BALTIC SEA BIODIVERSITY CONCEPT

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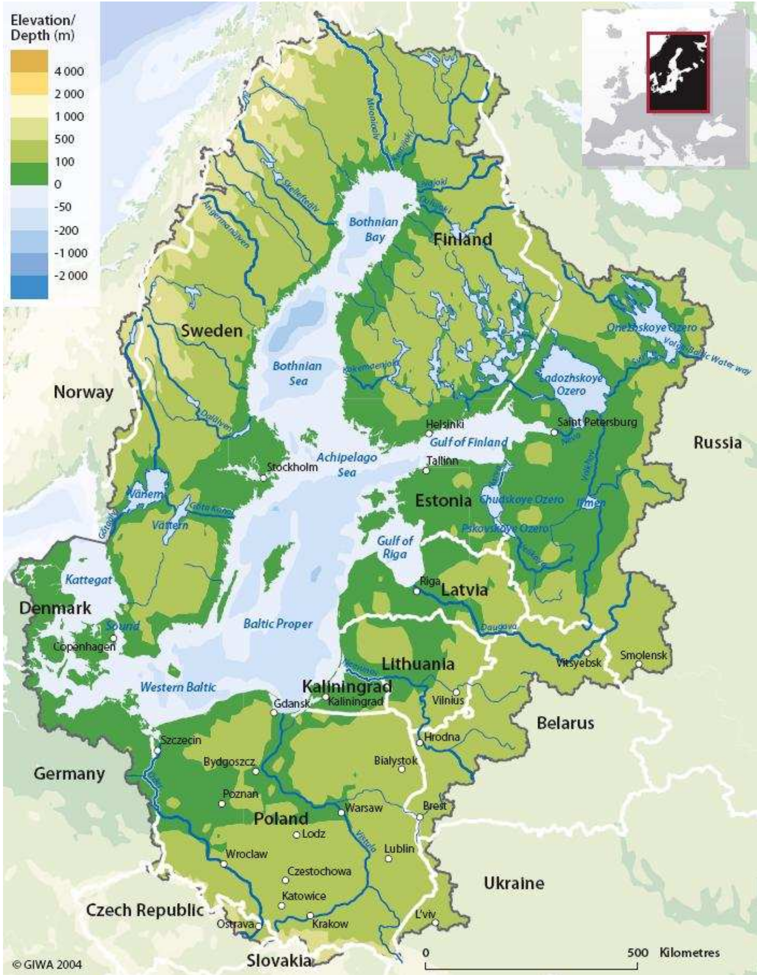
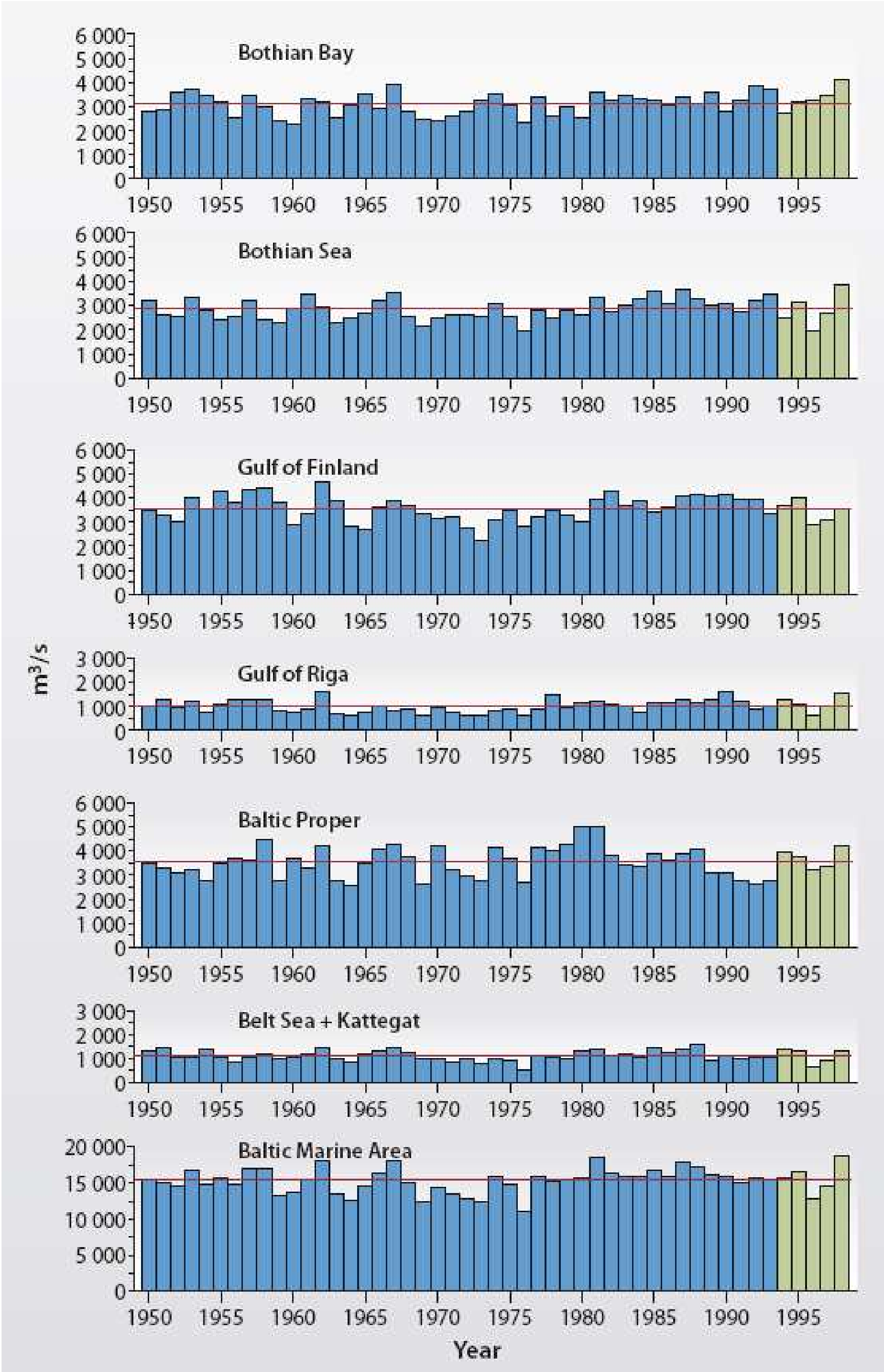
- Baltic Sea is a young sea and in glacial time it was a cold lake. Baltic Sea until now retains many features of lake.
- Baltic Sea is semi-closed, shallow, brackish water body having smooth salinity gradient and unique fauna and flora.
- Biodiversity of Baltic Sea is relatively low while in its own way is unique and needs special measures for its preservation.



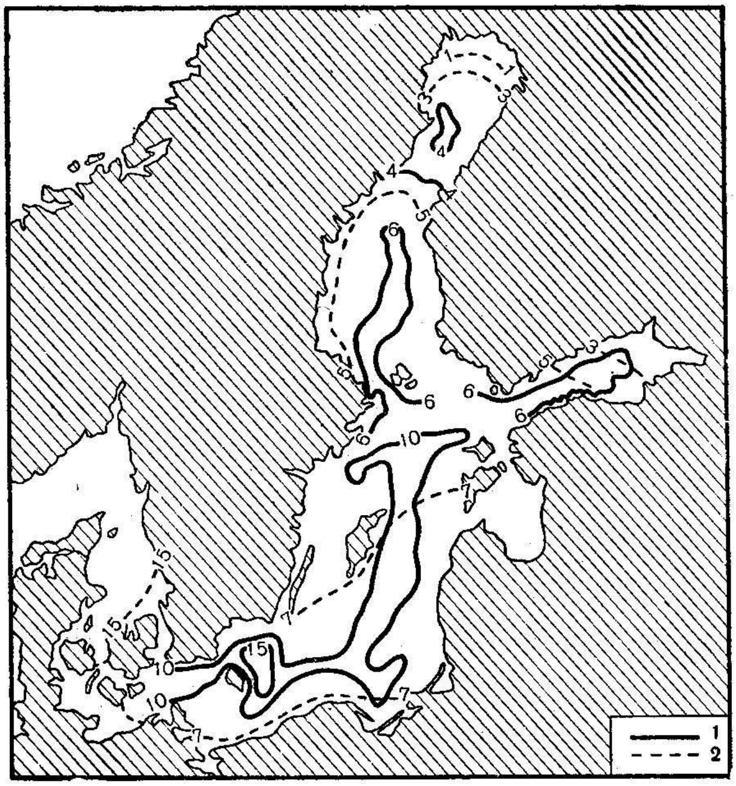
Sub-regions of Baltic Sea: 1. Baltic proper, 2. Kattegat, 3. The Sound, 4. Western Baltic, 5. Bothnian Bay, 6. Bothnian Sea, 7. Archipelago Sea, 8. Gulf of Finland, 9. Gulf of Riga.
Main rivers of Baltic Sea basin: Kattegat – 1. Götaälv; Baltic proper – 1. Göta Kanal, 2. Oder, 3. Vistula, 4. Nemunas; Bothnian Sea – 1. Dalälven, 2. Ångermanälven, 3. Kokemaenjoki; Bothnian Bay – 1. Skellefteälv, 2. Muonioalv, 3. Kemijoki, 4. Livajoki, 5. Oulujoki; Gulf of Finland – 1. Neva, 2. Narva; Gulf of Riga – 1. Daugava.



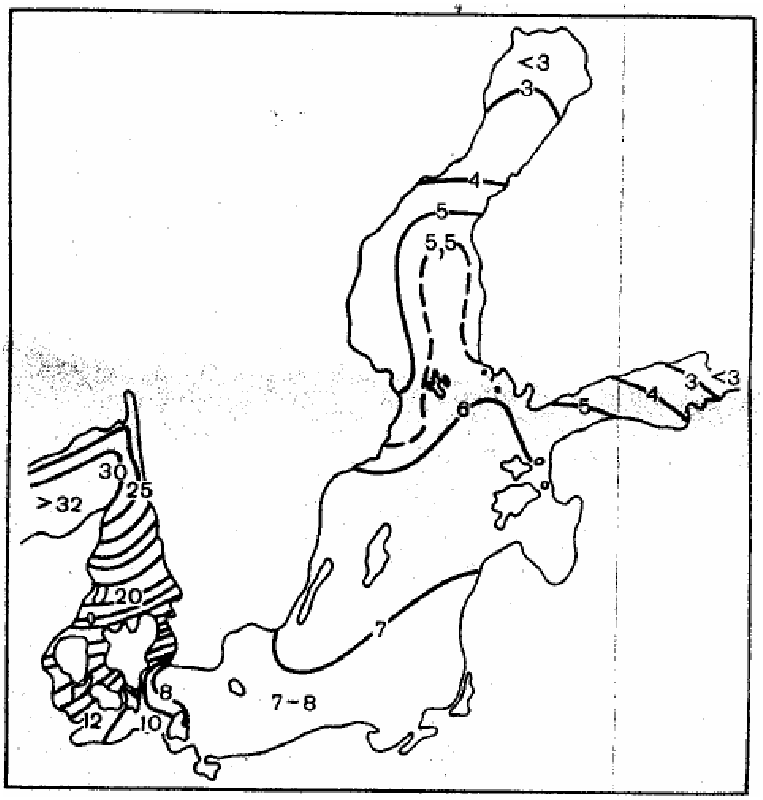
River run-off to the Baltic Sea and its various subcatchments from 1950 to 1998. *Note: The horizontal lines represent the mean values for the years 1950-1993. (Source: HELCOM 2002)*

Riverine waters are giving considerable contribution practically to all water areas of the Baltic Sea.

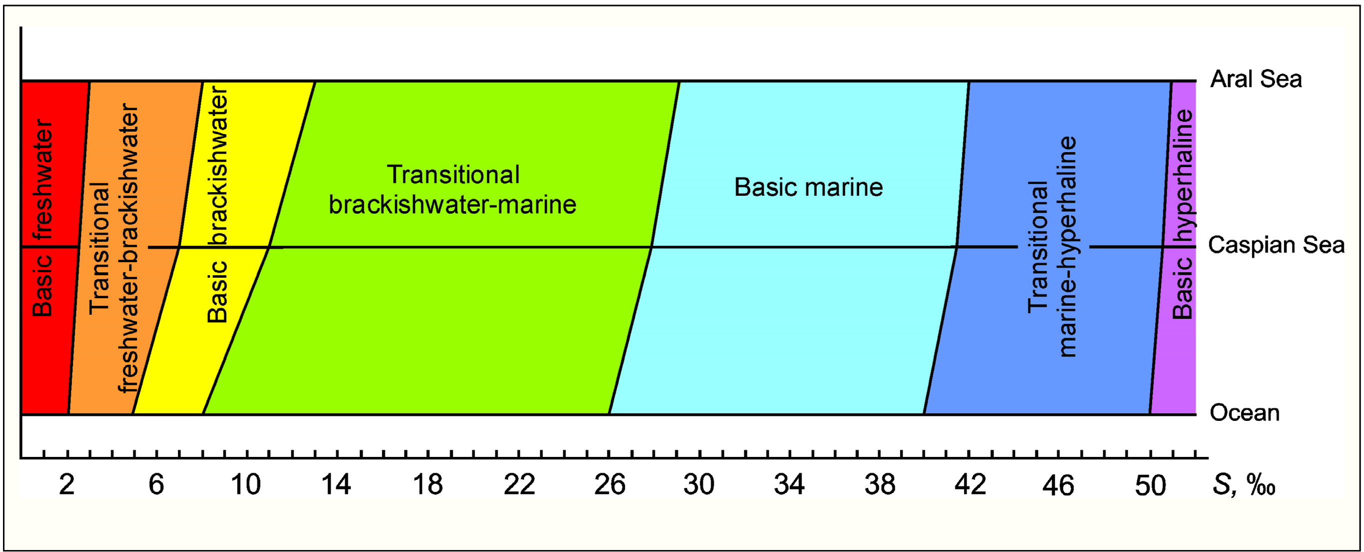
- In the Baltic Sea there are oligohaline and mesohaline water areas, and each of them has its own specific flora and fauna.
- The most freshened areas there are Gulf of Finland and Gulf of Bothnia.
- Central water area of Baltic Sea has pronounced mesohaline character.
- Only in Kattegat and Sound can polyhaline conditions be found.



Near-bottom (1) and surface (2) isohalines (‰) of the Baltic Sea (by S. Ekman).



