PARASITES IN NEARSHORE MARINE ECOSYSTEMS OF ARCTIC – DIVERSITY, TRANSMISSION PATTERNS AND CONSEQUENCE OF ACCELERATING CLIMATE CHANGES AND ANTHROPOGENIC IMPACT ECOSYSTEMS

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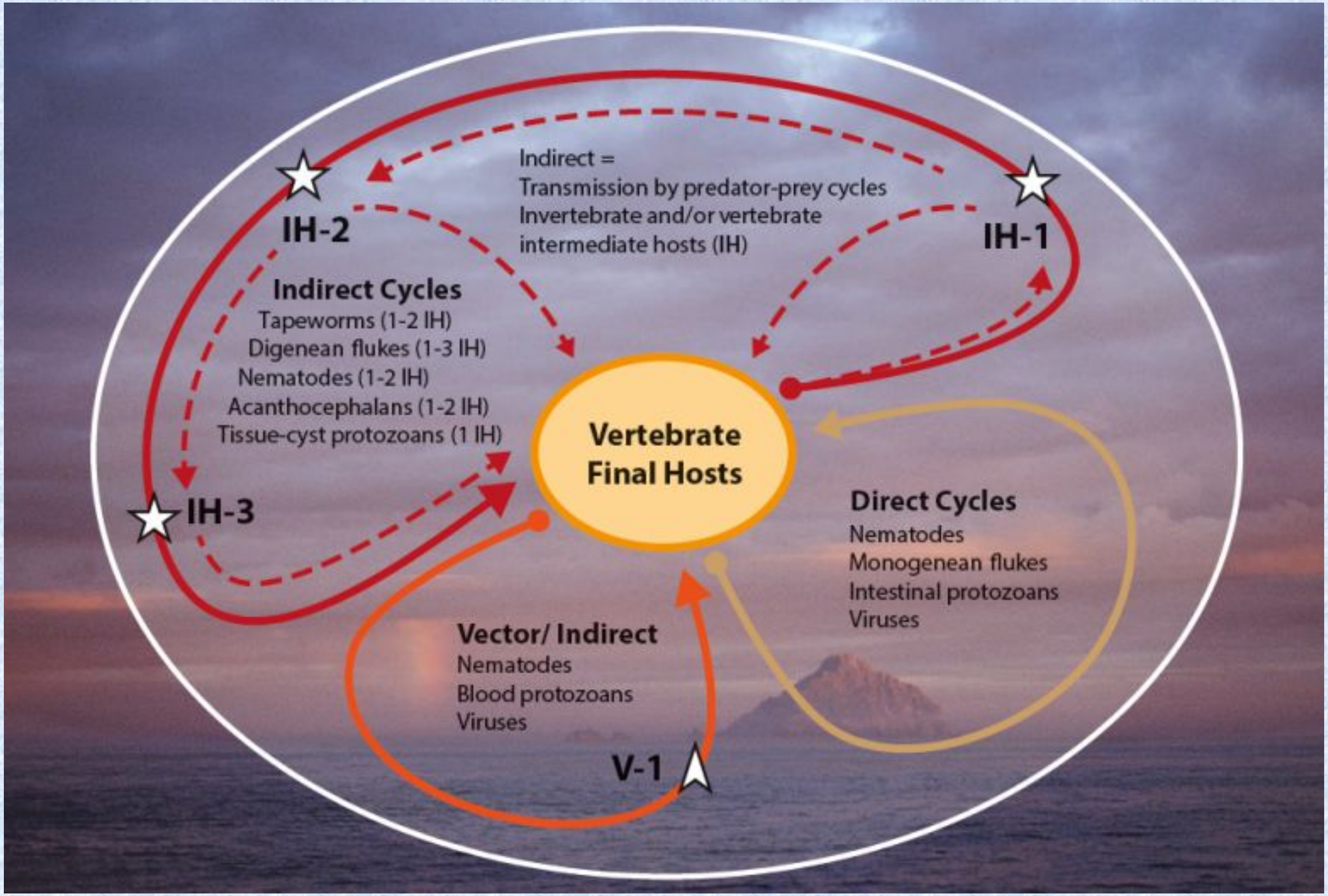
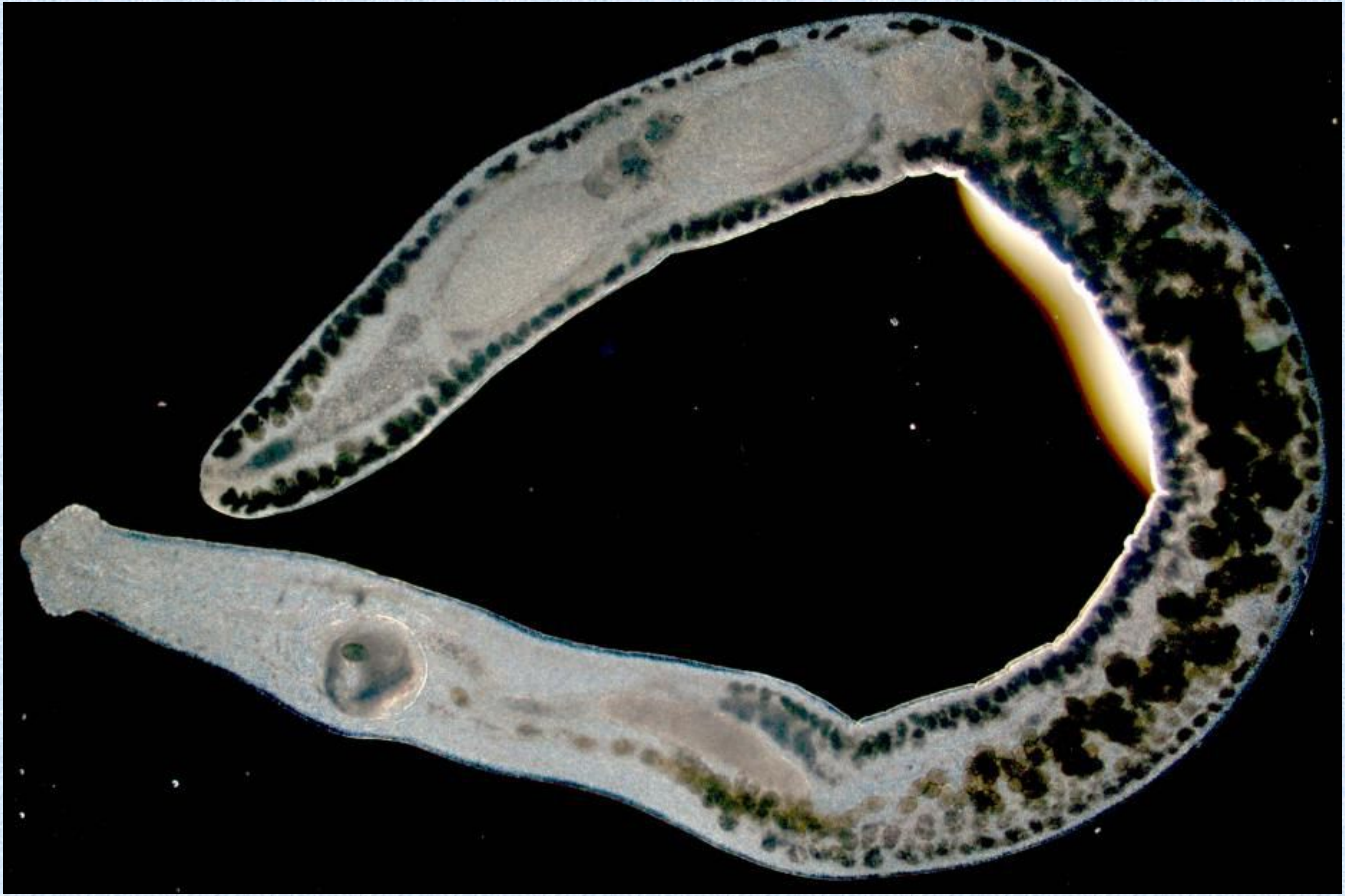


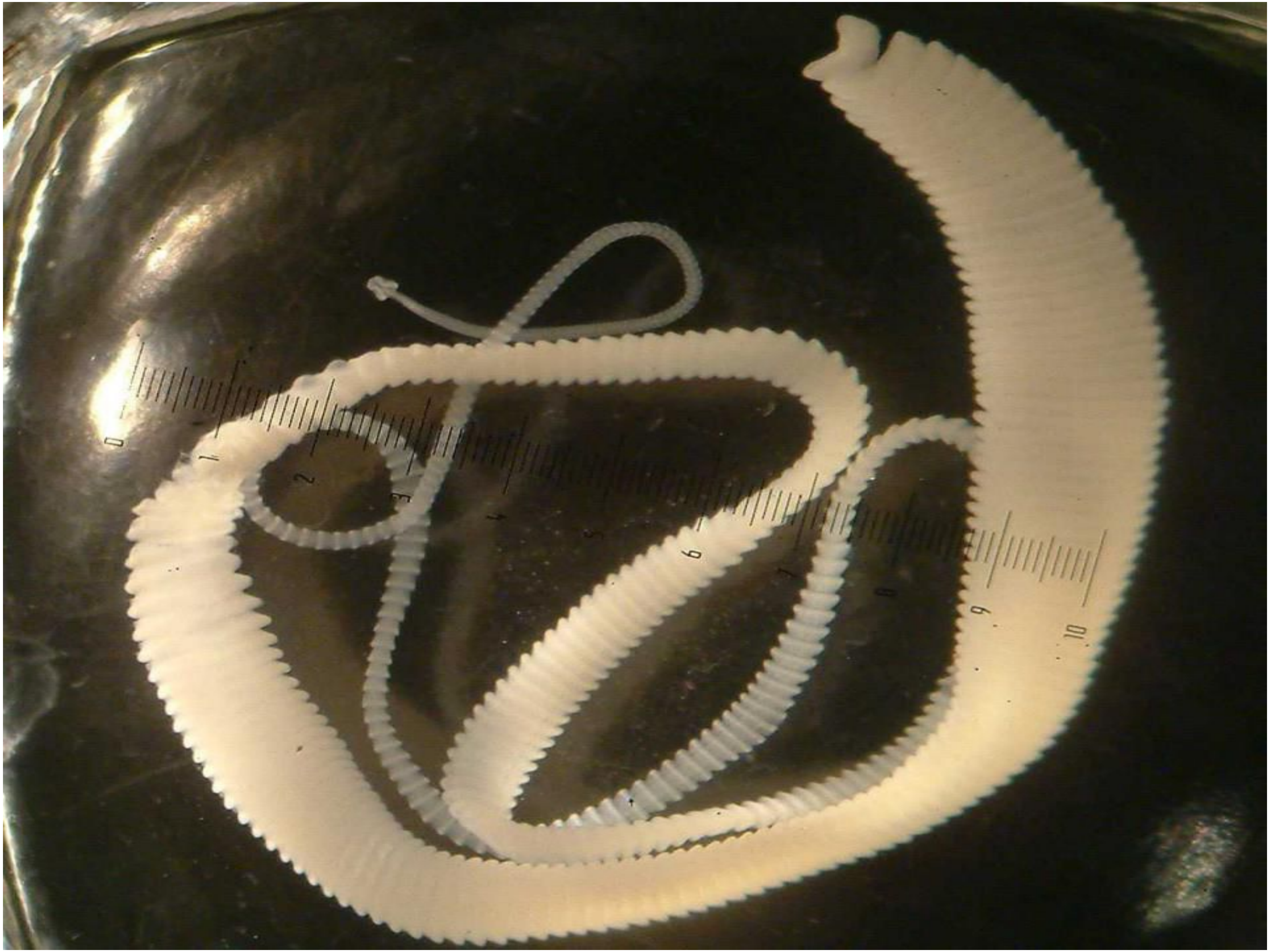
Life cycles for parasites

Direct cycles involve transmission between definitive hosts, often with infective stages distributed in the environment. Indirect (complex) cycles involving development of larval stages in intermediate hosts (IH-1 to IH-3) are typical for most helminth parasites. Indirect cycles may also involve arthropod vectors (V-1) that are required for development and transmission of parasites to the final host, usually for parasites in the blood.

(Reproduced from Hoberg et al., 2013)


Our long-term studies were focused on marine and coastal bird parasites which were transmitted in coastal ecosystems of the Arctic seas.






