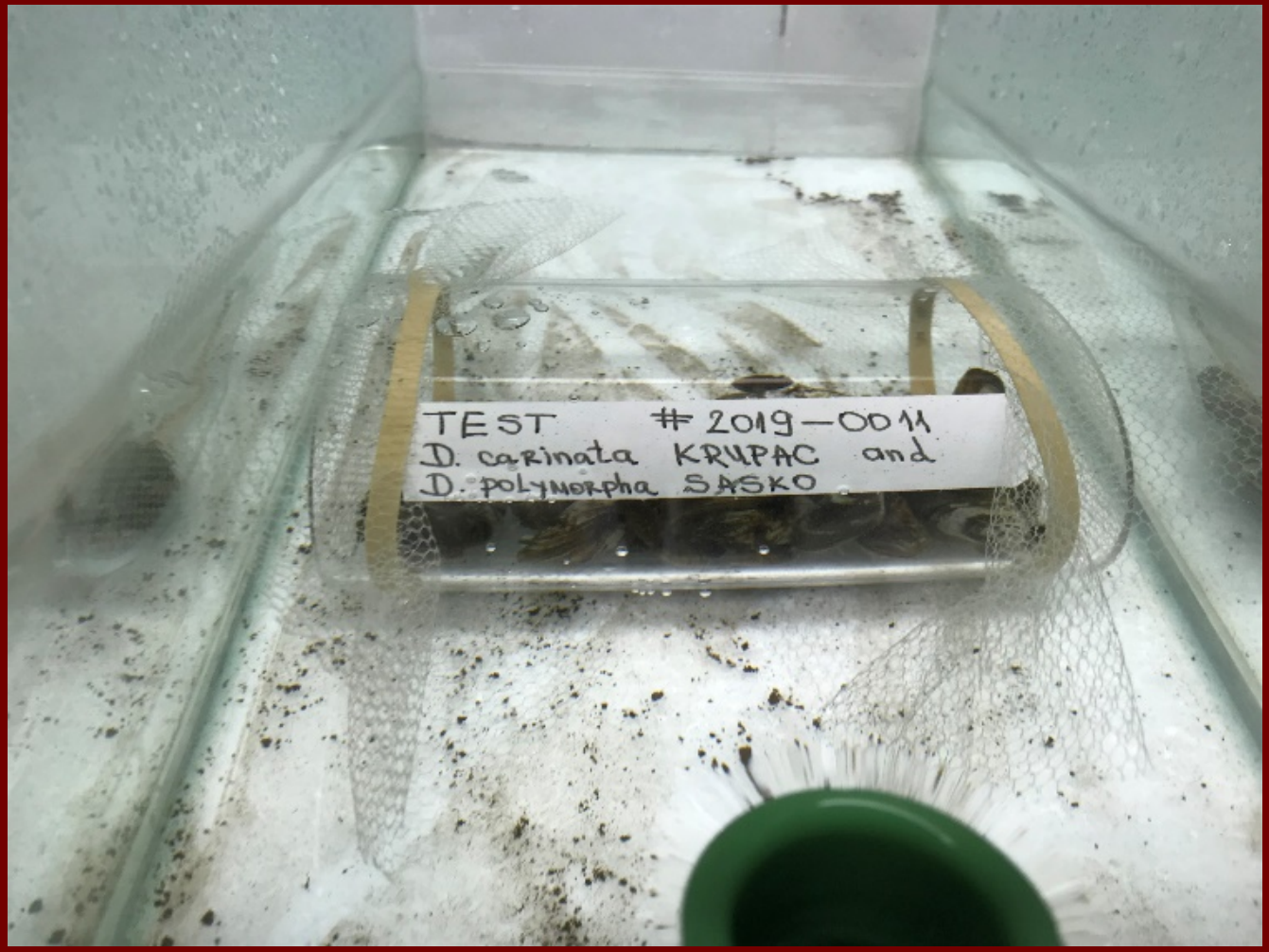
Mihailo Jovićević

Labwork

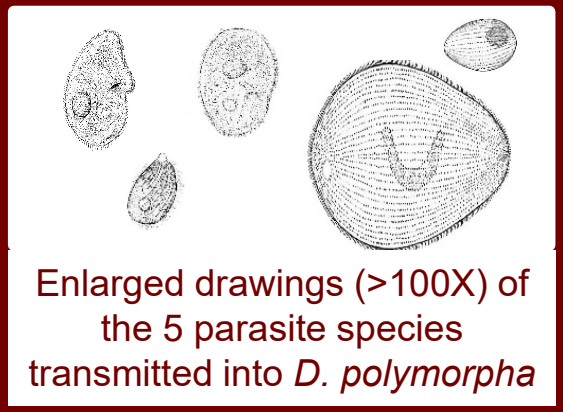
Milena Iković



….and in 2019 we started doing experiments in the research trailer trying to transmit parasites from “cousin” *D. carinata* into *D. polymorpha* -- to our knowledge, something never before ever attempted in science …



…and these experiments succeeded in transmitting all 5 species of ciliate parasites present in “cousin” *D. carinata* into *D. polymorpha* -- a **major milestone achievement** for the project *!!*



Enlarged drawings (>100X) of the 5 parasite species transmitted into *D. polymorpha*

“Cousin” D. carinata → *D. polymorpha*

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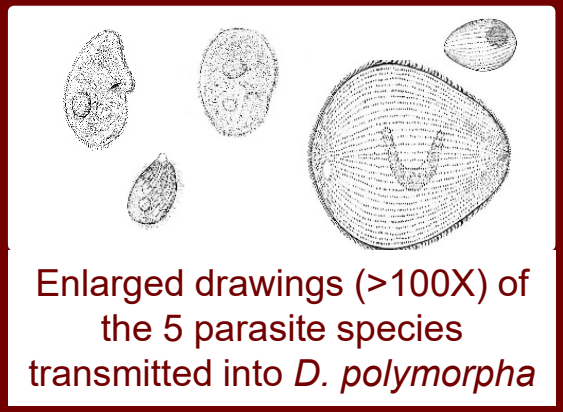

Enlarged drawings (>100X) of the 5 parasite species transmitted into *D. polymorpha*

“Cousin” D. carinata → *D. polymorpha*

But now **longer-term** experiments are critically needed to indicate if any of these 5 parasites are “novel” enough to actually kill *D. polymorpha*. To accomplish this, the research trailer needs to be kept operating **year round** (in 2019 we could afford to keep it open only May through September).

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- Year-round collection-dissection of "cousin" *Dreissena* species in search for their most "novel" (i.e., lethal) parasites
- Year-round conduct of long-term infection trials (against both zebra and quagga mussels) using "novel" parasites from "cousin" *Dreissena* species

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…and finally ….don't be surprised if…

…. some "novel", inexpensive, environmentally-safe, **parasite discovered by this project** proves to be that above-mentioned **LIVE** control agent used throughout North America *!!*

Project's International Team of Collaborating Scientists

…and ***special thanks*** to the team of scientists working on this project with me

NORTH MACEDONIA
Sasho Trajanovski

NORTH MACEDONIA
Tino Zdarveski

ALBANIA
Spase Shumka

ITALY
Sergei Fokin

TURKEY
Zeki Yildirim

FRANCE
Laure Giamberini

MONTENEGRO
Mihailo Jovićević

MONTENEGRO
Vladimir Pešić

MONTENEGRO
Milena Iković

USA
Jacque Keele

USA
Yale Passamaneck

USA
Sherri Pucherelli

Thank you very much for your attention!