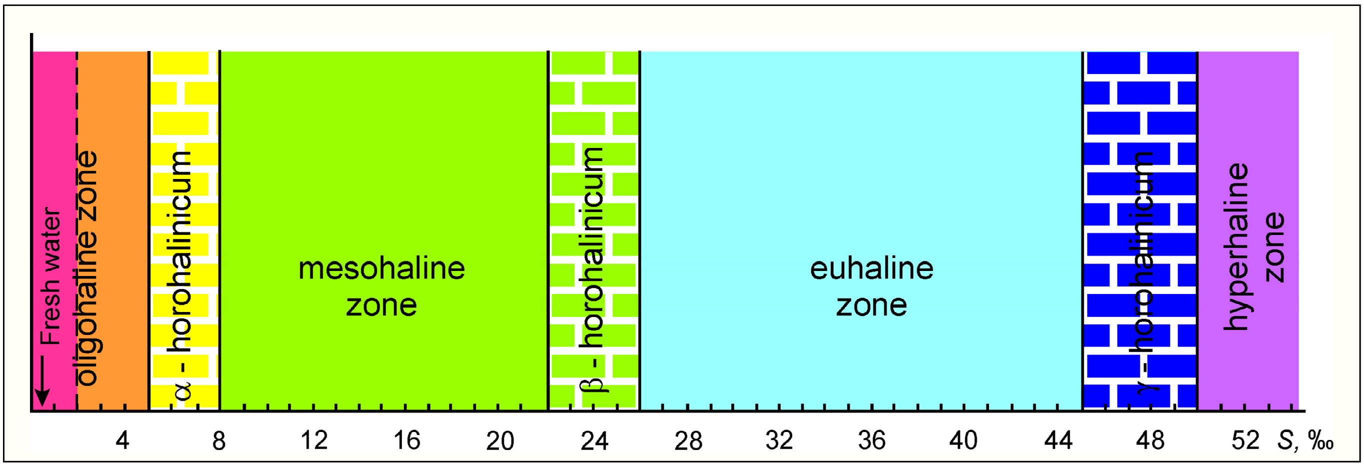
Salinity (‰) at surface in the Baltic Sea and in the zone of transition to the North Sea in August (by P.Hunfer, 1982)



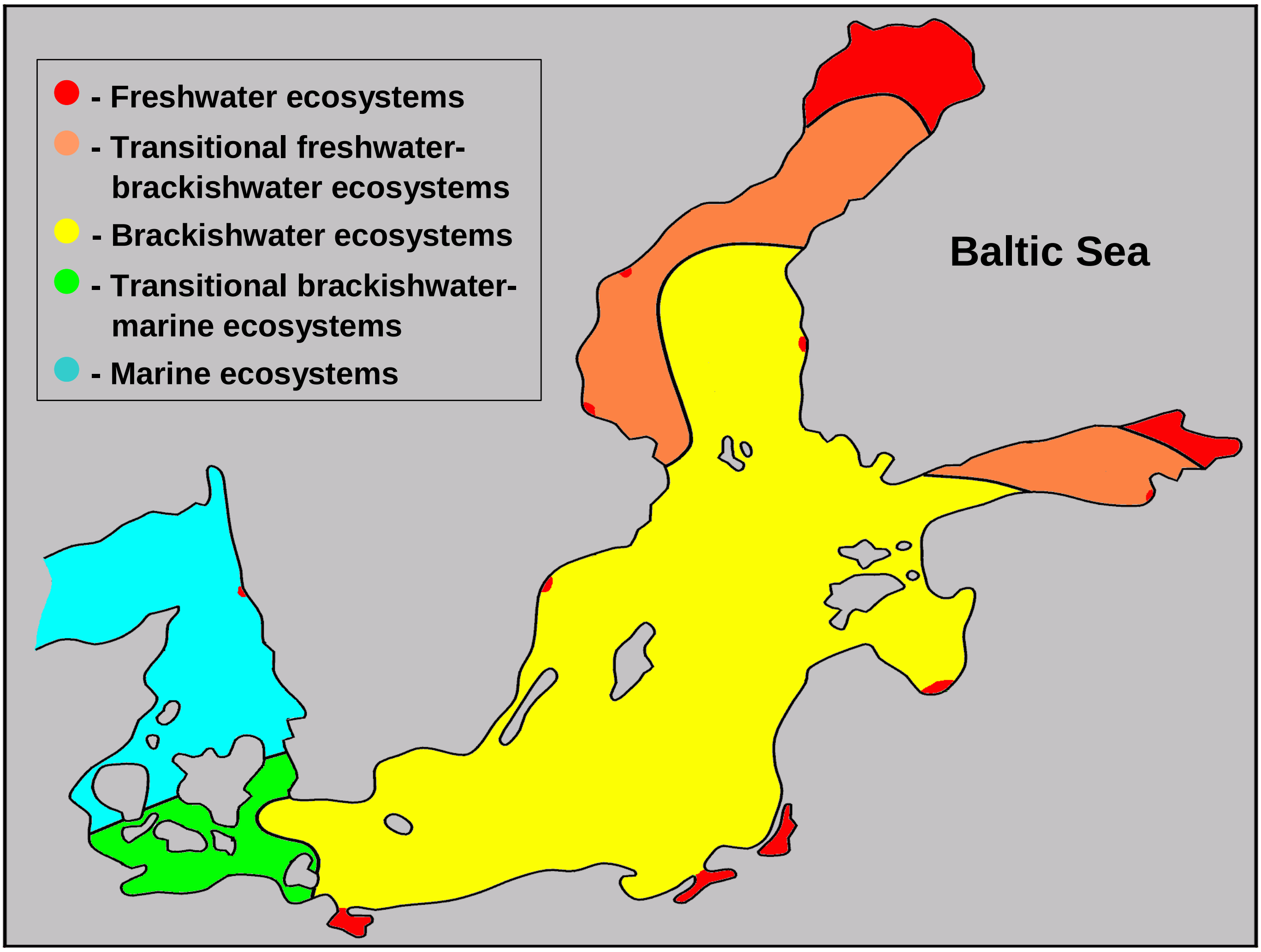
Following main principles of conception of relativity and plurality of salinity barrier zones (Aladin, 1986a,b, 1988) the following salinity zones were suggested for oceanic, Caspian and Aral waters.

Percentage of water areas of different salinity zones in different brackish water seas and lakes Area of different salinity zones in different brackish water seas and lakes.

Zones	Ocean	Caspian	Aral
Basic freshwater	0-2 ‰	0-2.5 ‰	0-3 ‰
Transitional freshwater-brackishwater	2-5 ‰	2.5-7 ‰	3-8 ‰
Basic brackishwater	5-8 ‰	7-11 ‰	8-13 ‰
Transitional brackishwater-marine	8-26 ‰	11-28 ‰	13-29 ‰
Basic marine	26-40 ‰	28-41 ‰	29-42 ‰
Transitional marine-hyperhaline	40-50 ‰	41-50.5 ‰	42-51 ‰
Basic hyperhaline	> 50 ‰	> 50.5 ‰	> 51 ‰



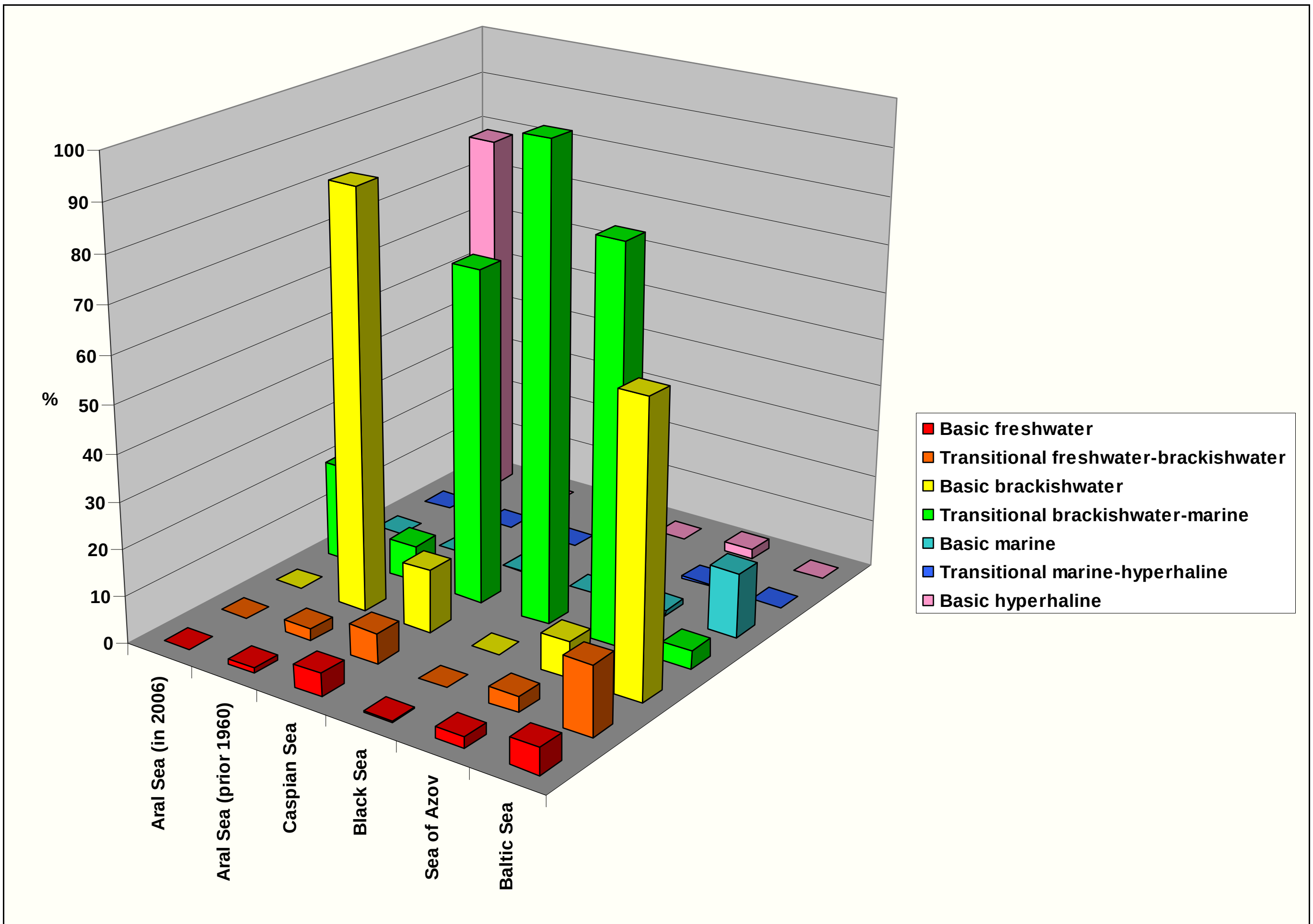
α-, β- and γ- horohalinicums in the waters classified by salinity (by: Aladin, 1986a,b, 1988; Khlebovich, 1989).



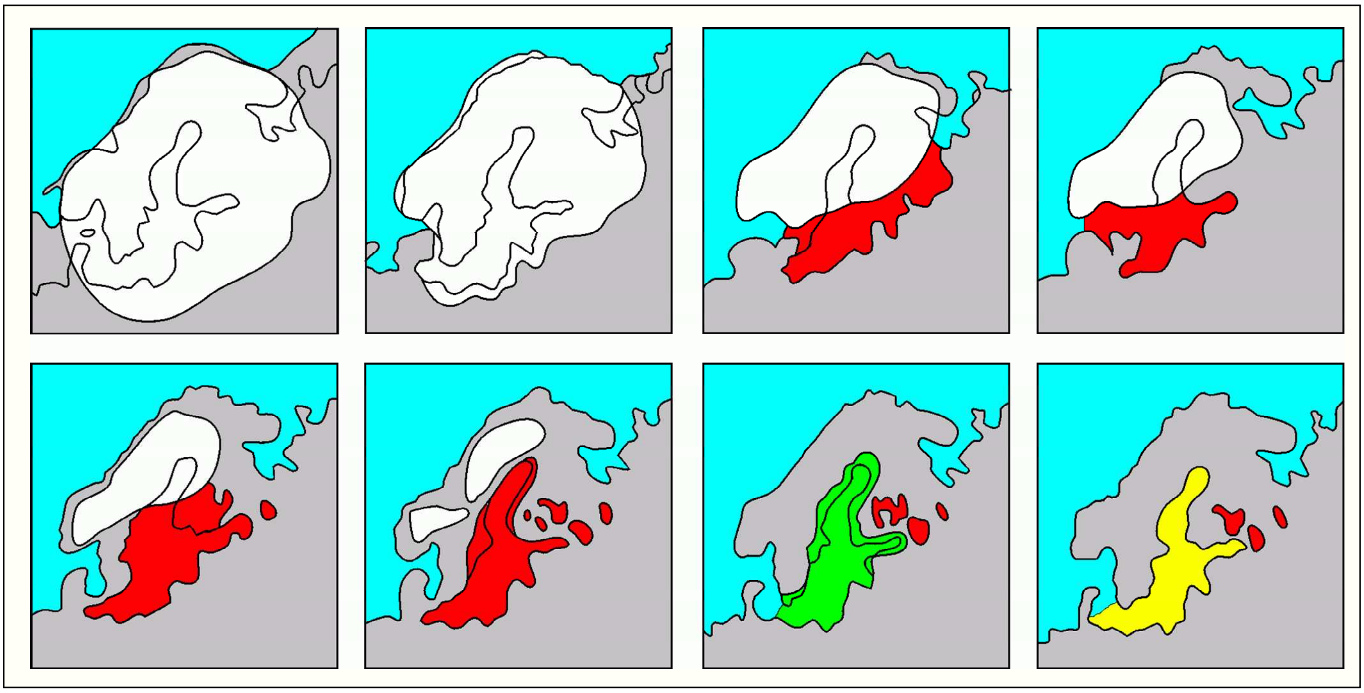
Percentage of water areas of different salinity zones in different brackishwater seas and lakes.

Zones	Aral Sea (in 2006)	Aral Sea (prior 1960)	Caspian Sea	Black Sea	Sea of Azov	Baltic Sea
Basic freshwater	0.01	0.93	5.02	0.25	2.26	5.63
Transitional freshwater-brackishwater	0.04	2.58	6.52	0.03	3.33	14.89
Basic brackishwater	0.23	88.65	13.42	0.02	7.87	61.54
Transitional brackishwater-marine	20.71	7.84	70.87	99.70	82.90	4.10
Basic marine	0.00	0.00	0.04	0.00	1.15	13.84
Transitional marine-hyperhaline	0.00	0.00	0.03	0.00	0.53	0.00
Basic hyperhaline	79.01	0.00	4.11	0.00	1.96	0.00

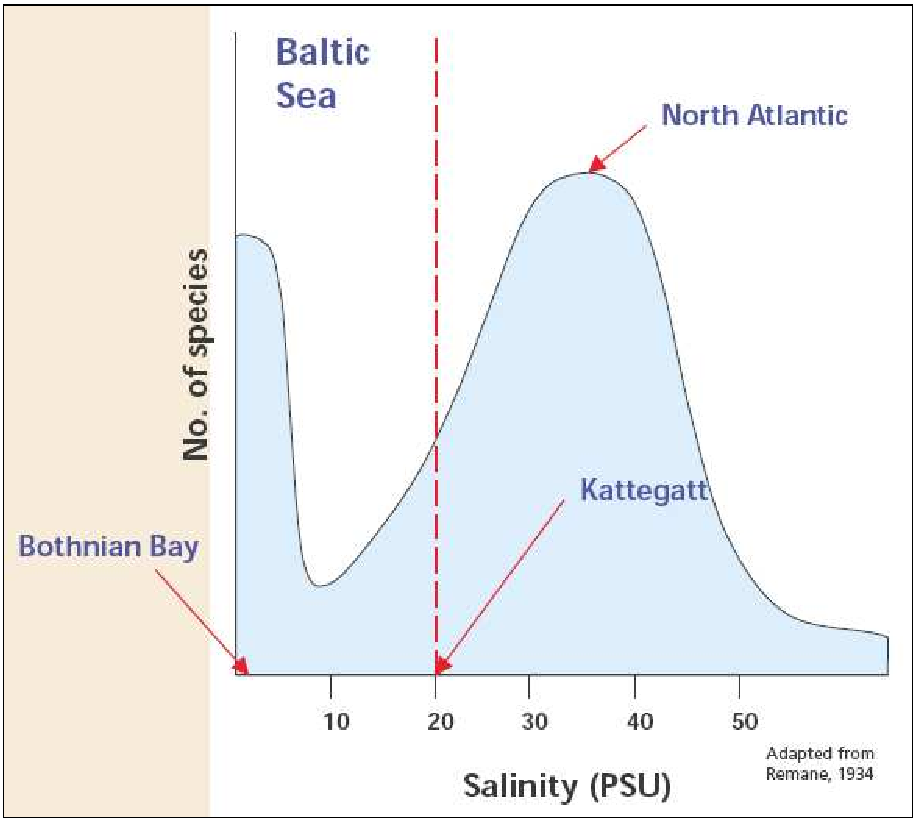
At present Baltic Sea is the only sea where basic brackishwater zone is occupying more than half of its area (> 60%).