0 1 2 3 4 5 6

Number of helminth parasites species found in some marine birds along the coasts of North Atlantic and Arctic Ocean

Common eider (*Somateria mollissima*)						
East (Baltic Sea) and west (North Sea) coasts of Sweden*	Iceland**	White Sea***	South-west Barents Sea****	South-east Barents Sea5*	Spitz-bergen5*	Franz-Josef Land5*
24	26	22	25	11	7	6

Kittiwake (*Rissa tridactyla*)			
South-west Barents Sea****	Spitzbergen6*	Novaya Zemlya (south island)7*	Franz-Josef Land6*
14	5	7	7
Glaucous gull (*Larus hyperboreus*)			
no data	17	8	4

* Persson et al., 1974
** Skirnisson, 2014
*** Kulatchkova, 1979, our data
**** Belopolskaya, 1952

5* our data
6* Kuklin & Galaktionov, 2005
7* Markov, 1941

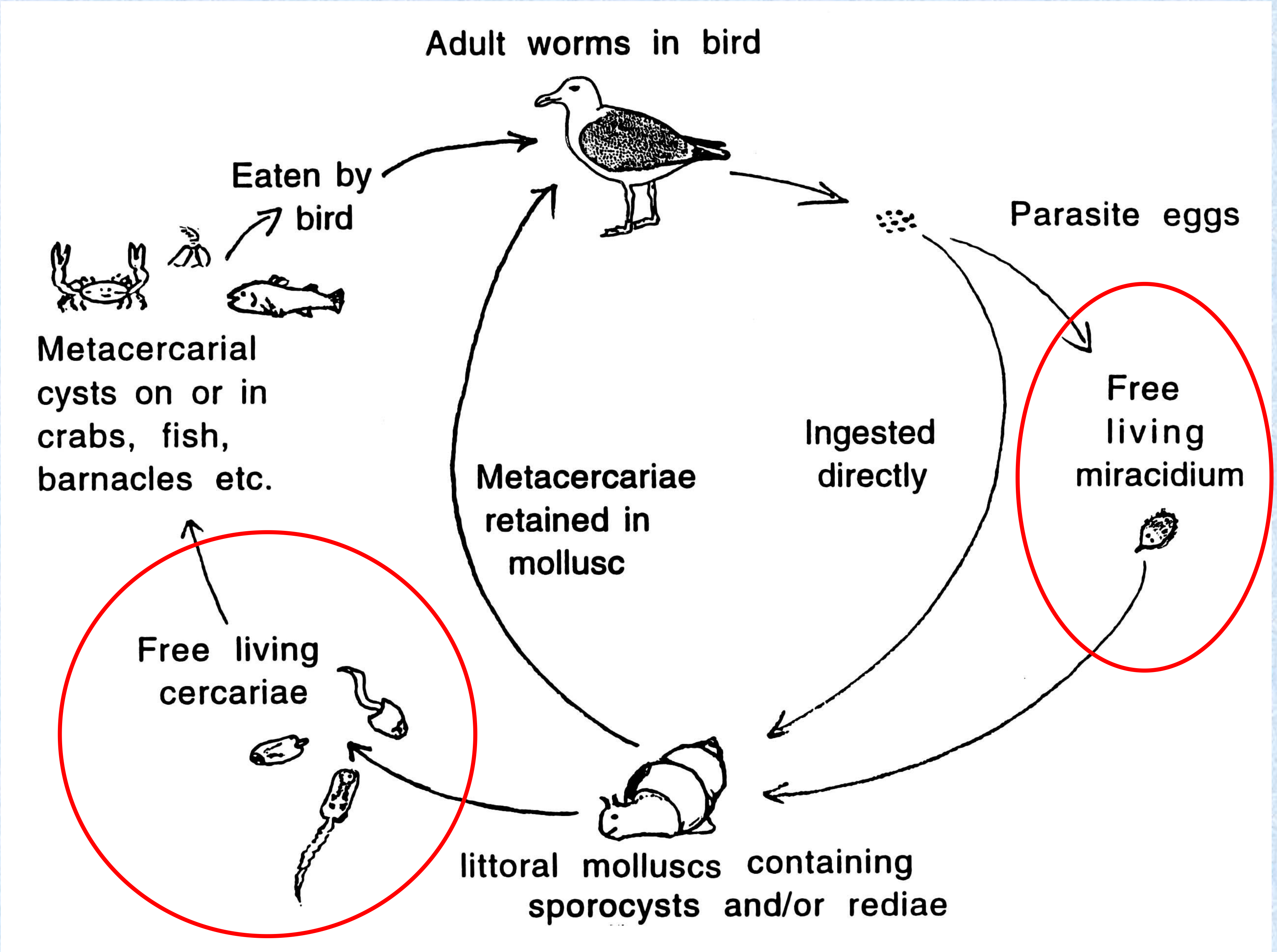
Number of trematode species found in intertidal snails (first intermediate hosts) of the northern seas

Molluscan host	British Isles and France (Atlantic coast)*	South-west Iceland**	White Sea***	South-west Barents Sea****	South-east Barents Sea****
Littorina spp.	26	12	14	14	6
Hydrobia ulvae and *H. ventrosa*	28	9	12	1	-

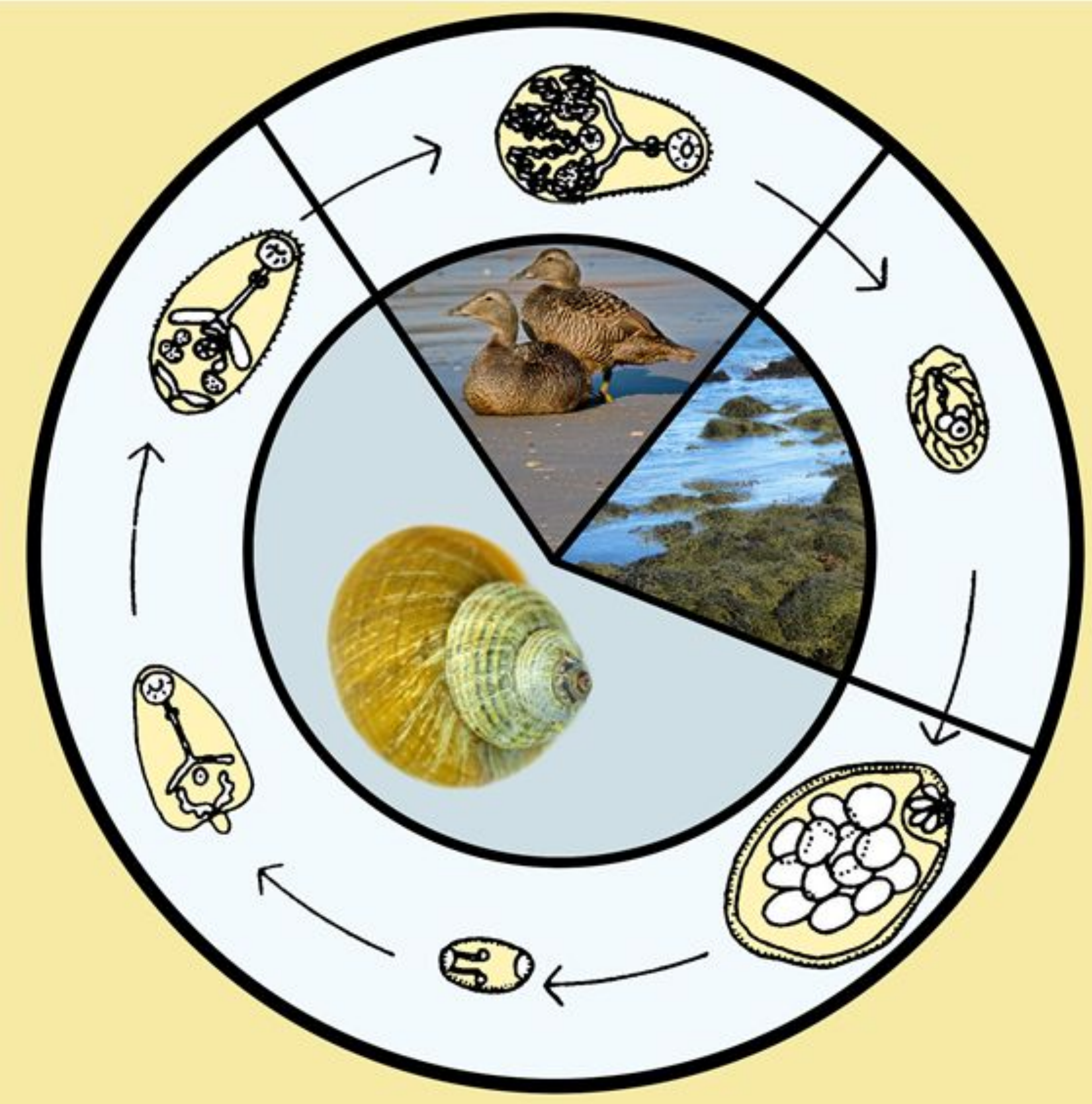
* James 1969; Combescot-Lang 1976; Lauckner 1980; Deblock, 1980; Irwin 1983
** Galaktionov & Skirnisson, 2000; Skirnisson & Galaktionov, 2002
*** our data
**** Galaktionov & Bustnes 1999; our data

Molluscan host	Northern coast of the Sea of Okhotsk*	Bering Sea*
Littorina sitkana and *L. aleutica*	11	2

* our data



GENERAL SCHEME OF TREMATODE LIFE CYCLES TRANSMITTED IN COASTAL ECOSYSTEMS

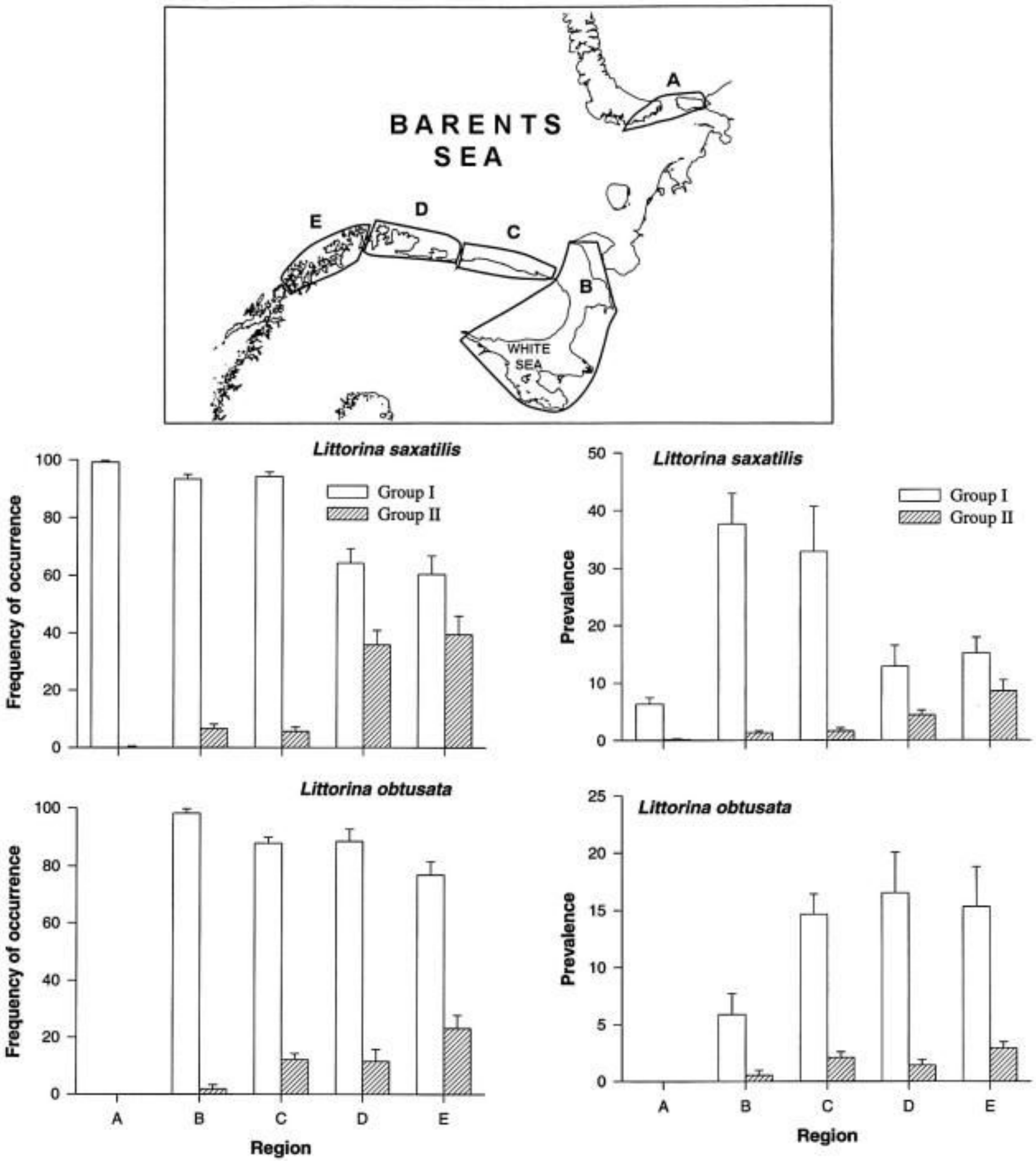


“Autonomic” life cycle (without free-living larval stages) of microphallids of the “*pygmaeus*” group (Trematoda)

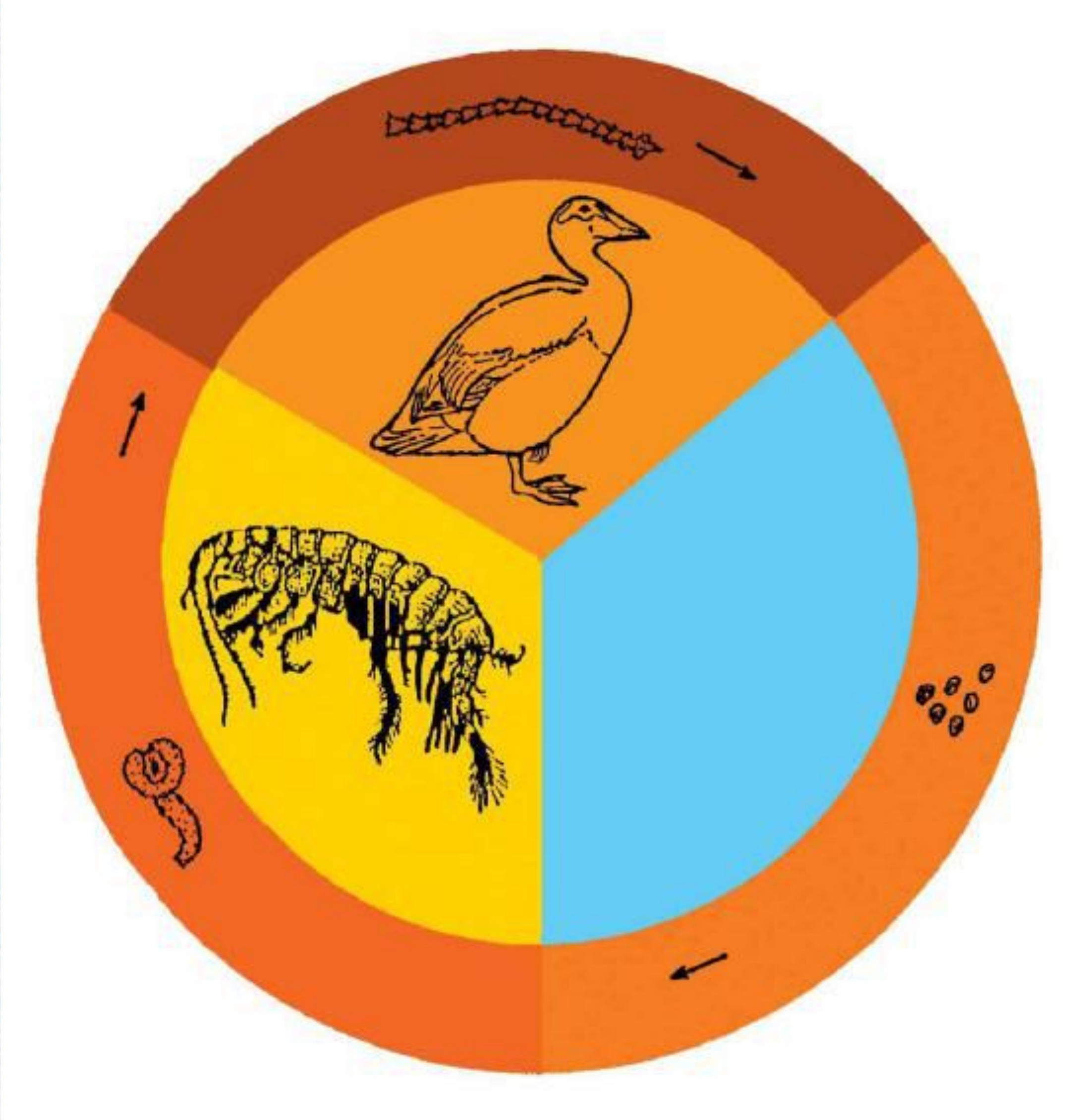
Group I = **trematodes with 1 intermediate host and no free-living larval stages in their life cycles (=autonomic life cycles).**

Group II = **trematodes with life cycles including more than 1 intermediate host and free-living larval stages.**

(after Galaktionov & Bustnes, 1999)

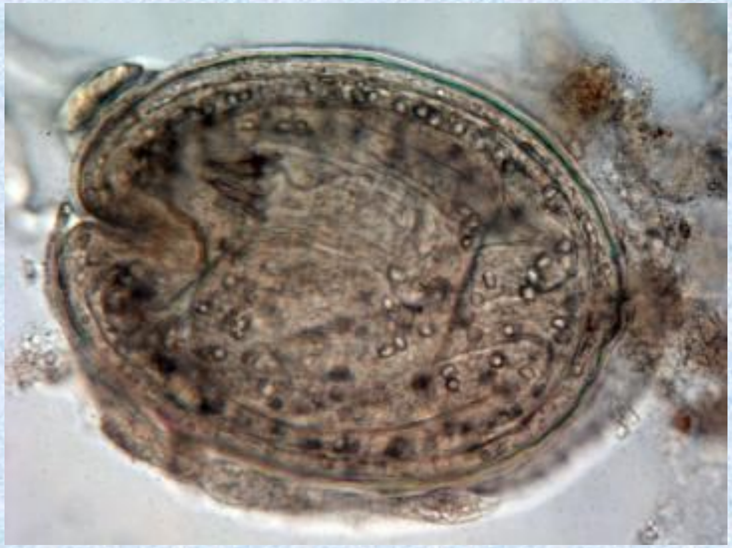


In boreal waters trematodes with free-living larval stages occupied a central place. If the forecasted climate warming does take place, these species will be able to implement their life cycles in the sub-Arctic more intensely and to colonize the Arctic. Judging from the modern distribution of closely related trematode species and subspecies in North Atlantic and North Pacific, the same situation occurred during warm interglacial periods in late Pliocene – Pleistocene.



Life cycle of cestode *Microsomacanthus* spp. – common parasite of seaducks

Packet of eggs in environment



Encysted larva (metacestoda) in crustacean intermediate host

Life cycle stages of pathogenic parasite of common eider – acanthocephalan (thorny-headed worm) *Plymorphus phippsi*

Adult worms in common eider (final host) intestine

Encysted larva (cystacant) in amphipods (intermediate host)

Stomach contents of some seabird species of the Franz Josef Land archipelago and food items characteristics

Seabird species and prey items	Mean wet weight (mg)	Frequency of occurrence F%
Somateria mollissima (n = 5)		
Polychaeta spp.	200	20
Margarites spp.	491	100
Onisimus spp.	14	20
Gammarellus homari	511	20
Gammarus setosus	207	20
Weyprechtia pinguis	43	20
Boreogadus saida	11,087	20
Sterna paradisaea (n = 5)		
Polychaeta (pelagic)	200	20
Apherusa glacialis	5	20
Gammarus setosus	207	60
Gammarellus homari	511	100
Gammarus wilkitzkii	206	40
Pisces n.det.	1,000	20
Cepphus grylle (n = 5)		
Atylus carinatus	250	20
Gammarellus homari	250	20
Onisimus spp.	50	20
Gammarus wilkitzkii	150	40
Parathemisto libellula	25	20
Lebbeus polaris	800	40
Boreogadus saida	7,500	80
Myoxocephalus scorpus	1,000	20
Pisces n.det.	1,000	20
gravel		20

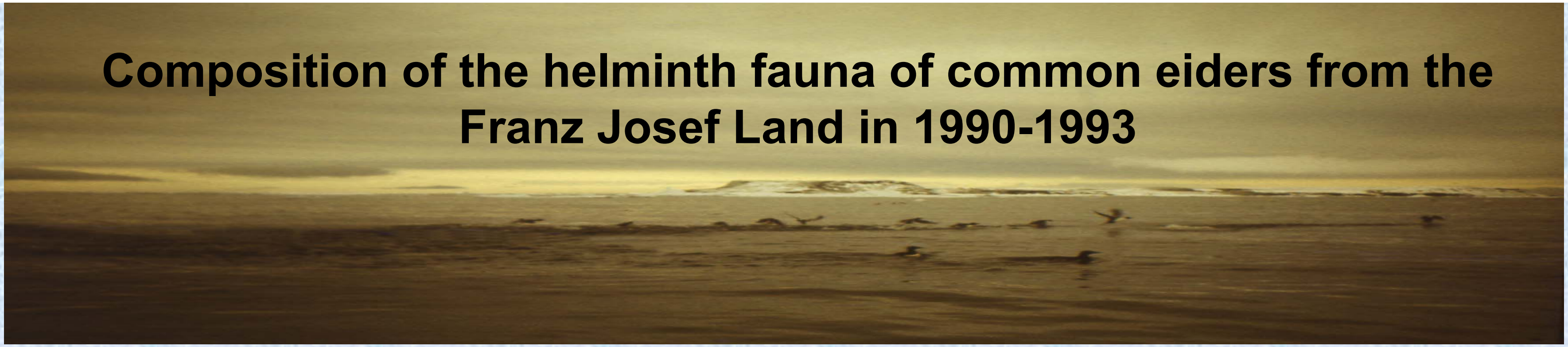
Seabird species and prey items	Mean wet weight (mg)	Frequency of occurrence F%
Rissa tridactyla (n = 19)		
Polychaeta spp. *(pelagic)*	60.0	16
Calanus spp.	7.0	16
Apherusa glacialis	6.4	22
Gammarus wilkitzkii	25.0	16
Parathemisto libellula	10.8	84
Meganyctiphanes norvegica	30.0	16
Boreogadus saida	133.1	58
Myoxocephalus scorpius	60.0	5
terrestrial plants	5.0	5
macrophytes	10.0	5
Uria lomvia (n = 11)		
Polychaeta spp. *(pelagic)*	60.0	18
Onisimus spp.	10.0	18
Rhachotropis aculeata	8.0	9
Gammarus wilkitzkii	25.0	54
Gammarus setosus	25.0	18
Parathemisto libellula	14.5	92
Thysanoessa inermis	25.0	9
Boreogadus saida	150.7 (	54
Pisces n.det.	50.0	18
gravel	10.0	18

After Weslawski, Stempniewicz, Galaktionov, 1994

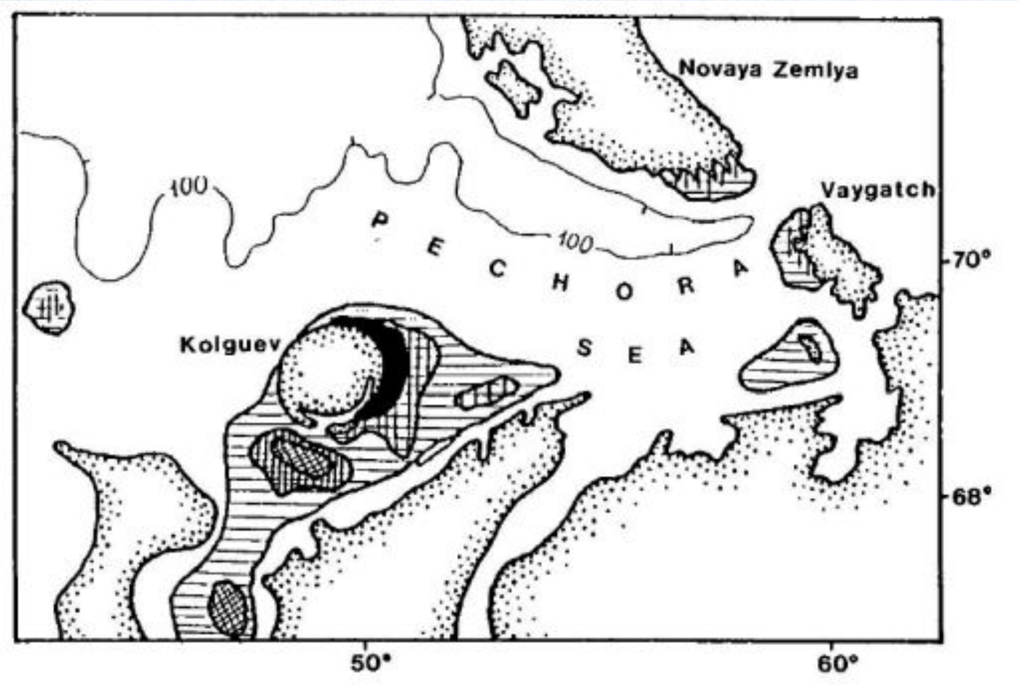
Composition of the helminth fauna of the Franz Josef Land marine and coastal birds in 1991-1993
(*after Galaktionov, 1996*)