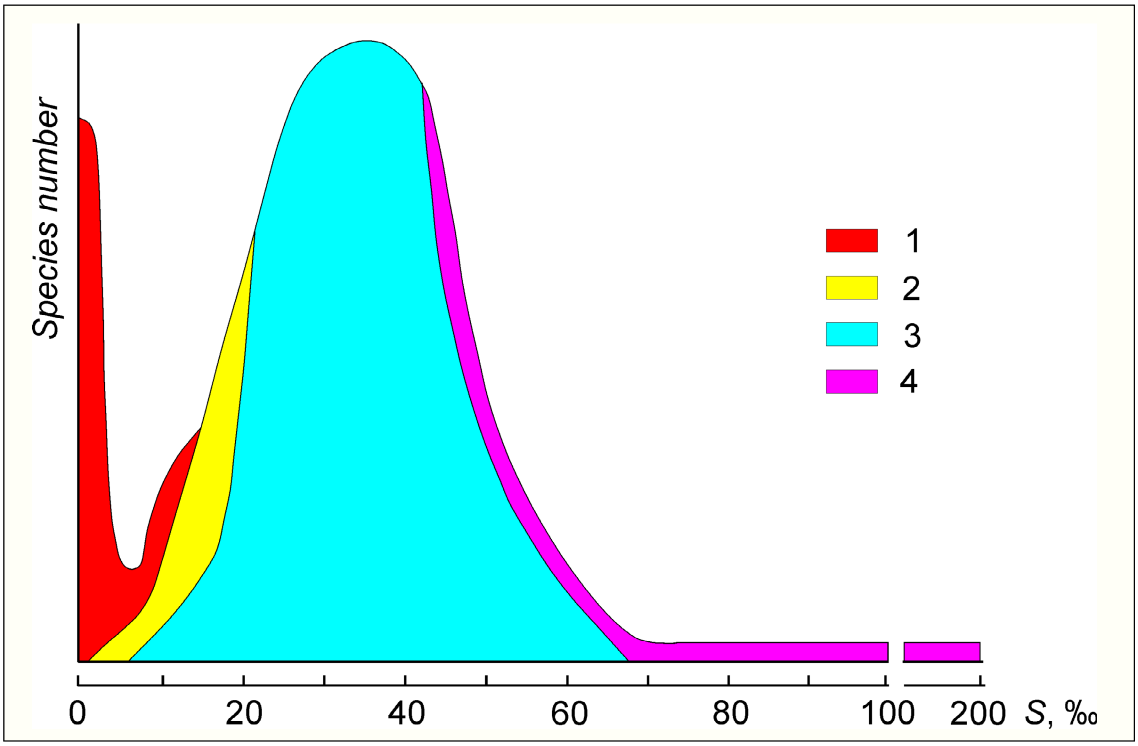
Area of different salinity zones in different brackish water seas and lakes.



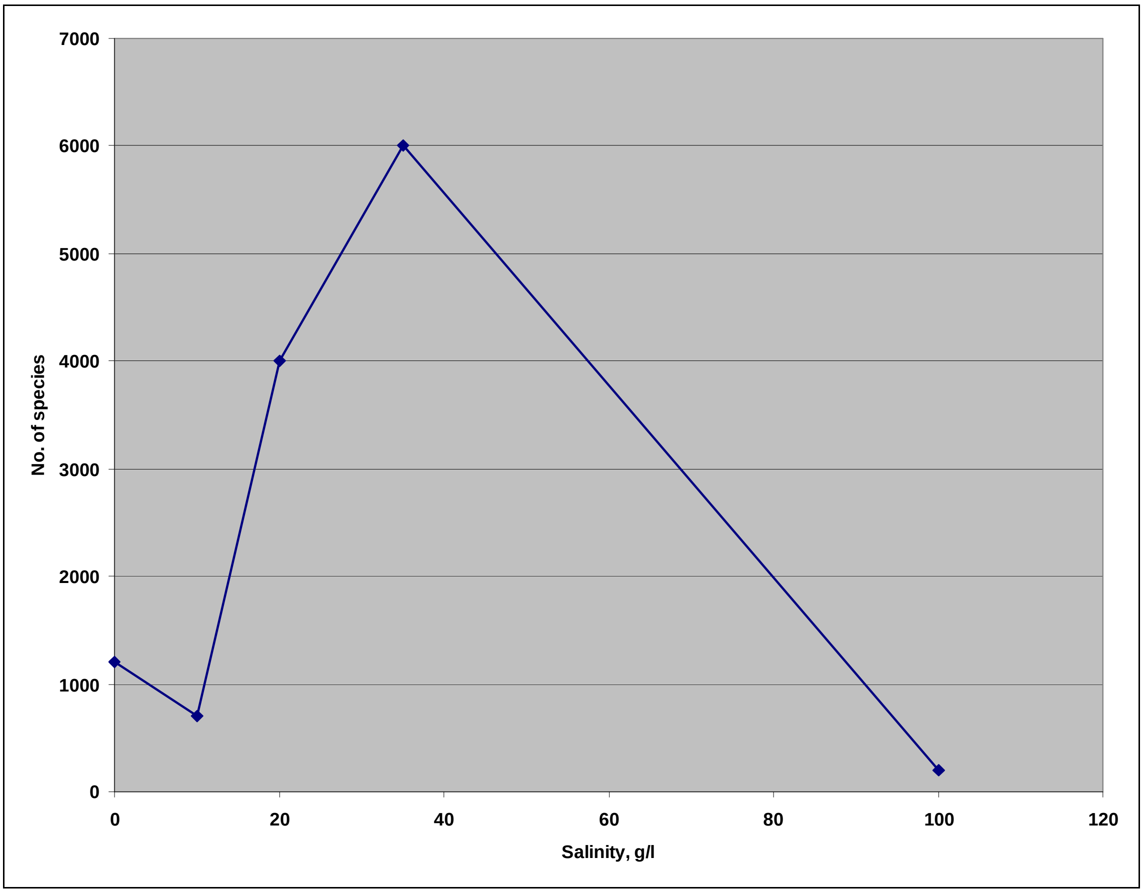
Water bodies of Paleo-Baltic Sea (by Zenkevich, 1963, with corrections and additions). 1 – maximal phase of the last glaciation; 2- Danish glaciation (15 ths B.P.); 3 – Baltic Glacial Lake (14 ths B.P.); 4 – Yoldia Sea (12 ths B.P.); 5 – Ancylus Lake-Sea (7 ths B.P.); 6 – last phase of Ancylus Lake-Sea (5 ths B.P.); 7 – Littorina Sea (4 ths B.P.); 8 – modern phase (since 2 ths B.P.). Indicated only average salinity without salinity gradient in the Baltic Sea: ● – 0-2‰; ● – 5-8‰; ● – 8-26‰; ● – 26-40‰.



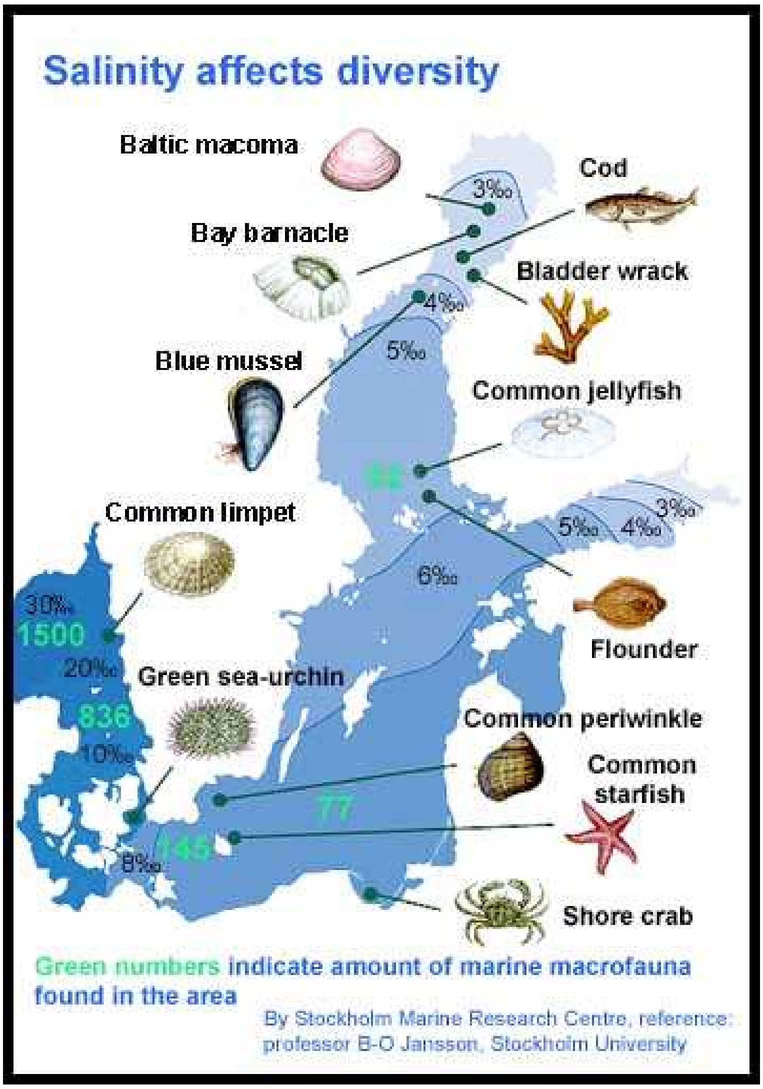
Changing of the species number in the Baltic Sea following salinity gradient.



Scheme of aquatic fauna pattern change in water bodies with different salinities (by: Remane, 1934; Khlebovich, 1962; Kinne, 1971; with additions and corrections): 1 – freshwater, 2 – brackish-water, 3 – marine, 4 – hyperhaline and ultrahaline species.



Changing of the species number following salinity gradient in the Baltic Sea.



Decreasing of marine species biodiversity following decreasing of the Baltic Sea salinity.

Number of fishes, free-living invertebrates and plants without micro-Metazoa, Protozoa and Bacteria in the Baltic Sea.

	By A.Alimov's formula ($n=199.21*S^{0.155}$)	From scientific literature by expert evaluation
Baltic Sea Proper	1370	700
Gulf of Finland	982	1000
Bay of Bothnia	1021	1100
Bothnian Sea	1144	1200
Gulf of Riga	896	900
Kattegat	985	4000

Large contribution for studying salinity influence on biodiversity have been made 2 scientists:
1. Prof. Otto Kinne and his theory on horohalinicum;
2. Prof. Vladislav Khlebovich and his theory of critical salinity.

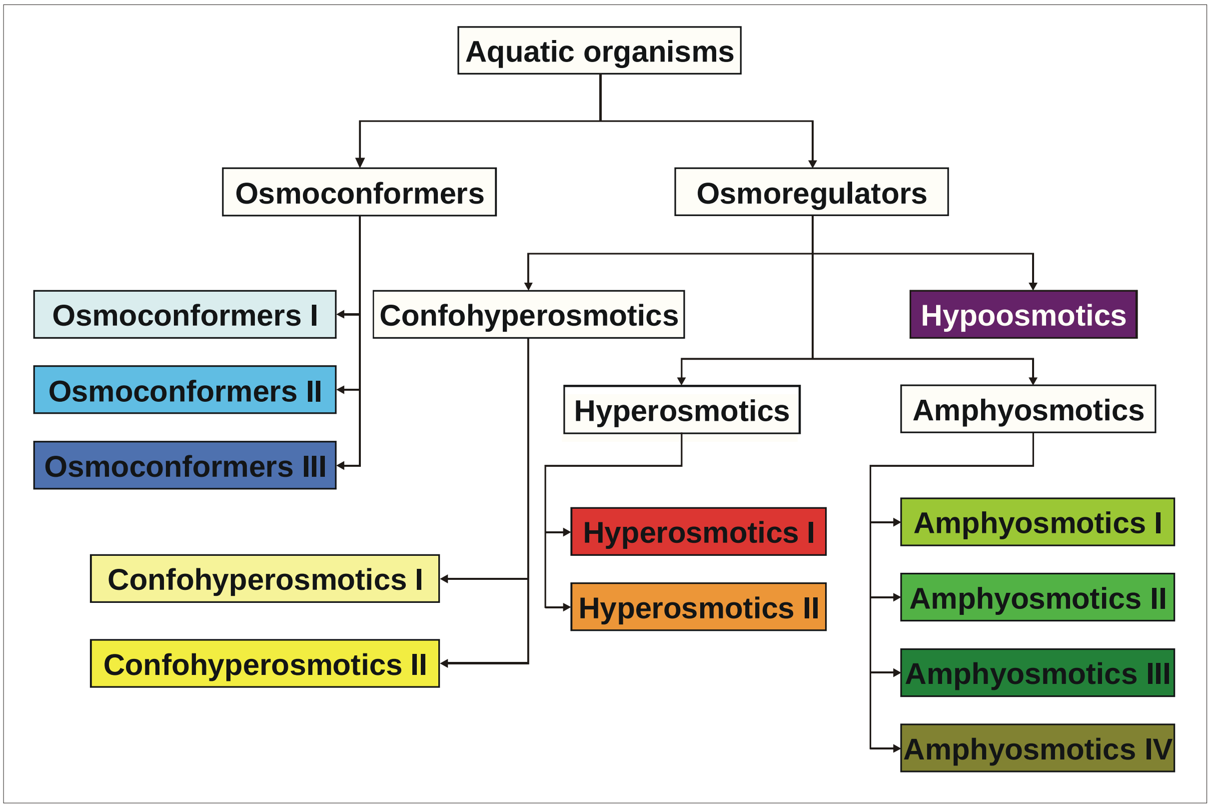
- Biodiversity of the Baltic Sea has been studied intensively since the middle of 19th century. Studies of Swedish zoologist Loven (1864) could be considered pioneering. It is important to also mention works of Möbius (1873) and Heinke (Möbius, Heinke, 1883), and also Brandt (1897) and Nordquist (1890).
- Since the beginning of 20th century, the number of works on the Baltic Sea biodiversity has increased. There were publications by Ekman (1913), Petersen (1913, 1914) and Thulin (1922). Later there were studies by Demel with co-authors (Demel et al., 1927-1954), by Remane (1933-1955), by Segersträle (1932-1958) and by Välikangas (1926-1933), by Kinne (1949-1970) and others.

Russian and soviet scientists also contributed to the studies of Baltic Sea biodiversity. A few of them, with years of their major scientific publications, include:
- Derjugin(1923-1924, 1934-1935)
- Nikolaev(1949-1985)
- Shurin(1957)
- Zenkevich(1963)
- Khlebovich(1974)
- Järvekülg(1960-1999)

and many others.