Bird species		Number of dissected birds	Cestoda		Acanthocephala	
			Prevalence %	Range in intensity	Prevalence %	Range in intensity
Kittiwake	ad.	17	82.3	1-52	11.8	2-4
(Rissa tridactyla)	juv.	4	100	1-8	0	0
Glaucous gull	ad.	8	75.0	2-11	0	0
(Larus hyperboreus)	juv.	4	100	1-10	0	0
Arctic tern *(Sterna paradisaea)*	ad.	11	9.1	1	72.7	8-227
Brunnich's guillemot	ad.	13	46.1	1-10	0	0
(Uria lomvia)	juv.	5	100	2-26	0	0
Black guillemot *(Cepphus grylle)*	ad.	11	27.3	1-7	18.2	1
Little auk *(Alle alle)*	ad.	15	6.7	1	0	0
Purple sandpiper *(Calidris maritima)*	ad.	7	28.6	3-142	14.3	2

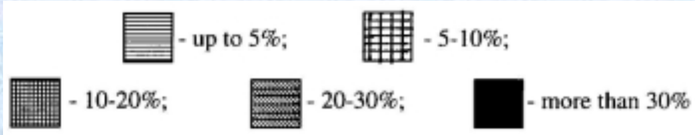
Composition of the helminth fauna of common eiders from the Franz Josef Land in 1990-1993



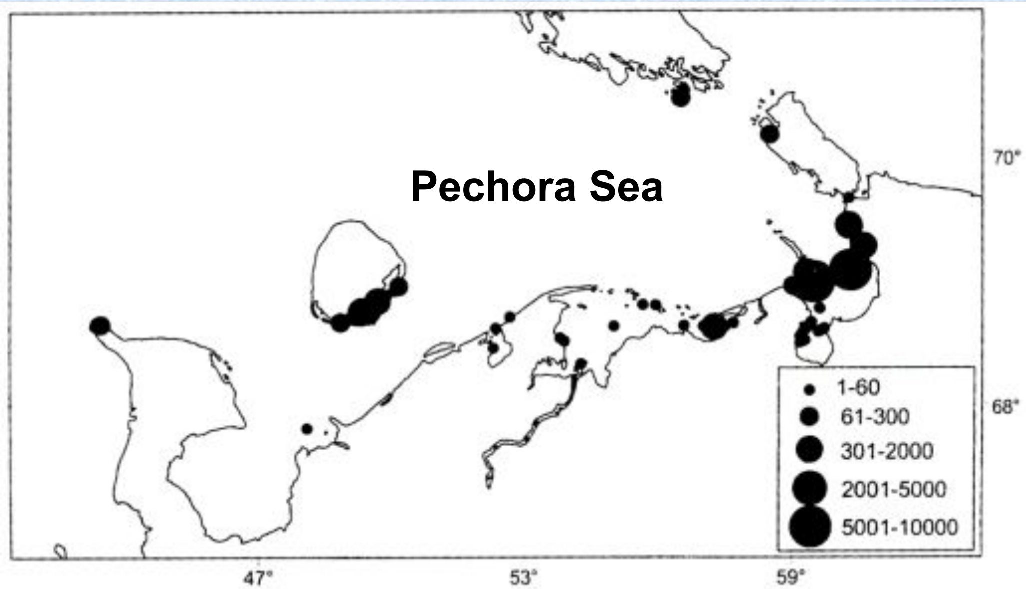
Part of the FJL	Southern islands			Northern islands		
Number of birds examined	12			4		
Infection indices	Preva-lence, %	Intensity of infection	Mean Abundance ±SE	Preva-lence, %	Intensity of infection	Mean Abundance ±SE
Parasite species						
Microphallus pseudopygmaeus	75	8-34900	5858±3710	25	8460	2115±2115
Microsomacanthus microsoma	100	30-76000	22163±8436	0	0	0
M. diorchis	66.7	6-7000	694±577	0	0	0
M. ductilis	0	0	0	100	3000-124400	73600±26308
M. jaegerskioeldi	100	15-60000	12115±5110	100	55000 - 103200	79550±12043
Polymorphus phippsi	100	30-1007	385±90	100	284-1188	814±192



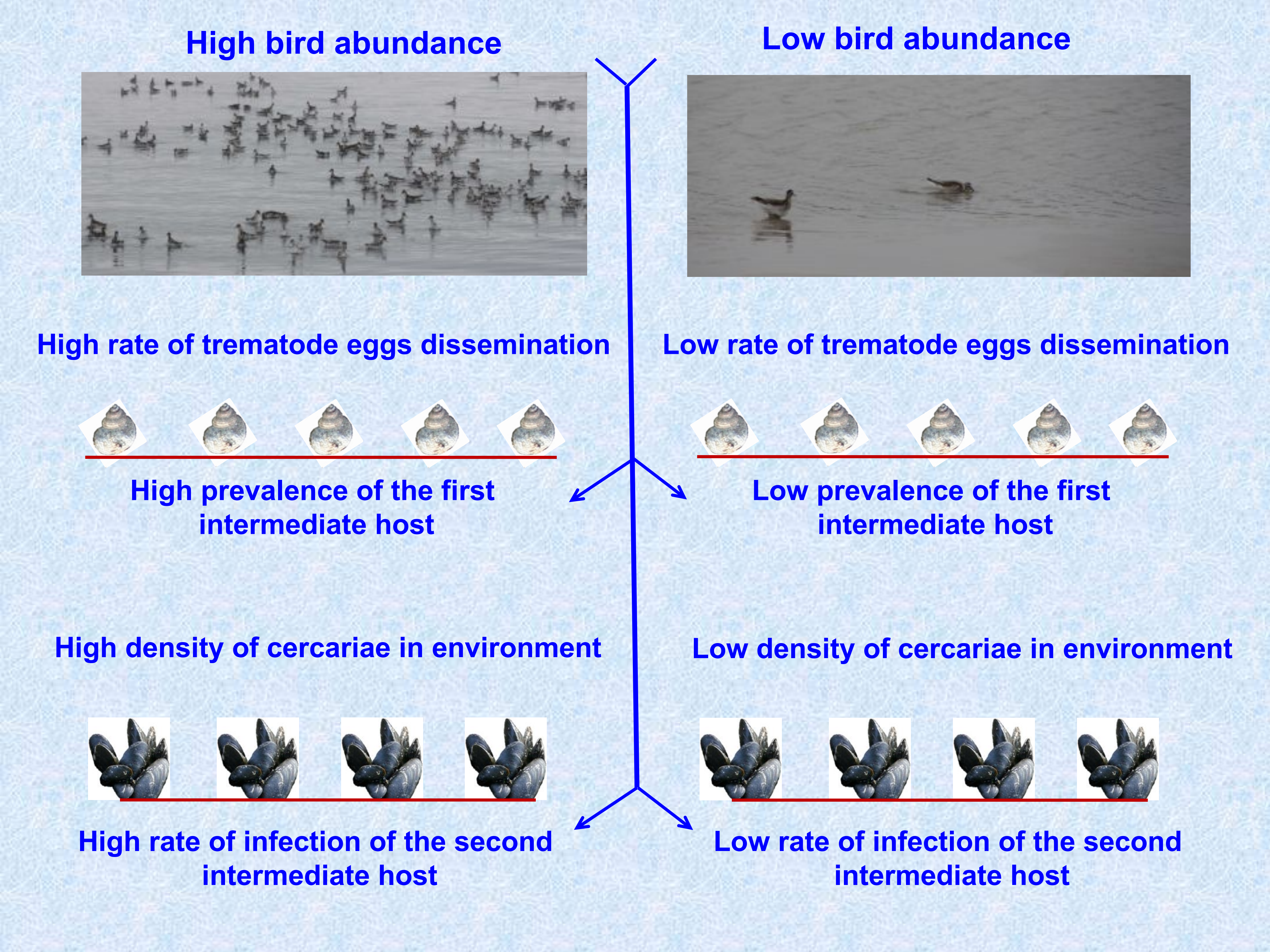
Prevalence of waterfowl trematode larvae in benthic molluscs:



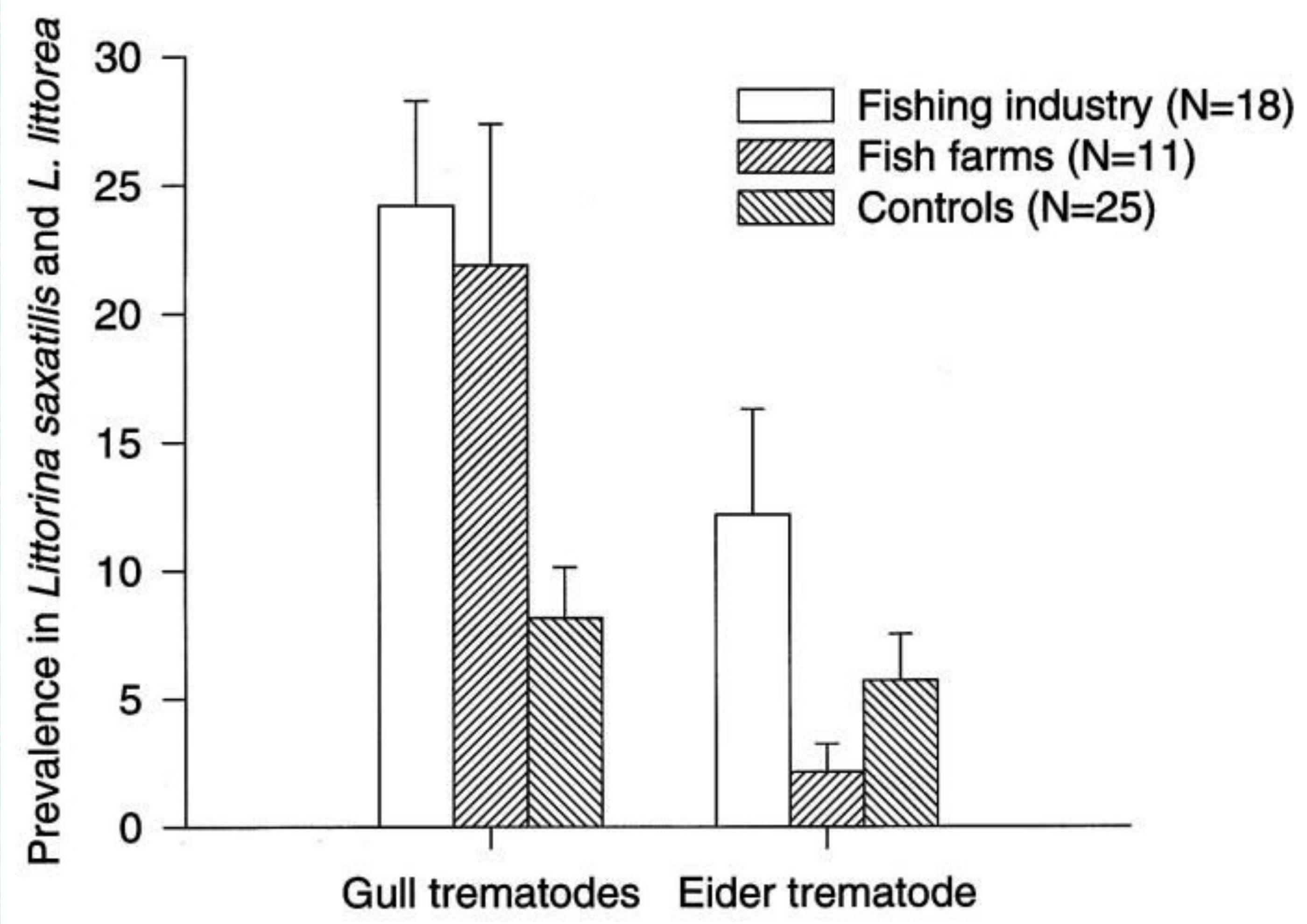
Distribution of the prevalence of subtidal molluscs (*Margarites groenlandicus, Solariella varicosa* and *Cryptonautica clausa*) with waterfowl trematode larvae in the south-eastern part of the Barents Sea (the Pechora Sea) (based of the original data of 1983-85 surveys)



Distribution of ducks on the Pechora Sea area in August 1998 according to airplane observations *(From Krasnov et al., 2002)*