Above-mentioned scientists from Baltic Sea states have demonstrated that biodiversity of this young sea was formed in the postglacial time and is highly heterogeneous by its composition. It consists of three main components:
1. marine
2. freshwater
3. brackishwater (*sensu stricta*).

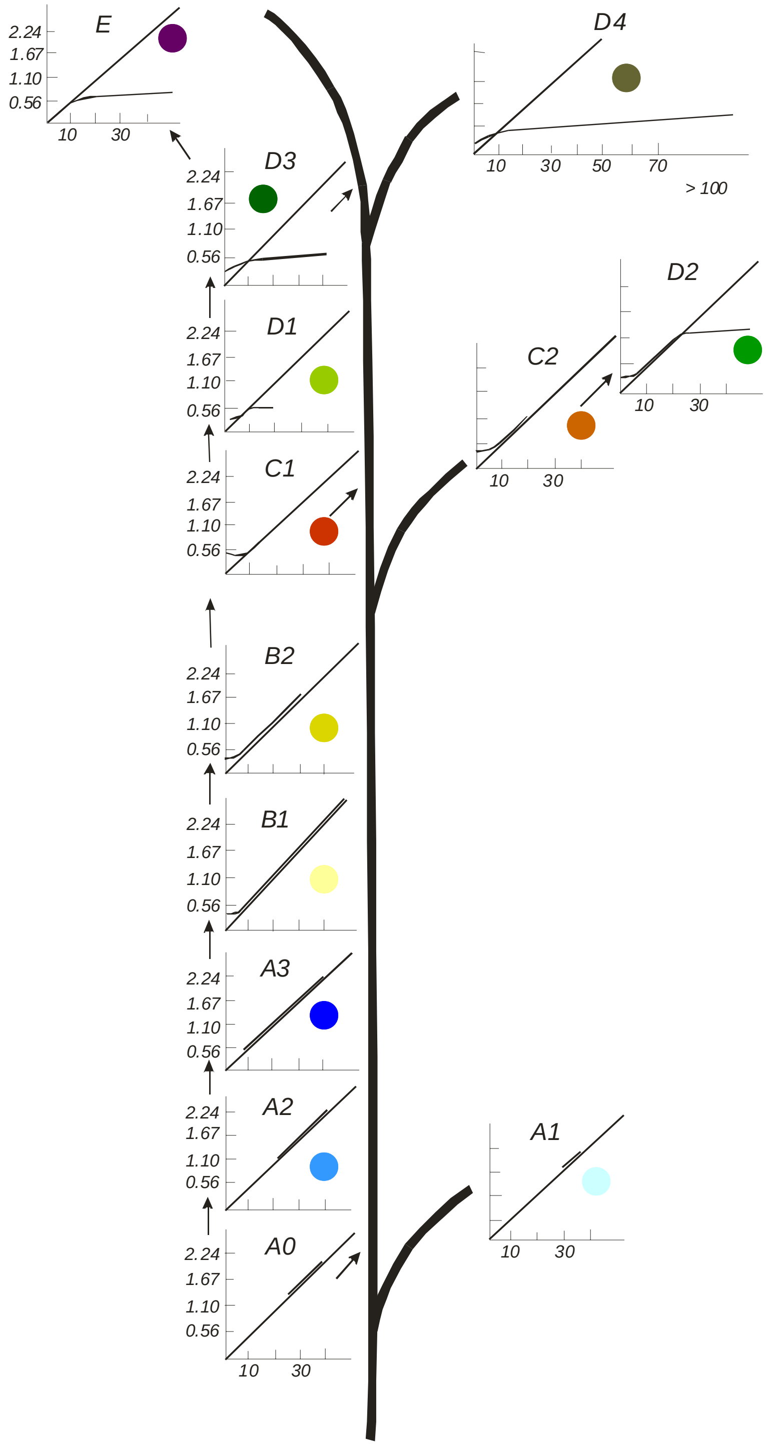
The first group is the main part of Baltic Sea biota. It includes relicts if previous geological times and immigrants from remote marine water bodies.
The second group includes large number of Baltic Sea inhabitants, which come together with freshwater inflow.
The third group is represented by large number of species and is divided into 2 subgroups:
1. Ancient brackishwater arctic relicts (pseudorelicts-immigrants) formed in the glacial time in freshened areas of arctic basin that migrated into the Baltic Sea in postglacial time from the North-East and East possibly via fresh waters.
2. Brackishwater forms originated from freshwater ones.



Classification of osmoconformers and osmoregulators.

General table of osmoconformers and osmoregulators.

Osmoconformers	Osmoregulators			
	Confohyperosmotics	Hyperosmotics	Amphyosmotics	Hypoosmotics
I	I	I	I	I
II	II	II	II	
III			III	
			IV	



Evolution of all known types of osmoregulation (by: Aladin, 1996):

A0 – Hypothetic ancestral osmoconformer;

A1 – Stenohaline marine hydrobionts (osmoconformers I) – 30-36‰;

A2 – Marine hydrobionts (osmoconformers II) – 20-40‰;

A3 – Euryhaline marine hydrobionts (osmoconformers III) – 8-40‰;

B1 – Widely euryhaline marine hydrobionts (confohyperosmotics I) – 3-50‰;

B2 – Brackish water hydrobionts of marine origin (confohyperosmotics II) – 0-30‰;

C1 – Freshwater hydrobionts (hyperosmotics I) – 0-8‰;

C2 – Brackish water hydrobionts of freshwater origin (hyperosmotics II or secondary confohyperosmotics) – 0-20‰;

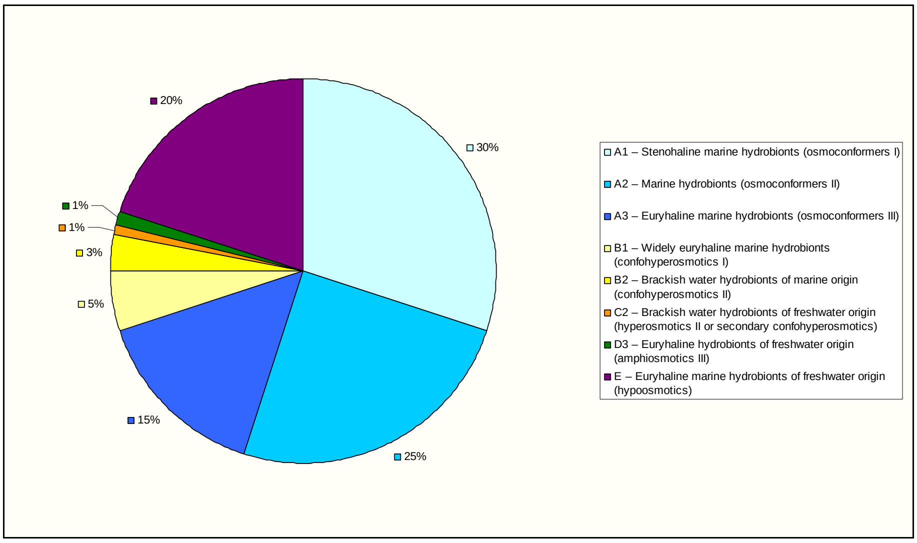
D1 – Some Caspian Brackish water hydrobionts (amphiosmotics I) – 0-20‰;

D2 – Some euryhaline Australian hydrobionts of freshwater origin (amphiosmotics II) – 0-50‰;

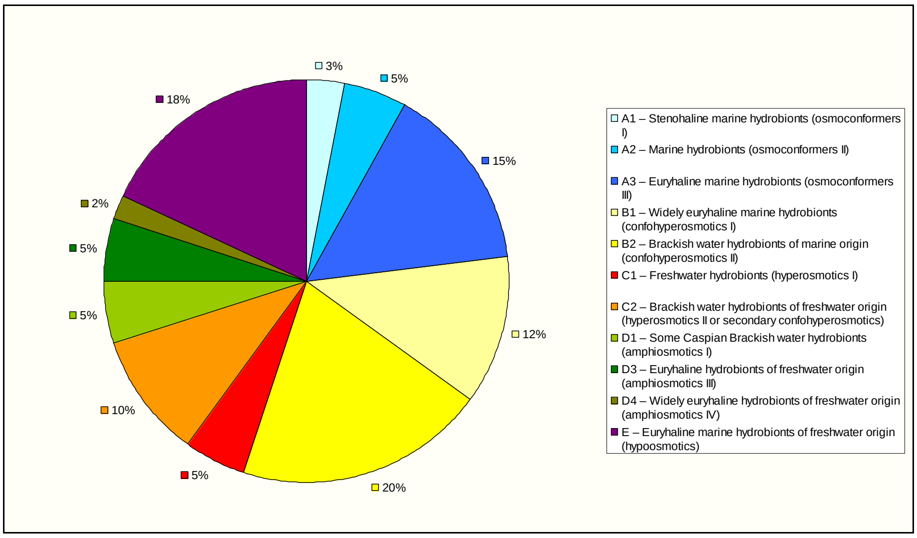
D3 – Euryhaline hydrobionts of freshwater origin (amphiosmotics III) – 0-50‰;

D4 – Widely euryhaline hydrobionts of freshwater origin (amphiosmotics IV) – 0-300‰;

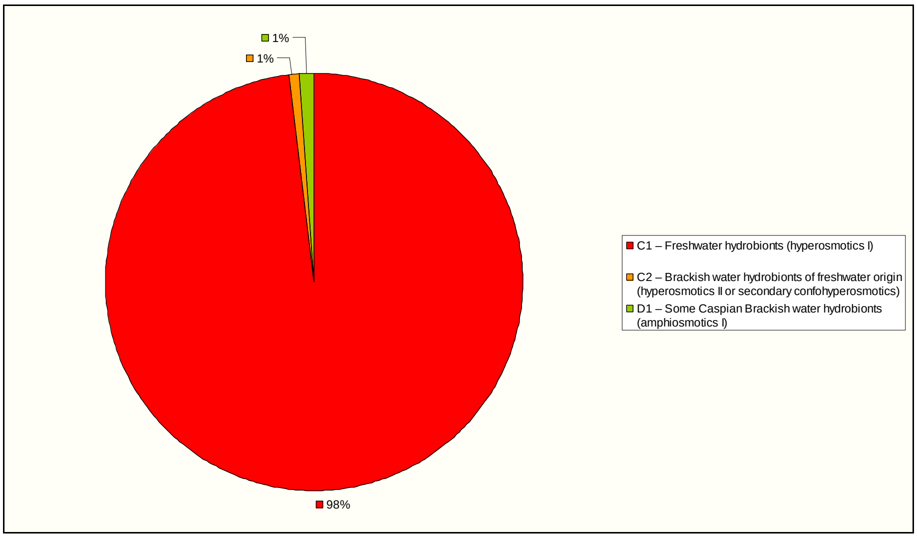
E – Euryhaline marine hydrobionts of freshwater origin (hypoosmotics) – 8-50‰.



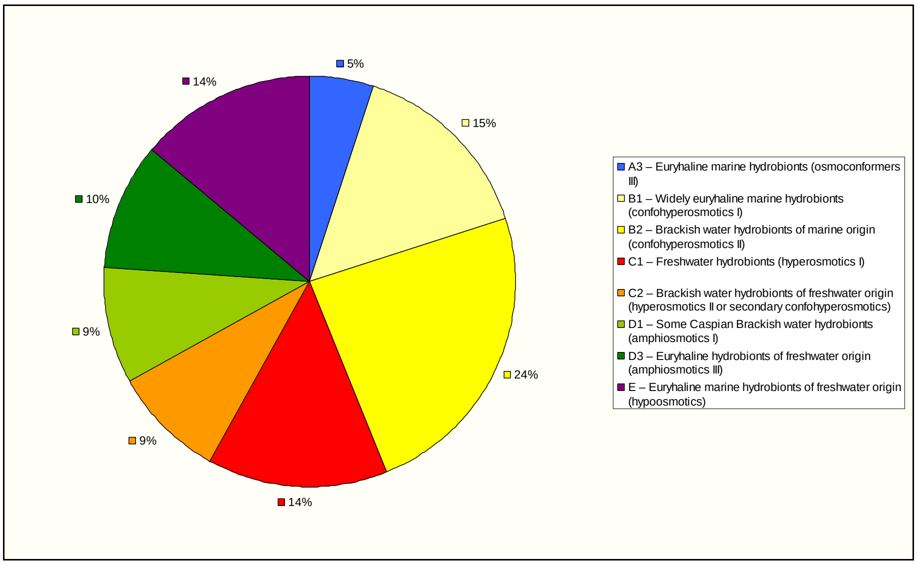
Percentage of different types of osmoconformers and osmoregulators in the World Ocean and fully saline seas as Barents Sea, Sea of Japan, etc.



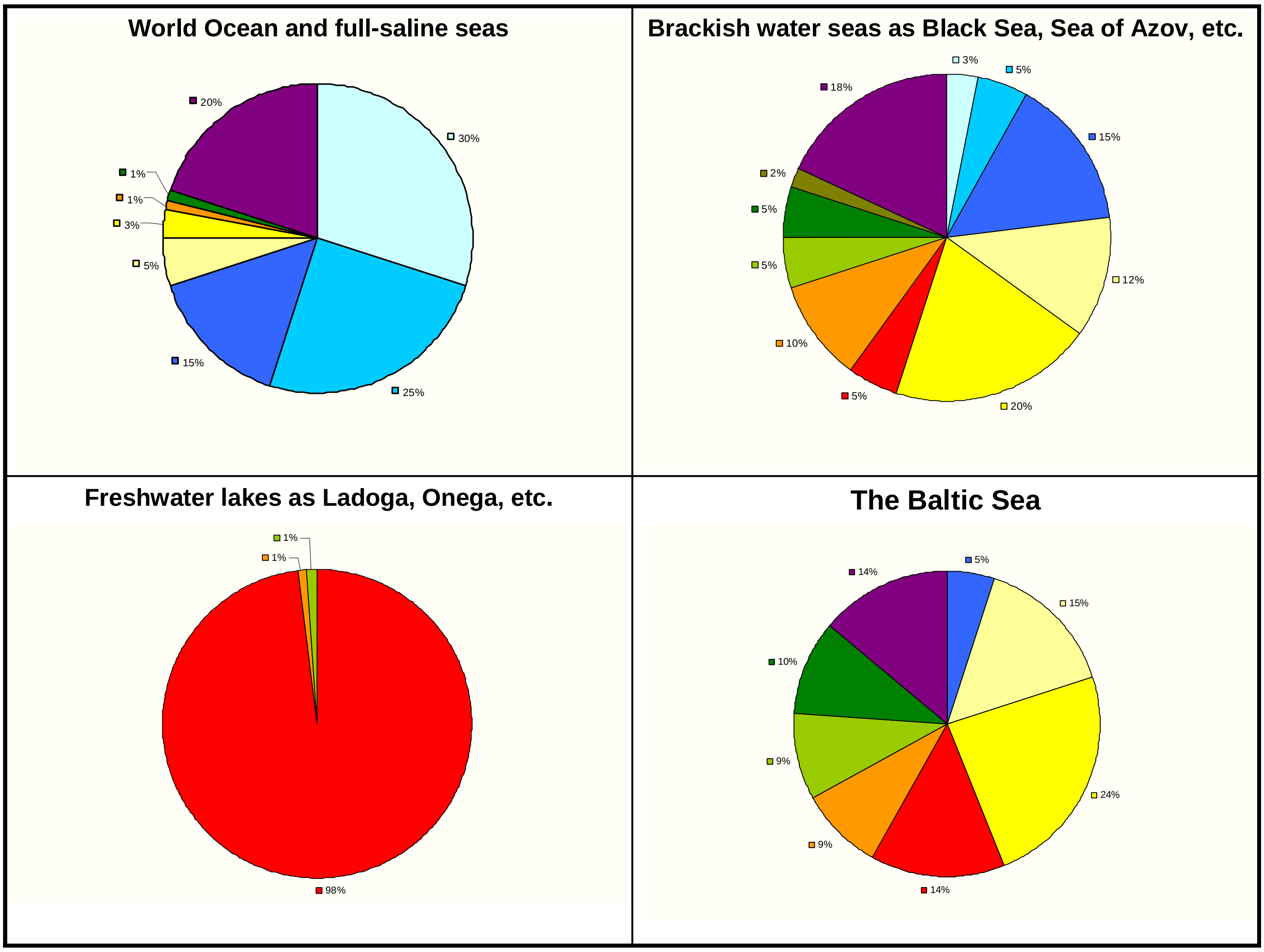
Percentage of different types of osmoconformers and osmoregulators in brackish water seas as Black Sea, Sea of Azov, etc.

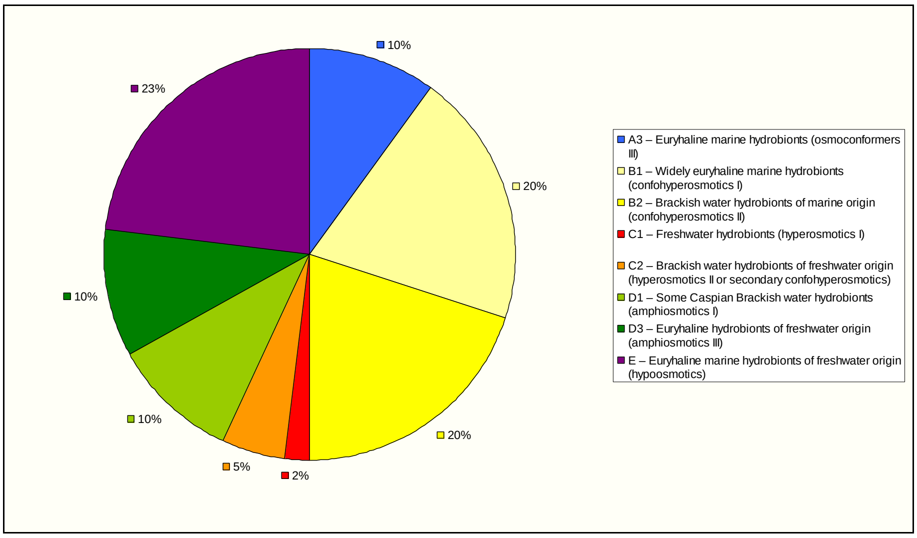


Percentage of different types of osmoconformers and osmoregulators in freshwater lakes as Ladoga, Onega, etc.

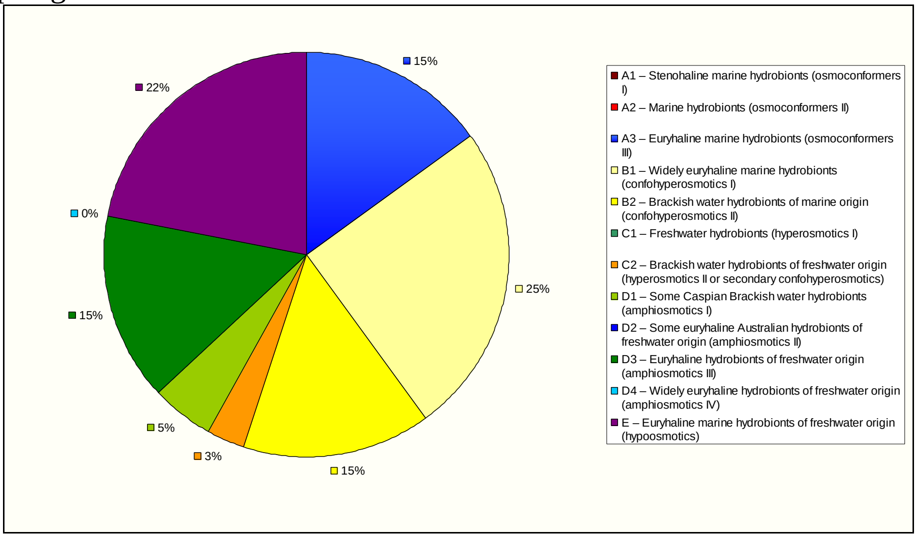


Percentage of different types of osmoconformers and osmoregulators in the Baltic Sea.

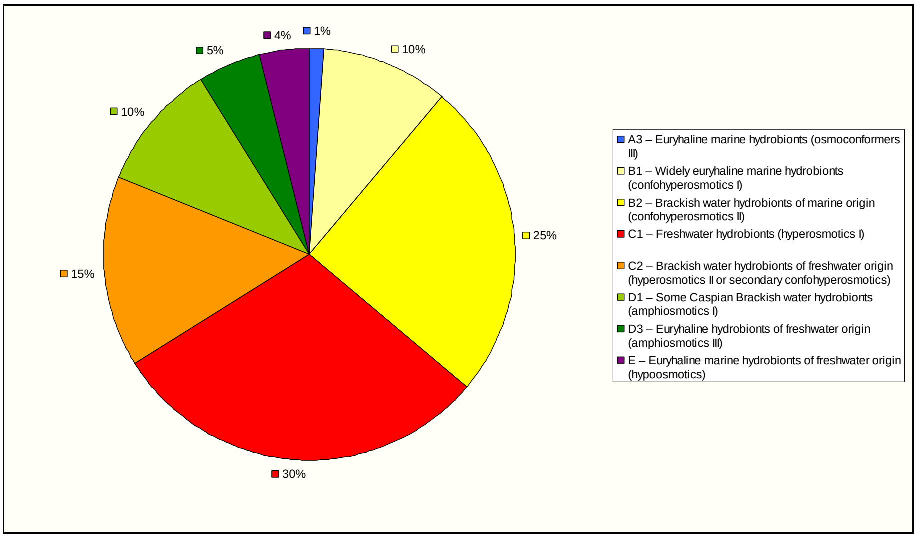




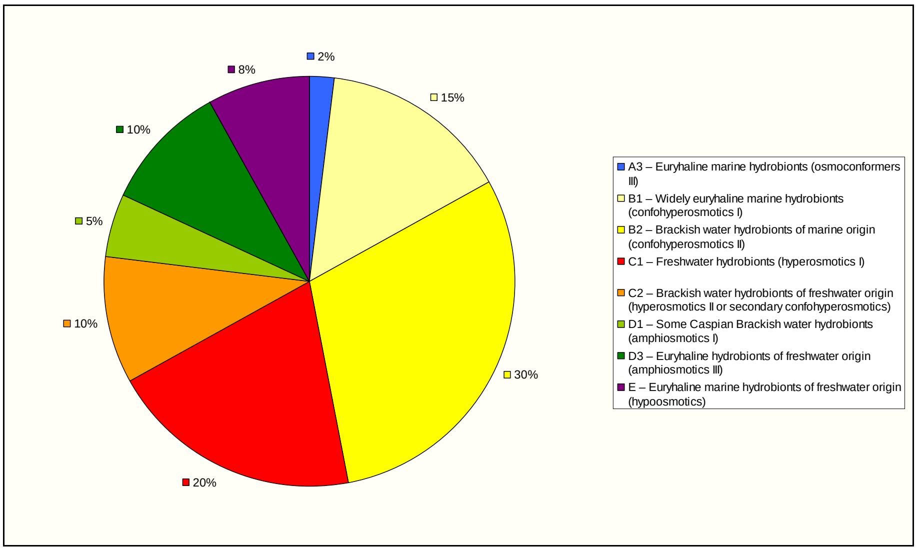
Percentage of different types of osmoconformers and osmoregulators in the Western Baltic, Baltic Sea proper and Archipelago Sea.



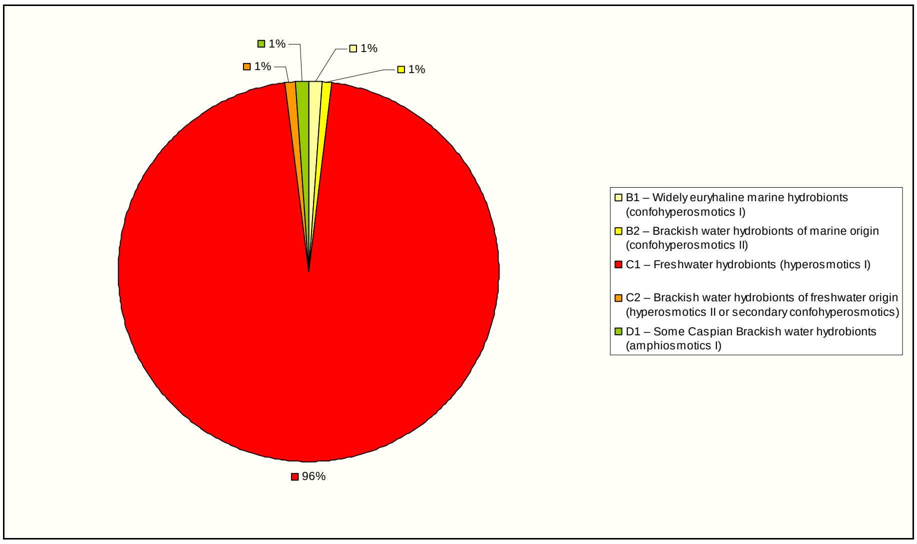
Percentage of different types of osmoconformers and osmoregulators in the Kattegat and the Sound.



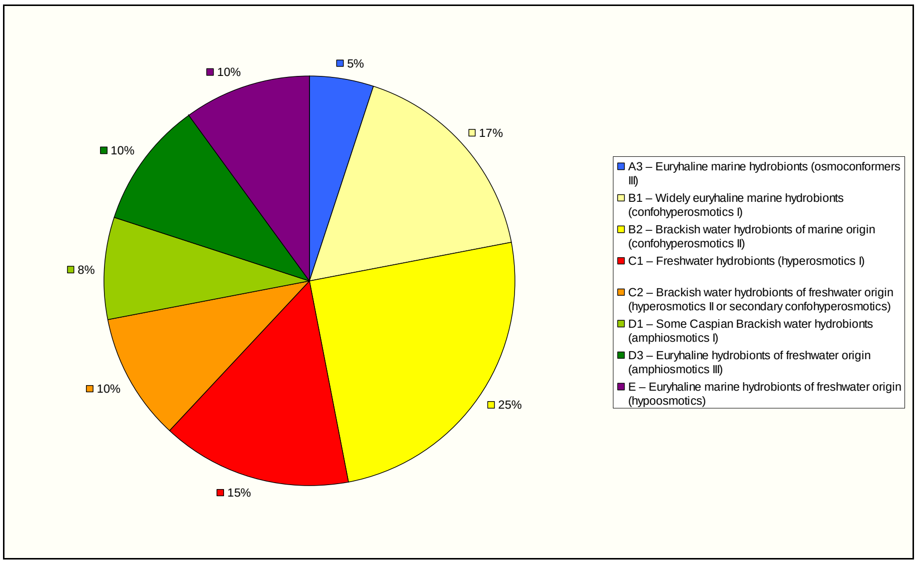
Percentage of different types of osmoconformers and osmoregulators in the Bothnian Bay and Bothnian Sea.



Percentage of different types of osmoconformers and osmoregulators in the Gulf of Finland.

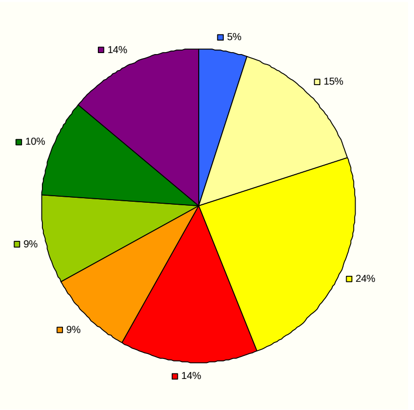


Percentage of different types of osmoconformers and osmoregulators in Neva Bay.

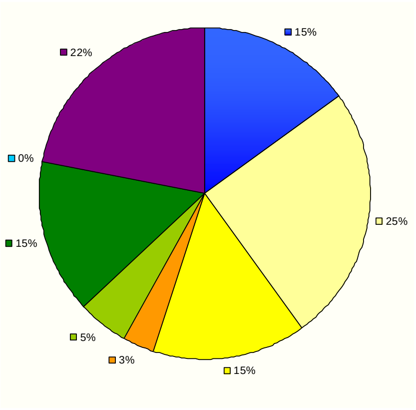


Percentage of different types of osmoconformers and osmoregulators in the Gulf of Riga.