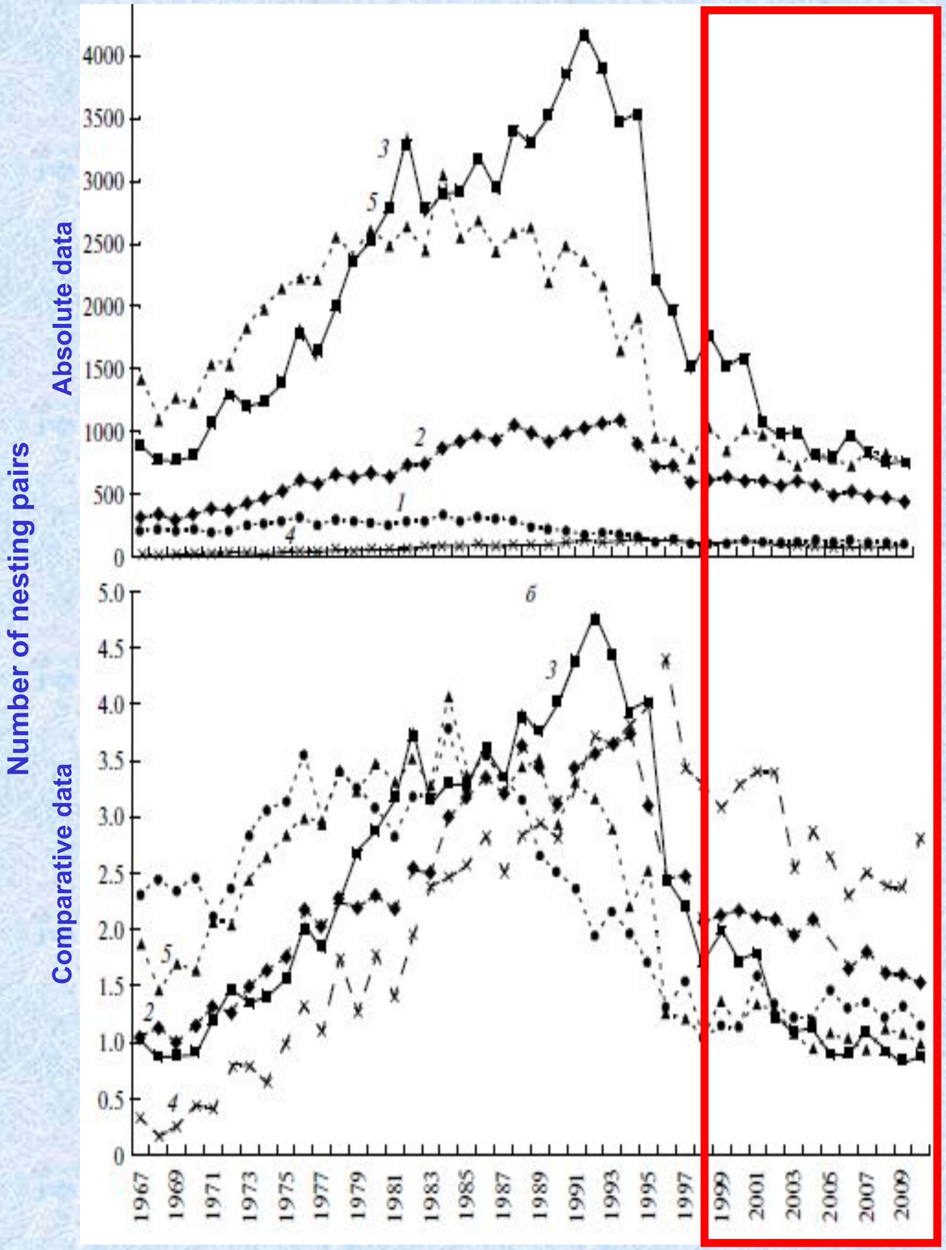


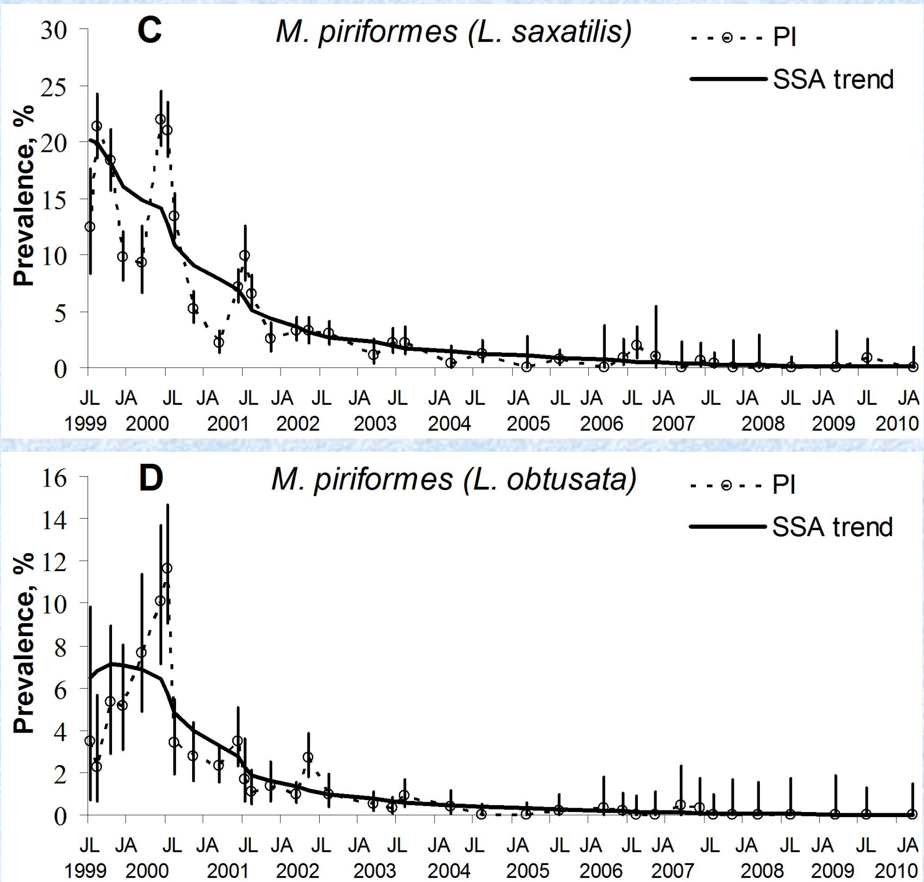
High bird abundance
Low bird abundance
High rate of trematode eggs dissemination
Low rate of trematode eggs dissemination
High prevalence of the first intermediate host
Low prevalence of the first intermediate host
High density of cercariae in environment
Low density of cercariae in environment
High rate of infection of the second intermediate host
Low rate of infection of the second intermediate host



Prevalence (% of infected individuals) of different groups of trematode species in periwinkles *Littorina saxatilis* and *L. obtusata* in sites with fish industry, fish farming and control sites, along the Norwegian Barents Sea coast.

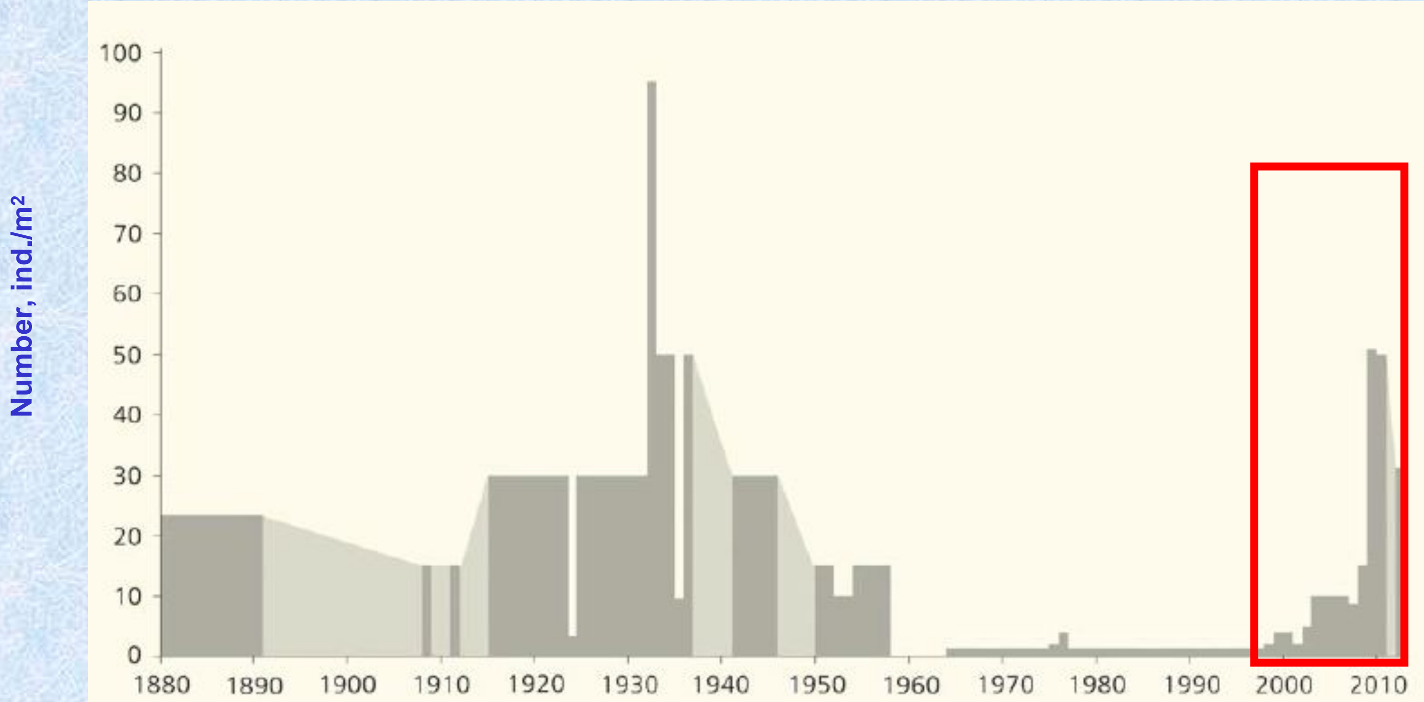
(After Bustnes & Galaktionov, 1999)



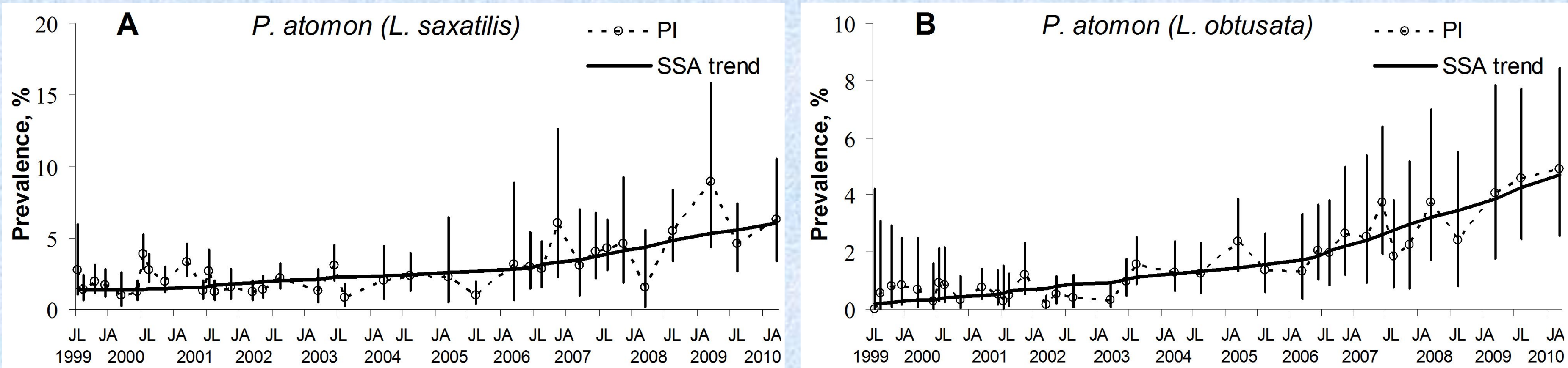


Prevalence (PI – percent of infected individuals) and the trends of PI changes extracted by Singular Spectral Analysis (SSA trends) of intramolluscan stages of gull trematode *Microphallus piriformes* in periwinkles *Littorina* saxatilis and *L. obtusata* in the Chupa Inlet (Kandalaksha Bay, White Sea) *(after Levakin, Galaktionov, Nikolaev, 2013).*

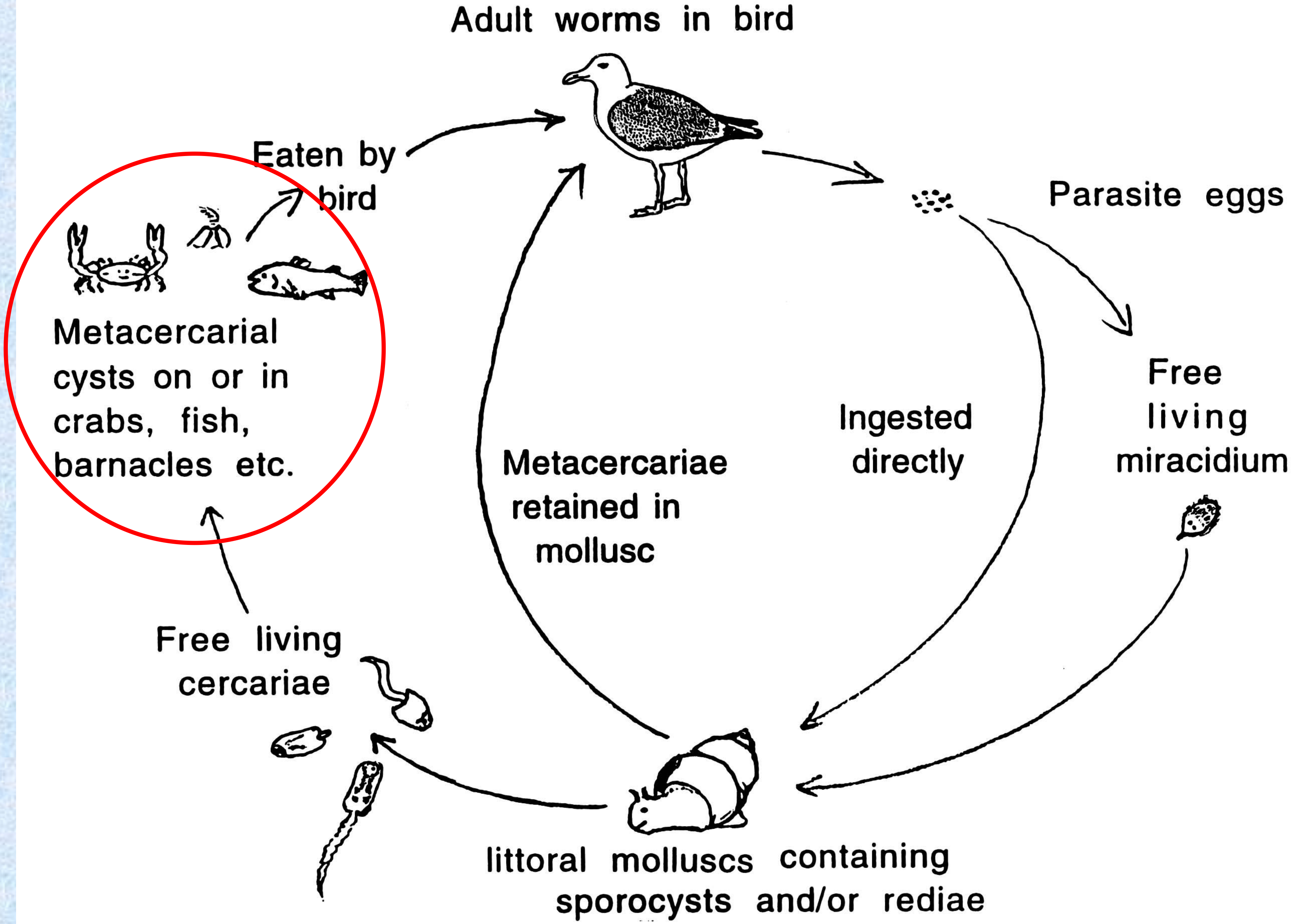
Number dynamics of shorebirds in the Kandalaksha Bay of the White Sea *(after Korjakin, 2012)*
1 – turnstone; 2 – oystercatcher; 3 – herring gull; 4 – great black-backed gull; 2 – common gull



Long-term number dynamics of stickleback (*Gasterosteus aculeatus*) in the White Sea *(after Lajus et al., 2013)*

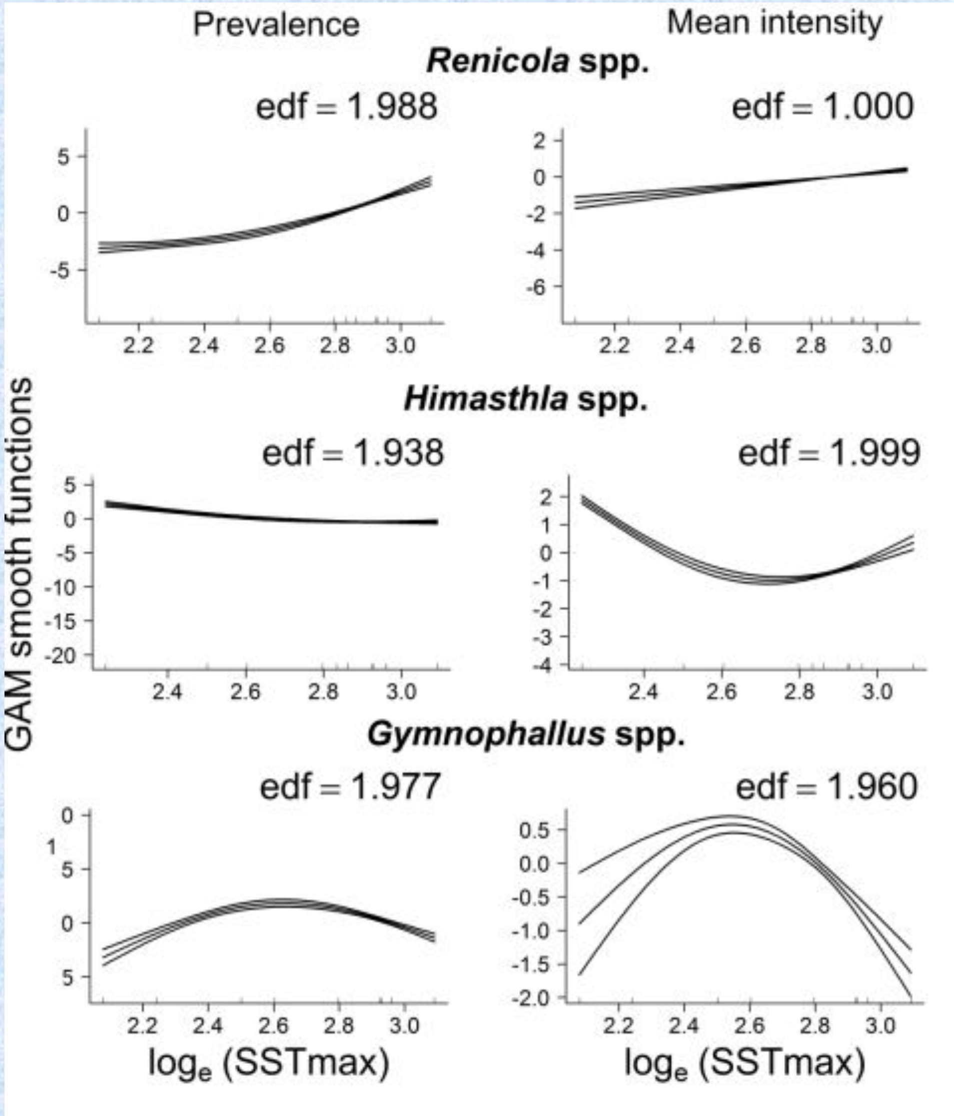


Prevalence (PI – percent of infected individuals) and the trends of PI changes extracted by Singular spectral analysis (SSA trends) of intramolluscan stages of fish trematode *Podocotyle atomon* in periwinkles *Littorina saxatilis* and *L. obtusata* in the Chupa Inlet (White Sea) *(after Levakin, Galaktionov, Nikolaev, 2013)*



GENERAL SCHEME OF TREMATODE LIFE CYCLES TRANSMITTED IN COASTAL ECOSYSTEMS

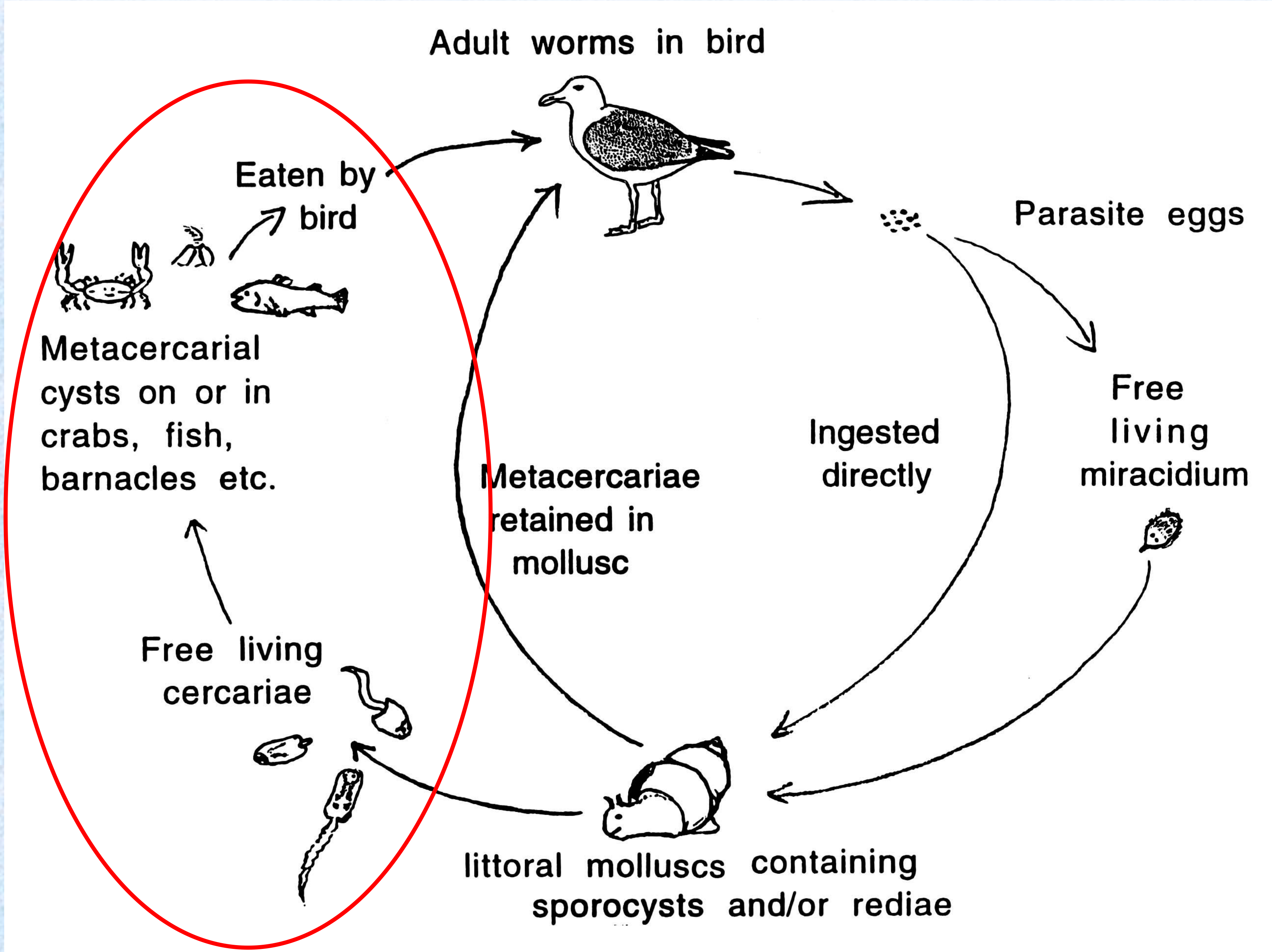
Geographical distribution of blue mussels (*Mytilus edulis*) sampling sites



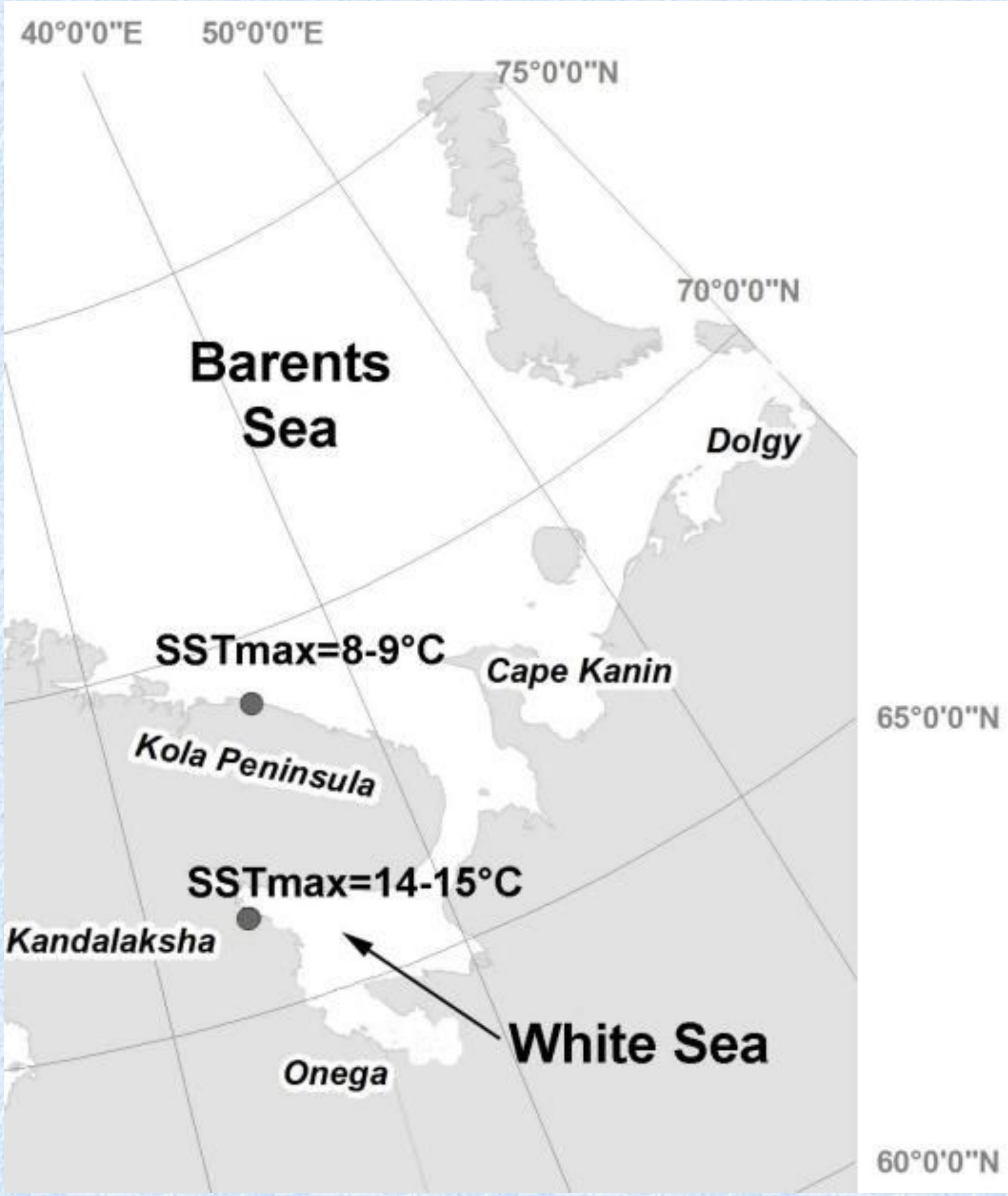
Long-scale effect of <u>maximal surface sea water temperature – SSTmax</u> on infection of blue mussels across the North Atlantic and Arctic Oceans