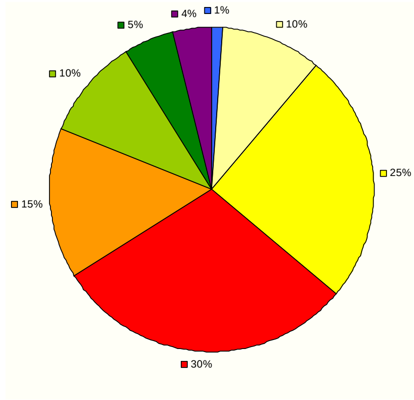
The Baltic Sea



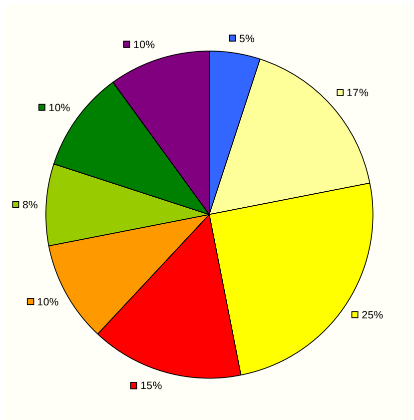
Kattegat and the Sound



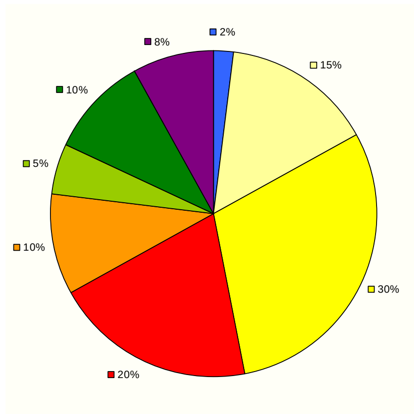
Bothnian Bay and Bothnian Sea



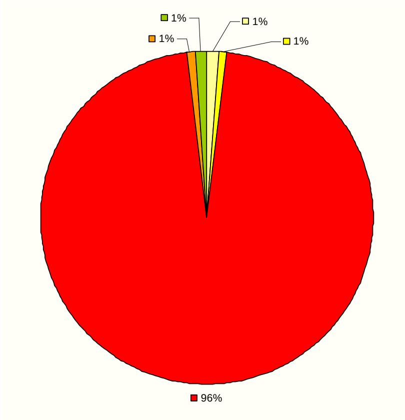
Gulf of Riga



Gulf of Finland



Neva bay



Baltic Sea Alien Species

Species	Ecofunctional group	Origin	Species status	Vector of introduction	First observed	Distribution in the Baltic Sea	Salinity in native habitats	Salinity in the Baltic Sea	Salinity tolerant range, ‰	Type of osmoregulation
Xiphosura										
Limulus polyphemus	benthic omnivores	North America	-	shipping	1968	Kattegat and Belt Sea	-	-		A1
Crustacea										
Acartia tonsa Dana, 1849	zooplankton suspension feeders	Indo-Pacific, North America	+	shipping	1925	Gulf of Bothnia, Gulf of Finland, Gulf of Riga, Kattegat and Belt Sea, Odra Lagoon	b-Mesohaline to Polymixohaline	b-Oligohaline to Polymixohaline	5-30	B1
Ameira divagans Nicholls, 1939	zooplankton suspension feeders	North America	+	shipping	1974 **	Kattegat and Belt Sea	-	-		?
Balanus improvisus (Darwin 1854)	benthic suspension feeders	North America	+	shipping	1844	Baltic Proper, Curonian Lagoon, Gulf of Bothnia, Gulf of Finland, Gulf of Riga, Kattegat and Belt Sea, Odra Lagoon, Vistula Lagoon	b-Oligohaline to Euhaline	b-Oligohaline to Polymixohaline	0.5-40	B1
Callinectes sapidus Rathbun, 1896	benthic predators	North America	-	shipping	1951	Kattegat and Belt Sea	b-Oligohaline to Euhaline	a-Mesohaline	0.5-40	B1
Cercopagis pengoi (Ostroumov, 1891)	zooplankton predators	Ponto-Caspian	+	shipping	1992	Baltic Proper, Curonian Lagoon, Gulf of Bothnia, Gulf of Finland, Gulf of, Kattegat and Belt Sea, Vistula Lagoon	Limnetic to a-Mesohaline	b-Oligohaline to b-Mesohaline	0-18	B2
Chaetogammarus ischnus (Stebbing, 1906)	nekto-benthic invertebrates	Ponto-Caspian	+	stocking	1964	Curonian Lagoon, Gulf of Finland, Odra Lagoon, Vistula Lagoon	Limnetic to a-Mesohaline	Limnetic to a-Oligohaline	0-18	B2
Chaetogammarus warpachowskyi (G.O. Sars, 1894)	nekto-benthic invertebrates	Ponto-Caspian	+	stocking	1964	Curonian Lagoon	Limnetic to b-Mesohaline	Limnetic to b-Mesohaline	0-10	B2

Species	Ecofunctional group	Origin	Species status	Vector of introduction	First observed	Distribution in the Baltic Sea	Salinity in native habitats	Salinity in the Baltic Sea	Salinity tolerant range, ‰	Type of osmoregulation
Chelicorophium curvispinum (G. O. Sars, 1895)	benthic deposit feeders	Ponto-Caspian	+	shipping	1920 **	Curonian Lagoon, Kattegat and Belt Sea, Odra Lagoon, Vistula Lagoon	b-Mesohaline to a-Mesohaline	Limnetic to b-Mesohaline	5-18	B2
Cornigerius maeoticus maeoticus (Pengo, 1879)	zooplankton predators	Ponto-Caspian	?	shipping	2003	Gulf of Finland	-	a-Oligohaline		D1
Dikerogammarus haemobaphes (Eichwald, 1841)	nekto-benthic invertebrates	Ponto-Caspian	+	stocking	1997	Vistula Lagoon	-	Limnetic to b-Oligohaline		B2
Dikerogammarus villosus Sovinskij	nekto-benthic invertebrates	Ponto-Caspian	+	stocking	1999	Odra Lagoon	-	Limnetic to b-Oligohaline		B2
Eriocheir sinensis (Milne Edwards, 1853)	benthic omnivores	China Seas	+	shipping	1926	Baltic Proper, Curonian Lagoon, Gulf of Bothnia, Gulf of Finland, Gulf of Riga, Kattegat and Belt Sea, Odra Lagoon, Vistula Lagoon	Limnetic to Polymixohaline	Limnetic to Polymixohaline	0-30	B2
Evadne anonyx Sars, 1887	zooplankton predators	Ponto-Caspian	+	shipping	2000	Gulf of Finland	a-Mesohaline	b-Oligohaline	10-18	D1
Gammarus tigrinus Sexton, 1939	nekto-benthic invertebrates	North America	+	shipping	1975	Curonian Lagoon, Darss-Zingst Boddens, Gulf of Finland, Gulf of Riga, Kattegat and Belt Sea, Odra Lagoon, Vistula Lagoon	Limnetic to Polymixohaline	Limnetic to Polymixohaline	0-30	B2
Gmelinoides fasciatus (Stebbing, 1899)	nekto-benthic invertebrates	Asia, Siberia (inland waters)	+	stocking	1972	Gulf of Finland	Limnetic	Limnetic to b-Oligohaline	0-0.5	B2
Hemimysis anomala G.O. Sars, 1907	nekto-benthic invertebrates	Ponto-Caspian	+	stocking	1962	Baltic Proper, Curonian Lagoon, Gulf of Bothnia, Gulf of Finland, Odra Lagoon, Vistula Lagoon	Limnetic to a-Mesohaline	Limnetic to b-Mesohaline	0-18	C2

Species	Ecofunctional group	Origin	Species status	Vector of introduction	First observed	Distribution in the Baltic Sea	Salinity in native habitats	Salinity in the Baltic Sea	Salinity tolerant range, ‰	Type of osmoregu lation
Jaera sarsi Valkanov, 1936	benthic omnivores	Ponto-Caspian	?	unknown	2004	Gulf of Finland	-	-		
Limnomysis benedeni Czerniavsky, 1882	nekto-benthic invertebrates	Ponto-Caspian	+	stocking	1962	Curonian Lagoon	Limnetic to a-Mesohaline	Limnetic to a-Oligohaline	0-18	C2
Obessogammarus crassus (G.O. Sars, 1894)	nekto-benthic invertebrates	Ponto-Caspian	+	stocking	1962	Curonian Lagoon, Vistula Lagoon	Limnetic to a-Mesohaline	Limnetic to a-Oligohaline	0-18	B2
Orchestia cavimana Heller, 1865	nekto-benthic invertebrates	Ponto-Caspian	+	shipping	1970 **	Baltic Proper, Odra Lagoon	-	-		
Orconectes limosus (Rafinesque, 1817)	benthic omnivores	North America	+	stocking	1890	Curonian Lagoon, Odra Lagoon	-	Limnetic to b-Mesohaline		
Orconectes virilis (Hagen, 1870)	benthic omnivores	North America	+	stocking	1960	Kattegat and Belt Sea	-	-		
Pacifastacus leniusculus (Dana, 1852)	benthic omnivores	North America	+	stocking	1960 **	Gulf of Bothnia	-	a-Oligohaline		C1
Palaemon elegans Rathke, 1837	benthic omnivores	-	?	shipping	1920 **	Baltic Proper, Gulf of Finland, Kattegat and Belt Sea, Vistula Lagoon	-	b-Oligohaline to a-Oligohaline		B1
Palaemon longirostris Milne Edwards, 1837	-	West Europe (Atlantic coast)	?	?	1999	Baltic Proper	-	-		B1
Paramysis lacustris (Czerniavskyi, 1882)	nekto-benthic invertebrates	Ponto-Caspian	+	stocking	1962	Curonian Lagoon, Gulf of Finland	Limnetic to a-Mesohaline	Limnetic to b-Mesohaline	0-18	B2
Pomatocypris humilis Sars	benthic deposit feeders	Africa, NW coast	?	shipping	1948	-	-	-		D3
Pontogammarus robustoides (G. O. Sars, 1894)	nekto-benthic invertebrates	Ponto-Caspian	+	stocking	1962	Curonian Lagoon, Gulf of Finland, Odra Lagoon, Vistula Lagoon	Limnetic to a-Mesohaline	Limnetic to a-Oligohaline	0-18	B2

Species	Ecofunctional group	Origin	Species status	Vector of introduction	First observed	Distribution in the Baltic Sea	Salinity in native habitats	Salinity in the Baltic Sea	Salinity tolerant range, ‰	Type of osmoregu lation
Rhithropanopeus harrisii (Gould, 1841)	benthic omnivores	North America	+	shipping	1948	Baltic Proper, Kattegat and Belt Sea, Odra Lagoon, Vistula Lagoon	b-Oligohaline to Polymixohaline	b-Oligohaline to a-Mesohaline	0.5-30	B2
Stenocuma graciloides (G.O. Sars, 1894)	benthic deposit feeders	Ponto-Caspian	?	shipping	2004	Gulf of Finland	Limnetic to a-Oligohaline	a-Oligohaline	0-5	C1
Ctenophora										
Mnemiopsis leidyi A. Agassiz, 1865		North America	?	shipping	2006	Baltic Proper, Kattegat and Belt Sea	a-Oligohaline to Euhaline	-	3-40	A3
Hydrozoa										
Bougainvillia rugosa Clarke, 1882	benthic suspension feeders	North America	+	shipping	1900 **	Kattegat and Belt Sea	b-Mesohaline to Polymixohaline	a-Mesohaline to Polymixohaline	5-30	A3
Clavopsella navis (Millard, 1959)	benthic suspension feeders	Africa, S coast	-	shipping	1960	Kattegat and Belt Sea	Polymixohaline	a-Mesohaline to Polymixohaline	18-30	A3
Cordylophora caspia (Pallas,1771)	benthic suspension feeders	Ponto-Caspian	+	shipping	1803 **	Curonian Lagoon, Gulf of Bothnia, Gulf of Finland, Gulf of Riga, Kattegat and Belt Sea, Odra Lagoon, Vistula Lagoon	Limnetic to Euhaline	Limnetic to a-Mesohaline	0-40	A3
Garveia franciscana (Torrey, 1902)	benthic suspension feeders	North America	?	shipping	1950	-	-	-		A3
Gonionemus vertens A. Agassiz, 1862	nekto-benthic invertebrates	Pacific	-	associated	1960	Kattegat and Belt Sea	-	-		A3
Maeotias marginata (Modeer, 1791)	zooplankton predators	Ponto-Caspian	?	shipping	1999	-	a-Oligohaline to b-Mesohaline	b-Mesohaline	3-10	A3
Mollusca										
Crassostrea gigas (Thunberg)	benthic suspension feeders	Japan Sea	-	stocking	1985	Kattegat and Belt Sea	Polymixohaline to Euhaline	a-Mesohaline	18-40	A2

Species	Ecofunctional group	Origin	Species status	Vector of introduction	First observed	Distribution in the Baltic Sea	Salinity in native habitats	Salinity in the Baltic Sea	Salinity tolerant range, ‰	Type of osmoregulation
Crassostrea virginica (Gmelin, 1791)	benthic suspension feeders	North America	-	stocking	1880	Kattegat and Belt Sea	a-Oligohaline to Euhaline	a-Mesohaline to Polymixohaline	3-40	A3
Crepidula fornicate (Linné, 1758)	benthic suspension feeders	North America	+	associated	1940 **	Kattegat and Belt Sea	a-Mesohaline to Polymixohaline	a-Mesohaline to Polymixohaline	10-30	A2
Dreissena bugensis Andrusov, 1897	benthic suspension feeders	Ponto-Caspian	?	shipping	2004	Gulf of Finland	Limnetic to b-Oligohaline	Limnetic to b-Oligohaline	0-3	C2
Dreissena polymorpha (Pallas, 1771)	benthic suspension feeders	Ponto-Caspian	+	shipping	1803 **	Curonian Lagoon, Gulf of Finland, Gulf of Riga, Odra Lagoon, Vistula Lagoon	Limnetic to a-Oligohaline	Limnetic to b-Mesohaline	0-5	C2
Ensis americanus (Gould, 1870)	benthic deposit feeders	North America	+	shipping	1981	Kattegat and Belt Sea	a-Oligohaline to Euhaline	a-Mesohaline to Polymixohaline	3-40	A3
Lithoglyphus naticoides (C. Pfeiffer 1828)	benthic deposit feeders	Ponto-Caspian	+	shipping	1903 **	Curonian Lagoon, Vistula Lagoon	Limnetic to b-Oligohaline	Limnetic to b-Oligohaline	0-3	C2
Mya arenaria L., 1758	benthic suspension feeders	North America	+	shipping	1245 **	Baltic Proper, Curonian Lagoon, Gulf of Bothnia, Gulf of Finland, Gulf of Riga, Kattegat and Belt Sea, Odra Lagoon, Vistula Lagoon	b-Mesohaline to Euhaline	a-Oligohaline to b-Mesohaline	5-40	A3
Mytilopsis leucophaeta (Conrad, 1831)	benthic suspension feeders	Africa, NW coast	+	shipping	1930 **	Gulf of Finland	Limnetic to Polymixohaline	Limnetic to b-Mesohaline	0-30	A3
Paphia philippinarum (A. Ad. & Rve.)	benthic suspension feeders	China Seas	?	associated	1983 **	-	a-Mesohaline to Euhaline	Polymixohaline	10-40	A3
Petricola pholadiformis (Lamarck, 1818)	benthic suspension feeders	North America	+	associated	1927	Kattegat and Belt Sea	-	a-Mesohaline to Polymixohaline		A3

Species	Ecofunctional group	Origin	Species status	Vector of introduction	First observed	Distribution in the Baltic Sea	Salinity in native habitats	Salinity in the Baltic Sea	Salinity tolerant range, ‰	Type of osmoregulation
Potamopyrgus antipodarum (Gray, 1843)	benthic deposit feeders	Pacific	+	shipping	1887	Curonian Lagoon, Gulf of Bothnia, Gulf of Finland, Gulf of Riga, Kattegat and Belt Sea, Odra Lagoon, Vistula Lagoon	Limnetic to Polymixohaline	Limnetic to a-Mesohaline	0-30	A3
Teredo navalis L., 1758	wood-borers	China Seas	+	shipping	1800 **	Kattegat and Belt Sea	b-Mesohaline to Euhaline	a-Mesohaline to Polymixohaline	5-40	A3
Monogenoidea										
Pseudodactylogyrus anguillae Yin. et Sproston, 1948	invertebrate parasites	Pacific	+	associated	1980 **	Kattegat and Belt Sea, Vistula Lagoon	-	Limnetic to a-Oligohaline		
Pseudodactylogyrus bini (Kikuchi, 1929)	invertebrate parasites	Pacific	+	associated	1980 **	-	-	-		
Nematoda										
Anguillicola crassus Kuwahara, Niimi et Itagaki, 1974	invertebrate parasites	Indo-Pacific	+	associated	1980	Baltic Proper, Curonian Lagoon, Kattegat and Belt Sea, Odra Lagoon, Vistula Lagoon	Limnetic to Polymixohaline	Limnetic to b-Mesohaline	0-30	
Oligochaeta										
Branchiura sowerbyi (Beddard, 1892)	benthic deposit feeders	Indo-Pacific	+	shipping	1976	Odra Lagoon	Limnetic	Limnetic	0-0.5	C1
Paranais frici Hrabe, 1941	benthic deposit feeders	Ponto-Caspian	+	shipping	1970 **	Gulf of Finland	Limnetic to a-Oligohaline	Limnetic to b-Mesohaline	0-5	C1
Potamothrix bedoti (Piguet, 1913)	-	Ponto-Caspian	+	unknown	1980 **	-	-	-		C1
Potamothrix heuscheri (Bretscher, 1900)	benthic deposit feeders	Ponto-Caspian	+	shipping, unknown	1915 **	-	-	Limnetic		C1
Potamothrix moldaviensis Vejdovský et Mrázek, 1903	-	Ponto-Caspian	+	-	1980 **	-	-	-		C1