Estimated smooths for the SSTmax in the generalized additive models (GAMs) predicting the prevalence (% of infected individuals), and mean intensity (mean number of metacercariae in infected mussels) of blue mussels with metacercariae of the most abundant seabird trematodes (edf – effective degrees of freedom)

After Galaktionov et al., 2014, Marine Biology (accepted)

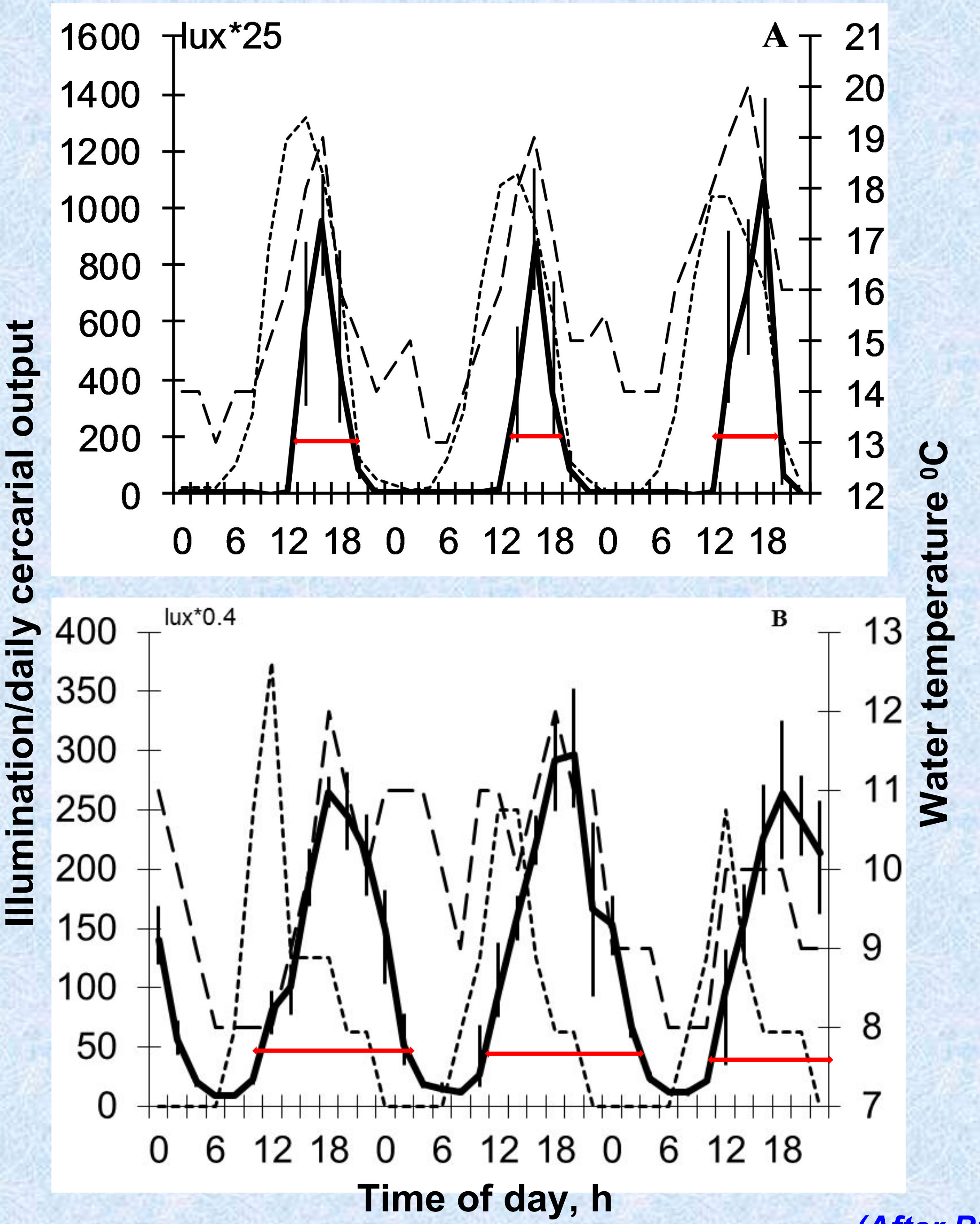


GENERAL SCHEME OF TREMATODE LIFE CYCLES TRANSMITTED IN COASTAL ECOSYSTEMS



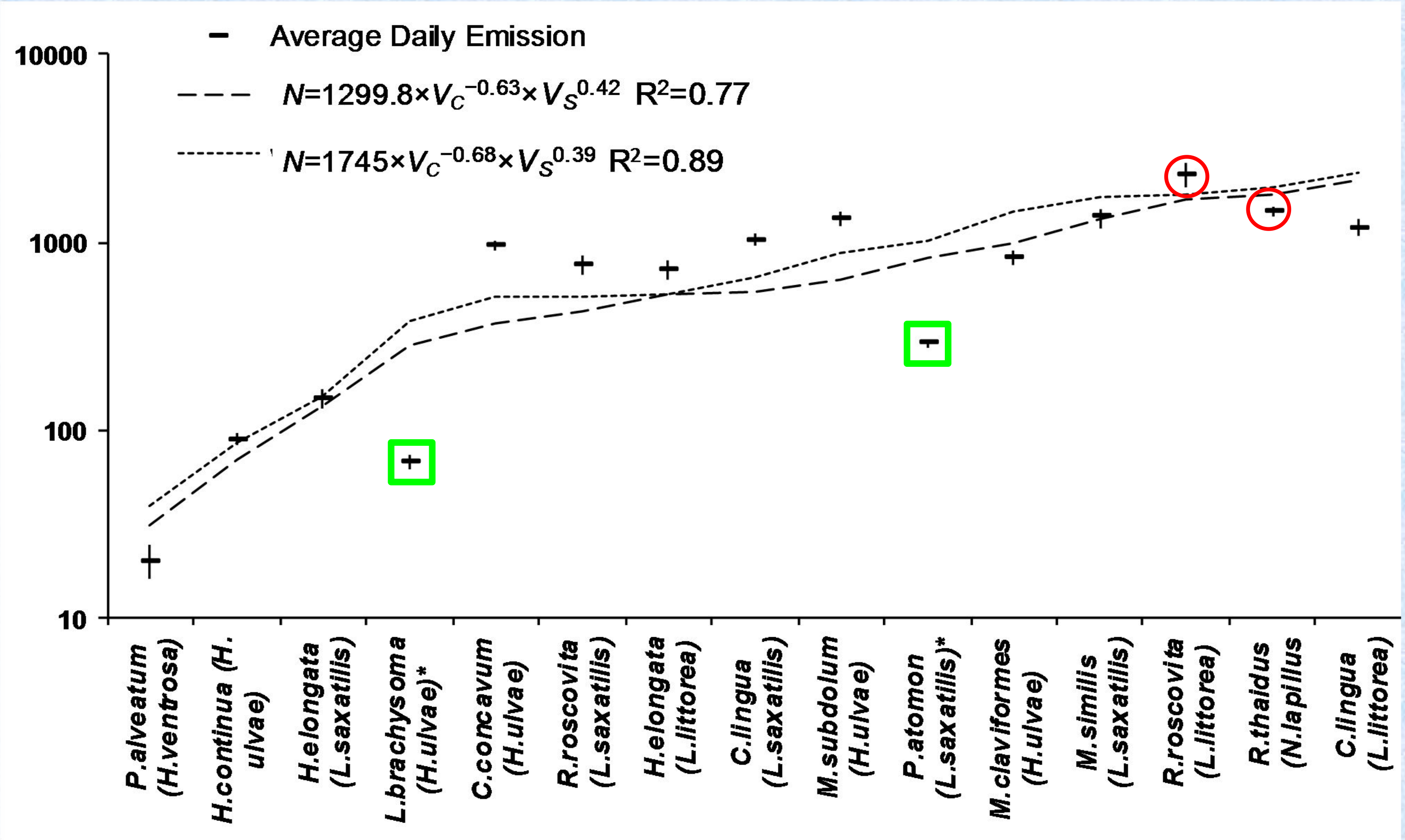
The intertidal sites at the White Sea and the Barents Sea where the rhythms of cercarial daily emergence from the molluscan hosts were studied in the course of *in situ* experiments

SSTmax – maximal surface sea water temperature



Daily emergency rhythm of cercariae *Renicola roscovita* from the White Sea periwinkle *Littorina littorea* (A) [the water temperature during observations was 15.5±0.5 (13 — 20) ^{0}C] and *Renicola thaidus* from the Barents Sea dog whelk *Nucella lapillus* (B) [the water temperature during observations was 9.7±0.4^{0}C (8 — 12) ^{0}C]

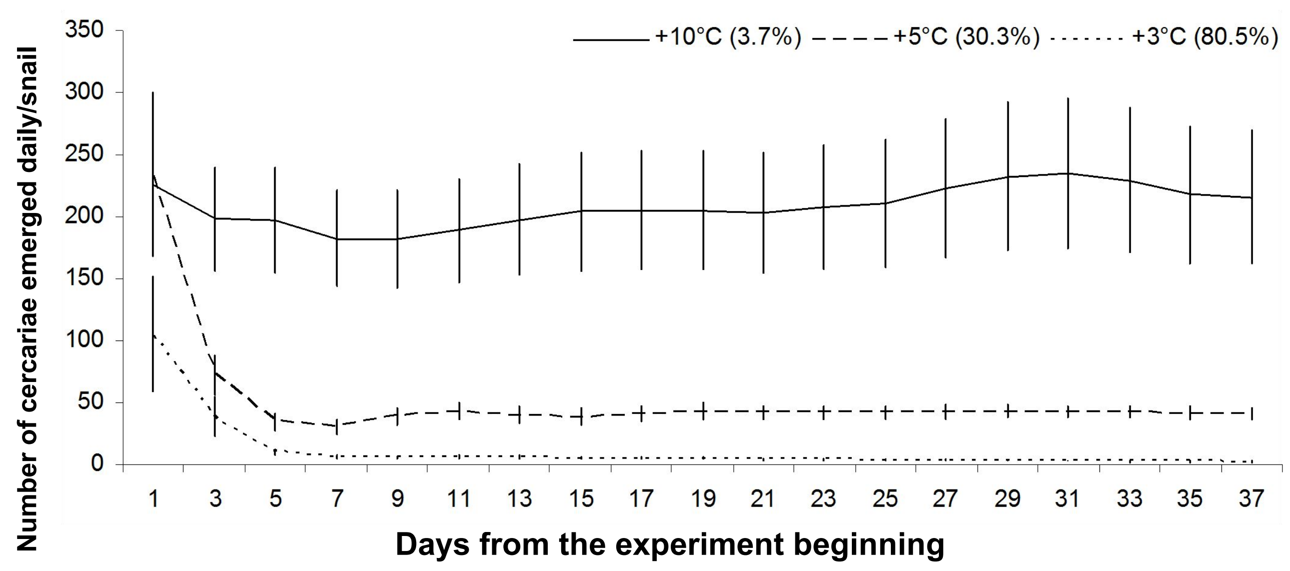
(After Prokofiev, Galaktionov, Levakin, submitted)



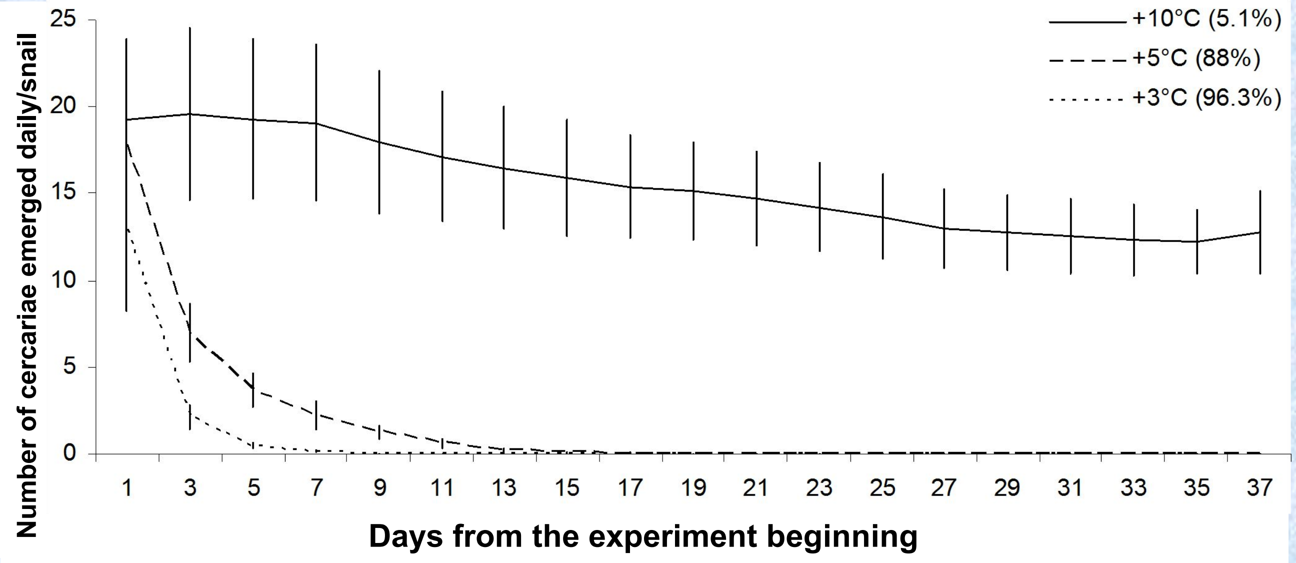
Multiple linear regression of the logarithm (*ln*) of daily cercarial outputs in 12 trematode species (*N*) from the molluscs of the White Sea and the Barents Sea from the logarithms (*ln*) of the relative volume of a cercaria (V_C) and the logarithm (*ln*) of the relative volume of the molluscan host (V_S).

(По Prokofiev, Galaktionov, Levakin, submitted)

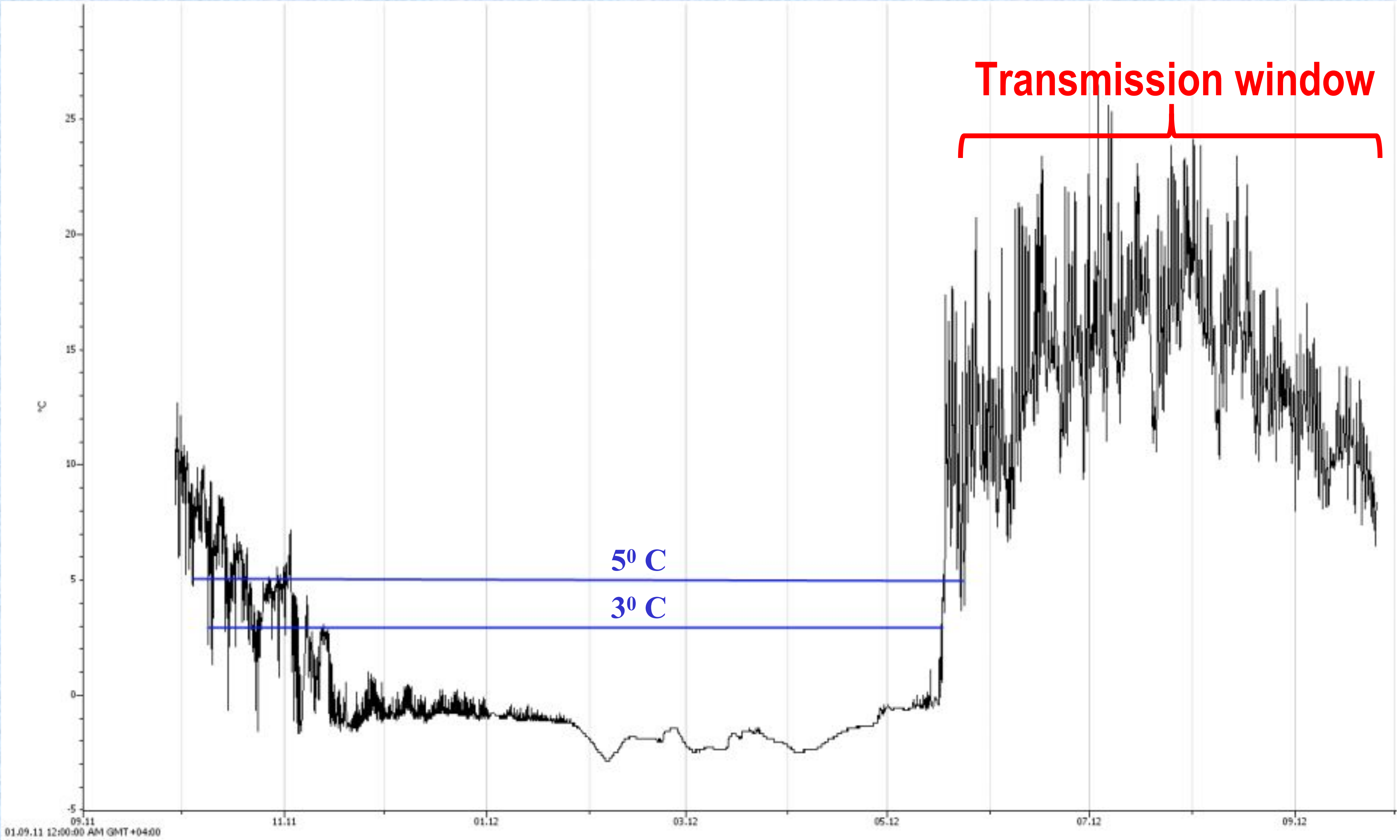
The long-term trends in dynamics of cercarial shedding from the White Sea molluscs extracted by Singular Spectral Analysis (based on the data of 37 days laboratory experiment under different constant temperatures)



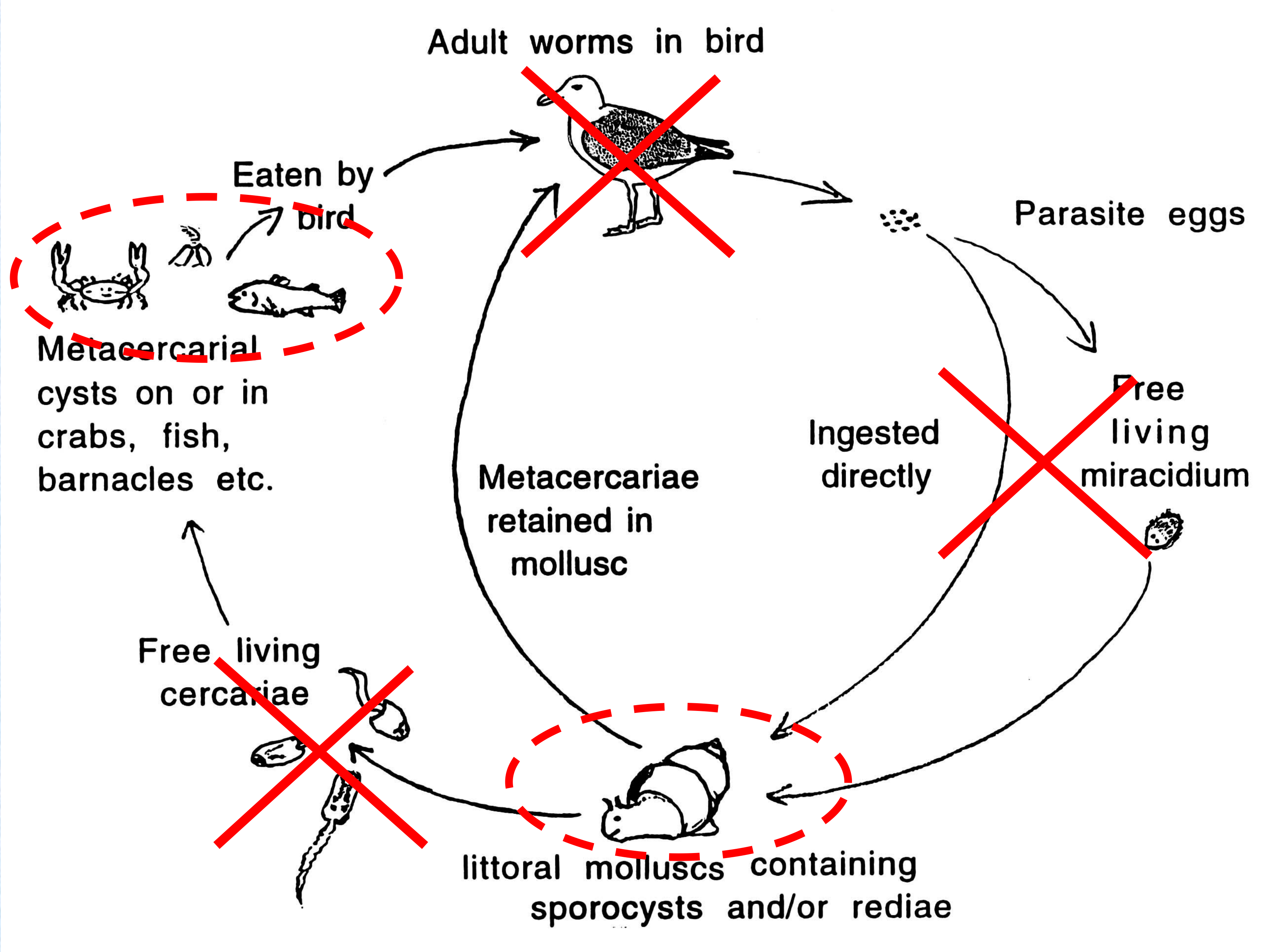
Cercariae *Cryptocotyle concavum* from *Hydrobia ulvae*



Cercariae *Himasthla continua* from *Hydrobia ulvae*



Annual changes in seawater temperature in the intertidal of the Chupa Bay (the White Sea, 66º20′09″ N, 33º38′02″ E) from September, 28, 2011 to September, 25, 2012



Afield of " transmission window " trematode infection is retained in coastal ecosystems as parthenogenetic generations (in the state of developmental arrest) in the first intermediate molluscan host and as larval stages (metacercariae) in the second intermediate host.

Intensified transmission for trematodes (flukes) represents an unfolding cascade in intertidal systems where:

- **the seasonal window for infection of molluscan intermediates will be prolonged;**

- **higher numbers of infected molluscan hosts will drive expansion of parasite populations in invertebrates and fishes that are primary prey for birds;**

- **prevalence and abundance of parasites in birds is predicted to increase coincidentally with patterns of atmospheric warming and increasing sea temperatures, leading to heightened levels of infection for molluscs.**

These feedback loops will be further enhanced as the duration for residency by shorebirds in seacoasts of the Sub-Arctic and Arctic broadens seasonally in response to ameliorating conditions linked to climate change (Lehikoinen et al. 2004).

CONCLUSIONS

- The fauna of helminth parasites, especially flukes, in the nearshore waters of the Arctic is poorer than in the boreal waters.
- The abundance of crustaceans in the diet of Arctic marine and coastal birds intensifies the transmission of cestodes and acanthocephalans.
- While the species richness of helminths in the Arctic is rather low, their infection indices in Arctic seabirds are high. This may further aggravate the negative influence of the harsh environmental factors on the hosts.
- Infection of invertebrates with helminth larvae is patchily distributed in nearshore ecosystems, areas with a high infection level alternating with areas with a low infection level or no infection at all.
- Anthropogenic impact on the Arctic sea coasts may enhance parasite transmission in coastal ecosystems. This may aggravate the negative effect of pollution on coastal communities.
- A consequence of climate warming that will be considered is the widening of the " transmission window " that may result in a cascade effect, with infection transmission intensifying along the chain of hosts involved in the parasite ' s life cycle.


THANKS FOR YOUR ATTENTION