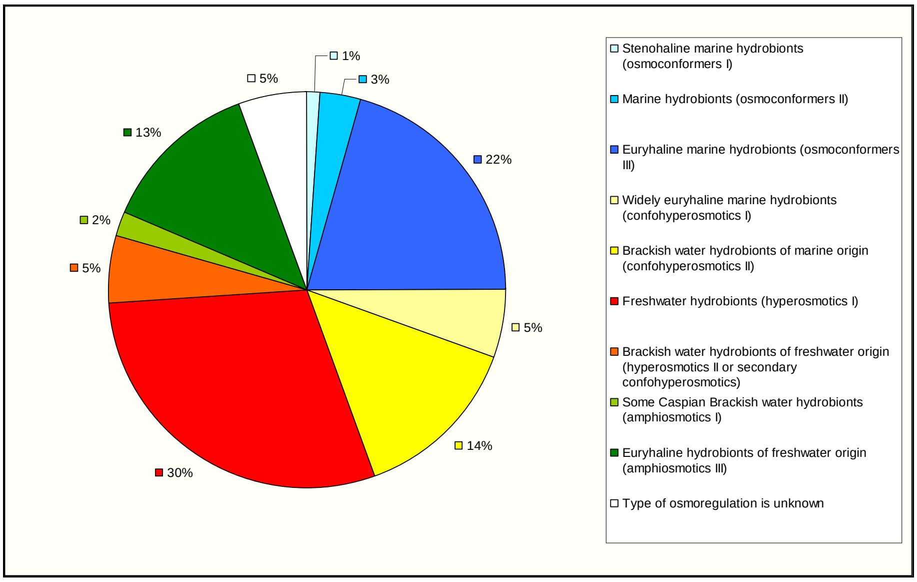
Species	Ecofunctional group	Origin	Species status	Vector of introduction	First observed	Distribution in the Baltic Sea	Salinity in native habitats	Salinity in the Baltic Sea	Salinity tolerant range, ‰	Type of osmoregulation
Potamothrix vejdovskyi (Hrabe, 1941)	benthic deposit feeders	Ponto-Caspian	+	shipping	1980 **	Gulf of Finland	-	Limnetic		C1
Tubificoides pseudogaster (Dahl, 1960)	benthic deposit feeders	North Sea	+	unknown	2000 **	Gulf of Finland	-	-		C1
Polychaeta										
Ficopomatus enigmaticus (Fauvel, 1923)	benthic suspension feeders	Indo-Pacific	+	shipping	1953	Kattegat and Belt Sea	b-Mesohaline to Euhaline	a-Mesohaline to Polymixohaline	5-40	A3
Marenzelleria arctia (Chamberlin, 1920)	-	Arctic waters	?	shipping	2005	Baltic Proper, Gulf of Bothnia	Limnetic to Polymixohaline	-	0-30	A3
Marenzelleria neglecta (Sikorsky & Bick 2004)	benthic deposit feeders, benthic suspension feeders	North America	+	shipping	1985	Baltic Proper, Curonian Lagoon, Gulf of Bothnia, Gulf of Finland, Gulf of Riga, Kattegat and Belt Sea, Odra Lagoon, Vistula Lagoon	a-Oligohaline to Euhaline	b-Oligohaline to Polymixohaline	3-40	A3
Marenzelleria viridis (Verrill, 1873)	benthic deposit feeders	North America	+	shipping	2005	Gulf of Bothnia, Kattegat and Belt Sea	-	-		A3
Polydora redeki (Horst, 1920)	benthic suspension feeders	North Sea	+	shipping	1960	Baltic Proper, Gulf of Bothnia	b-Oligohaline to a-Mesohaline	a-Oligohaline to b-Mesohaline	3-18	A3
Tunicata										
Styela clava Herdman, 1881	benthic suspension feeders	Pacific	+	shipping	1984 **	Kattegat and Belt Sea	Polymixohaline to Euhaline	Polymixohaline	18-40	A2
Pisces										
Acipenser baeri Brandt, 1869	fish predacious	Asia, Siberia (inland waters)	-	stocking	1962	Curonian Lagoon, Gulf of Finland, Gulf of Riga, Vistula Lagoon	Limnetic	Limnetic to b-Oligohaline	0-0.5	C1

Species	Ecofunctional group	Origin	Species status	Vector of introduction	First observed	Distribution in the Baltic Sea	Salinity in native habitats	Salinity in the Baltic Sea	Salinity tolerant range, ‰	Type of osmoregulation
Acipenser gueldenstaedti Brandt et Ratzeburg, 1883	fish predacious	Ponto-Caspian	-	stocking	1962	Curonian Lagoon, Gulf of Finland, Gulf of Riga, Vistula Lagoon	Limnetic to Polymixohaline	Limnetic to b-Mesohaline	0-30	D3
Acipenser ruthenus Linnaeus, 1758	fish predacious	Ponto-Caspian	-	stocking	1948	Curonian Lagoon, Gulf of Bothnia, Gulf of Finland, Gulf of Riga, Vistula Lagoon	Limnetic	Limnetic to b-Oligohaline	0-0.5	C1
Acipenser stellatus Pallas, 1771	fish predacious	Ponto-Caspian	?	stocking	1999	Gulf of Bothnia	Limnetic to Polymixohaline	-	0-30	D3
Aristichthys nobilis (Richardson, 1845)	fish planktivorous	Asia, Siberia (inland waters)	?	stocking	1960 **	Gulf of Riga	Limnetic	a-Oligohaline to b-Mesohaline	0-0.5	C1
Carassius gibelio (Bloch, 1782)	fish bentophagous	Asia, Siberia (inland waters)	+	stocking	1889	Baltic Proper, Gulf of Finland, Gulf of Riga, Vistula Lagoon	-	Limnetic to a-Oligohaline		C1
Catostomus catostomus rostratus Tilesius, 1813	fish bentophagous	Asia, Siberia (inland waters)	?	stocking	1984 **	Gulf of Finland	Limnetic to a-Oligohaline	a-Oligohaline	0-5	C1
Cyprinus carpio Linnaeus, 1758	fish bentophagous	Ponto-Caspian	+	stocking	1400 **	Curonian Lagoon, Gulf of Finland, Gulf of Riga, Vistula Lagoon	Limnetic	Limnetic to a-Oligohaline	0-0.5	C1
Coregonus autumnalis migratorius (Georgi, 1775)	fish planktivorous	Asia, Siberia (inland waters)	?	stocking	1957	Gulf of Finland	Limnetic to b-Mesohaline	a-Oligohaline	0-10	C1
Coregonus muksun (Pallas, 1814)	fish planktivorous	Asia, Siberia (inland waters)	?	stocking	1970	Gulf of Finland	Limnetic to a-Oligohaline	a-Oligohaline	0-5	C1
Coregonus nasus (Pallas, 1776)	fish planktivorous	Asia, Siberia (inland waters)	?	stocking	1960	Gulf of Finland	Limnetic to b-Mesohaline	-	0-10	C1

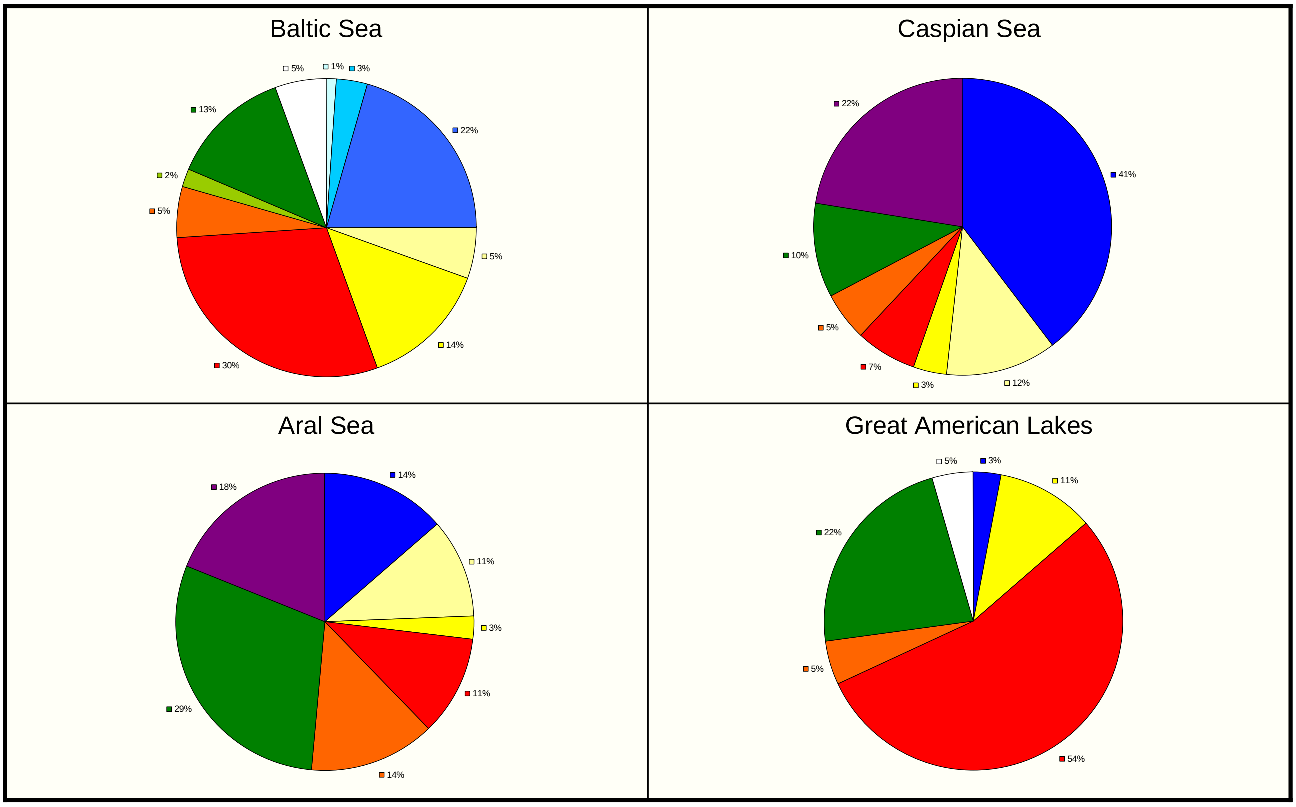
Species	Ecofunctional group	Origin	Species status	Vector of introduction	First observed	Distribution in the Baltic Sea	Salinity in native habitats	Salinity in the Baltic Sea	Salinity tolerant range, ‰	Type of osmoregulation
Coregonus peled (Gmelin, 1789)	fish planktivorous	Asia, Siberia (inland waters)	?	stocking	1965	Curonian Lagoon, Gulf of Bothnia, Gulf of Finland, Vistula Lagoon	Limnetic	-	0-0.5	C1
Ctenopharyngodon idella (Valenciennes, 1844)	fish phytophagous	Asia, Siberia (inland waters)	-	stocking	1970	Kattegat and Belt Sea	Limnetic	a-Mesohaline to Polymixohaline	0-0.5	C1
Hypophthalmichthys molitrix (Valenciennes, 1844)	fish planktivorous	Asia, Siberia (inland waters)	?	stocking	1960	Gulf of Riga, Vistula Lagoon	Limnetic	b-Oligohaline to a-Oligohaline	0-0.5	C1
Huso huso (Linnaeus, 1758)	fish predacious	Ponto-Caspian	?	stocking	1962	Gulf of Riga	Limnetic to Polymixohaline	a-Oligohaline	0-30	D3
Ictalurus melas (Rafinesque, 1820)	fish predacious	North America	+	stocking	1984 **	-	Limnetic	-	0-0.5	C1
Lepomis gibbosus (Linnaeus, 1758)	fish bentophagous	North America	+	ornamental	1975	Odra Lagoon	Limnetic to a-Mesohaline	Limnetic to a-Oligohaline	0-5	C1
Micropterus dolomieu Lacepède, 1802	fish predacious	North America	?	unknown	1890	Kattegat and Belt Sea	Limnetic	-	0-0.5	C1
Mugil labrosus Risso, 1827	fish bentophagous	Indo-Pacific	+	unknown	1998	-	Limnetic to Polymixohaline	a-Oligohaline to b-Mesohaline	0-30	D3
Neogobius melanostomus (Pallas, 1814)	fish predacious	Ponto-Caspian	+	shipping	1990	Baltic Proper, Curonian Lagoon, Gulf of Finland, Gulf of Riga, Kattegat and Belt Sea, Vistula Lagoon	Limnetic to a-Mesohaline	Limnetic to b-Mesohaline	0-5	C1
Oncorhynchus clarki (Richardson, 1836)	fish predacious	Pacific	-	stocking	1960 **	Kattegat and Belt Sea	Limnetic to Euhaline	a-Mesohaline to Polymixohaline	0-40	D3
Oncorhynchus gorbusha (Walbaum, 1792)	fish predacious	Pacific	-	stocking	1973	Gulf of Riga	-	a-Oligohaline		D3

Species	Ecofunctional group	Origin	Species status	Vector of introduction	First observed	Distribution in the Baltic Sea	Salinity in native habitats	Salinity in the Baltic Sea	Salinity tolerant range, ‰	Type of osmoregulation
Oncorhynchus keta (Walbaum, 1792)	fish predacious	Pacific	-	stocking	1971	Gulf of Riga	Limnetic to Euhaline	a-Oligohaline	0-40	D3
Oncorhynchus kisutch (Walbaum, 1792)	fish predacious	Pacific	-	stocking	1975	-	Limnetic to Euhaline	-	0-40	D3
Oncorhynchus mykiss (Walbaum, 1792)	fish predacious	Pacific	+	stocking	1890	Curonian Lagoon, Gulf of Bothnia, Gulf of Finland, Kattegat and Belt Sea, Vistula Lagoon	Limnetic to Euhaline	Limnetic to a-Oligohaline	0-40	D3
Oncorhynchus nerka (Walbaum, 1792)	fish predacious	Pacific	-	stocking	1959	Kattegat and Belt Sea	Limnetic to Euhaline	a-Mesohaline to Polymixohaline	0-40	D3
Percottus glehni Dybowski, 1877	fish predacious	Asia, Siberia (inland waters)	+	ornamental	1916	Gulf of Finland, Vistula Lagoon	Limnetic to a-Oligohaline	Limnetic to b-Oligohaline	0-5	C1
Salvelinus fontinalis (Mitchill, 1814)	fish predacious	North America	-	stocking	1872	Kattegat and Belt Sea	Limnetic to Polymixohaline	a-Oligohaline to Polymixohaline	0-30	D3
Salvelinus namaycush (Walbaum 1794)	fish predacious	North America	-	stocking	1959	Gulf of Bothnia	Limnetic to a-Oligohaline	b-Oligohaline	0-5	C1

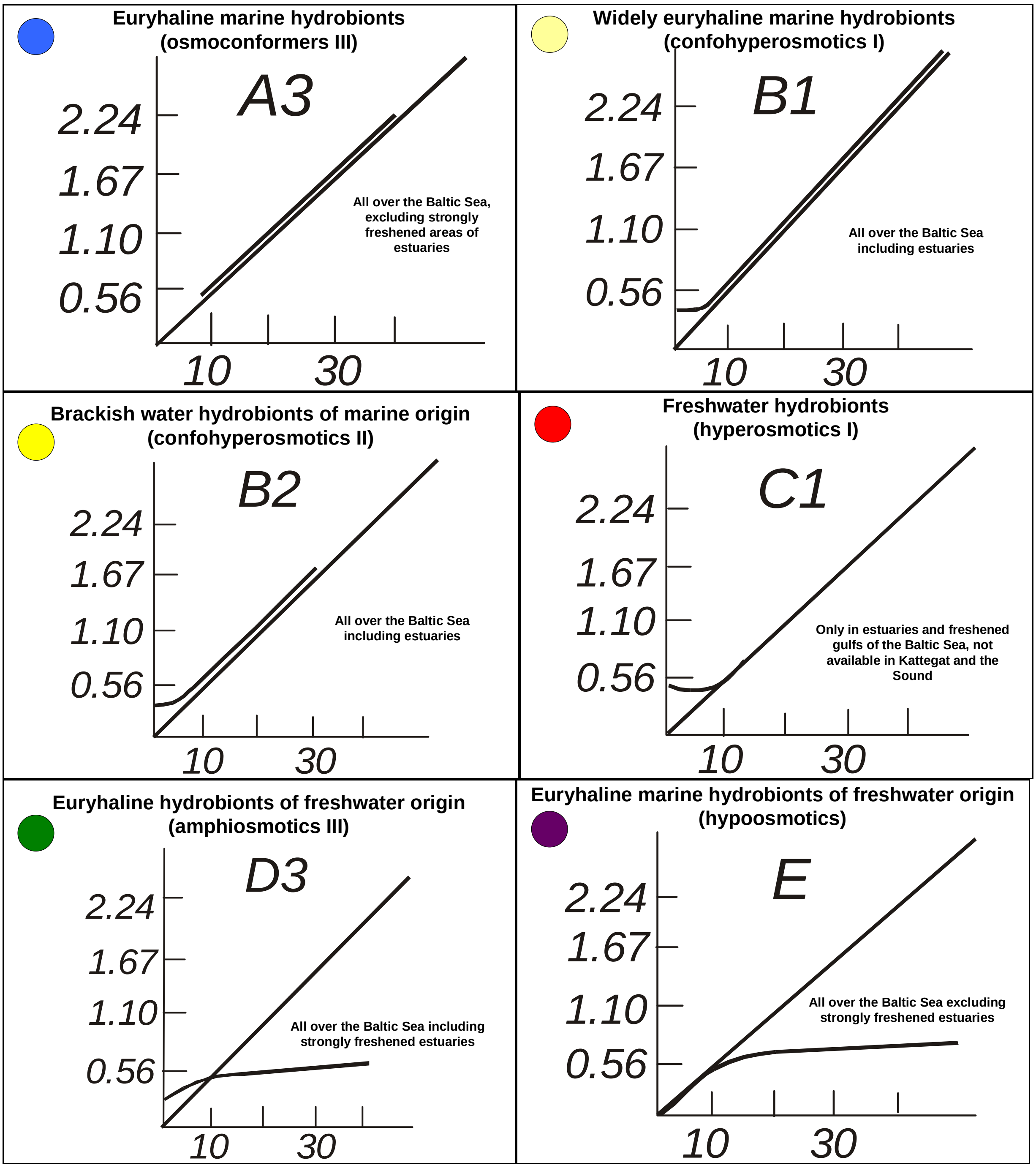
The mark ** next to the year means, that only decade (sometimes even century) is known.

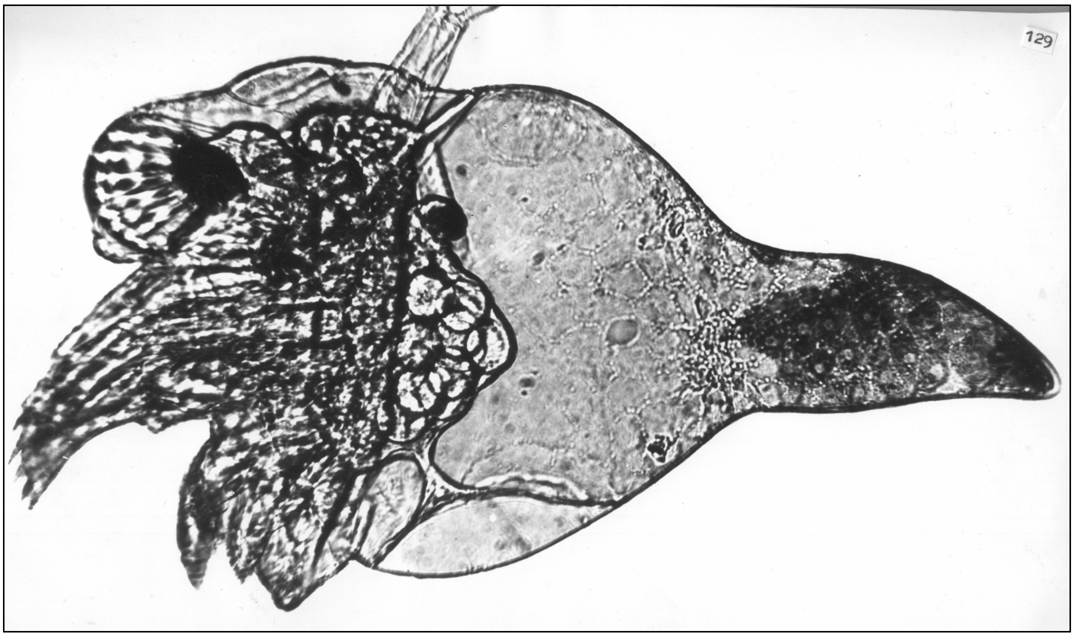


Aquatic alien animal species with the different types of osmoconformity and osmoregulation in the Baltic Sea.

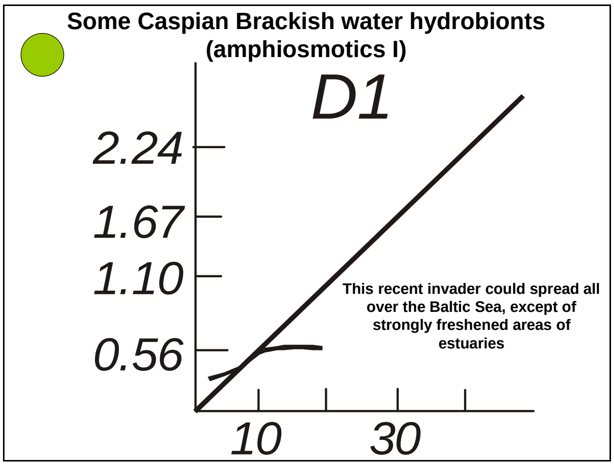


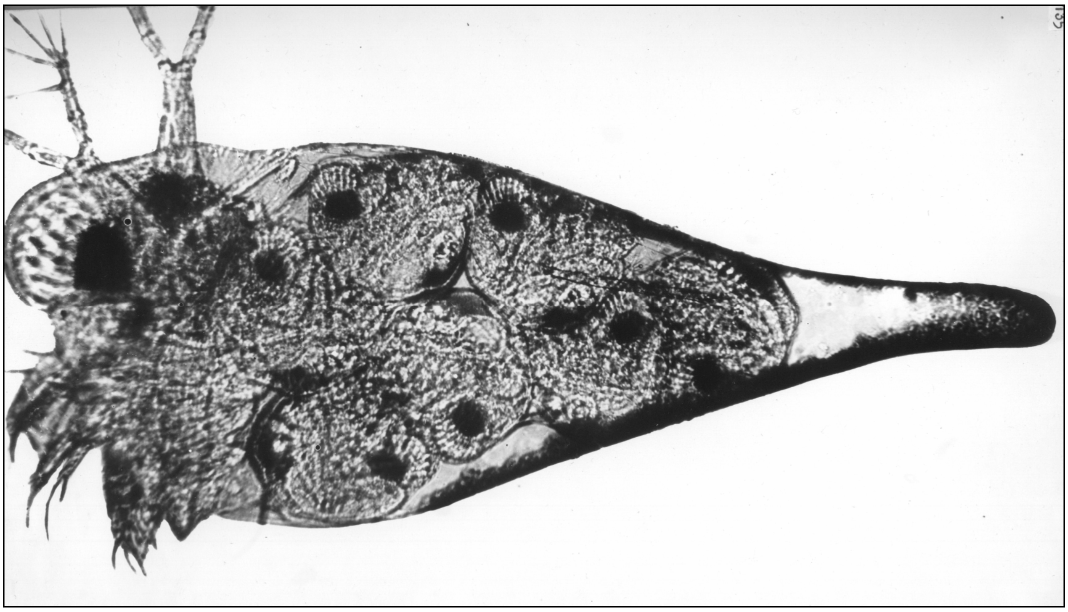
Aquatic alien animal species with the different types of osmoconformity and osmoregulation in different aquatic environments.


Euryhaline marine hydrobionts
(osmoconformers III)
A3
2.24
1.67
1.10
0.56
10
30
All over the Baltic Sea, excluding strongly freshened areas of estuaries
Widely euryhaline marine hydrobionts
(confohyperosmotics I)
B1
2.24
1.67
1.10
0.56
10
30
All over the Baltic Sea including estuaries
Brackish water hydrobionts of marine origin
(confohyperosmotics II)
B2
2.24
1.67
1.10
0.56
10
30
All over the Baltic Sea including estuaries
Freshwater hydrobionts
(hyperosmotics I)
C1
2.24
1.67
1.10
0.56
10
30
Only in estuaries and freshened gulfs of the Baltic Sea, not available in Kattegat and the Sound
Euryhaline hydrobionts of freshwater origin
(amphiosmotics III)
D3
2.24
1.67
1.10
0.56
10
30
All over the Baltic Sea including strongly freshened estuaries
Euryhaline marine hydrobionts of freshwater origin
(hypoosmotics)
E
2.24
1.67
1.10
0.56
10
30
All over the Baltic Sea excluding strongly freshened estuaries



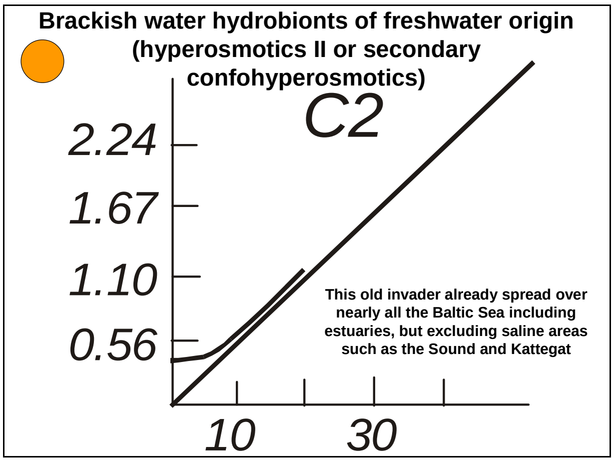
Recent invader to the Baltic Sea *Evadne anonyx*. Parthenogenetic female with developing embryos on initial stages in the closed brood pouch.





Recent invader to the Baltic Sea *Evadne anonyx*. Parthenogenetic female with developing embryos on final stages in the closed brood pouch.

“Old” invader to the Baltic Sea *Cercopagis pengoi* (Photo by Dr. Flinkman).

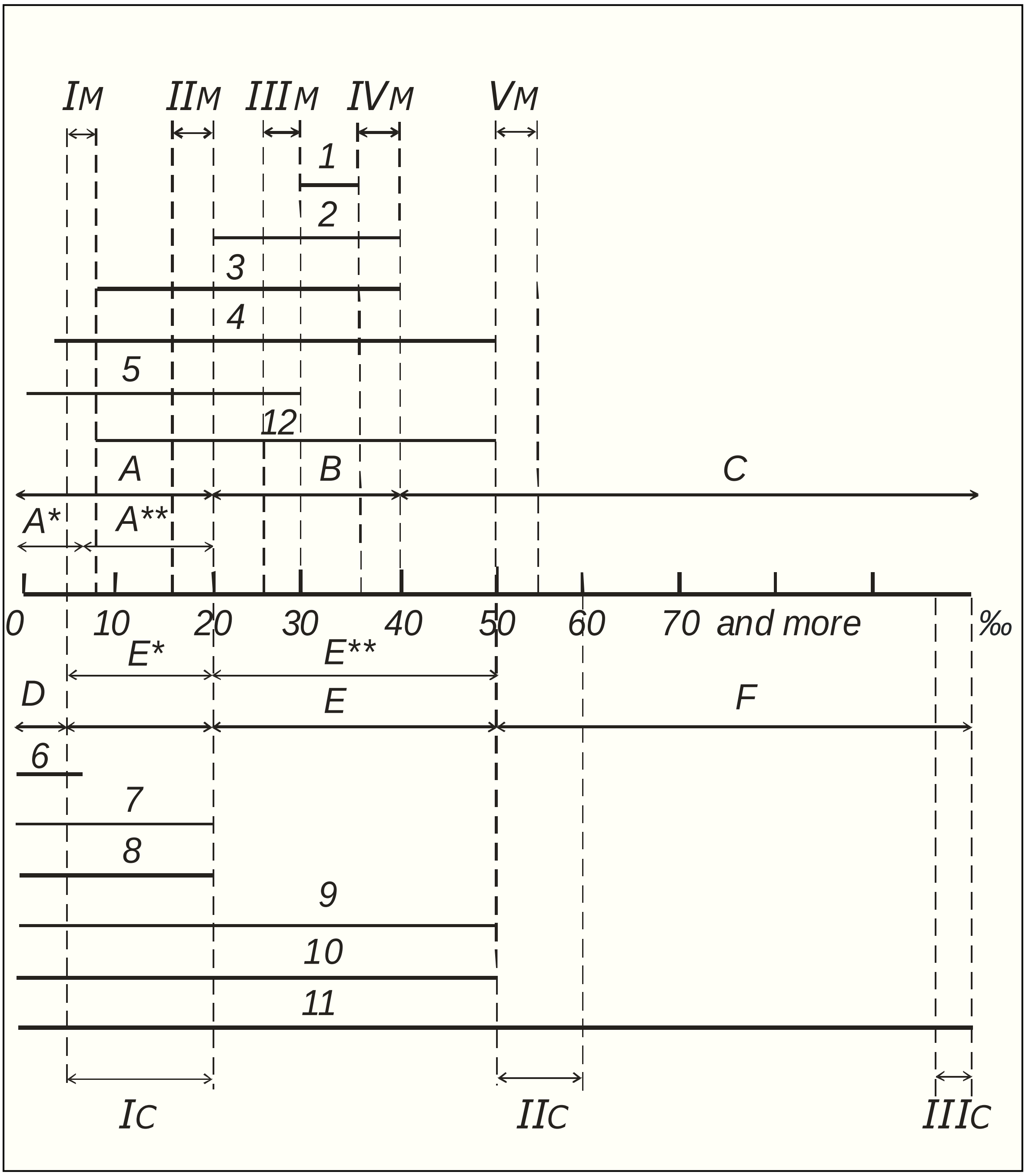


In the nearest future one more Cladocera could appear in the Baltic Sea: *Podonevadne camptonyx*. It has the same type of osmoregulation as *Evadne anonyx*.

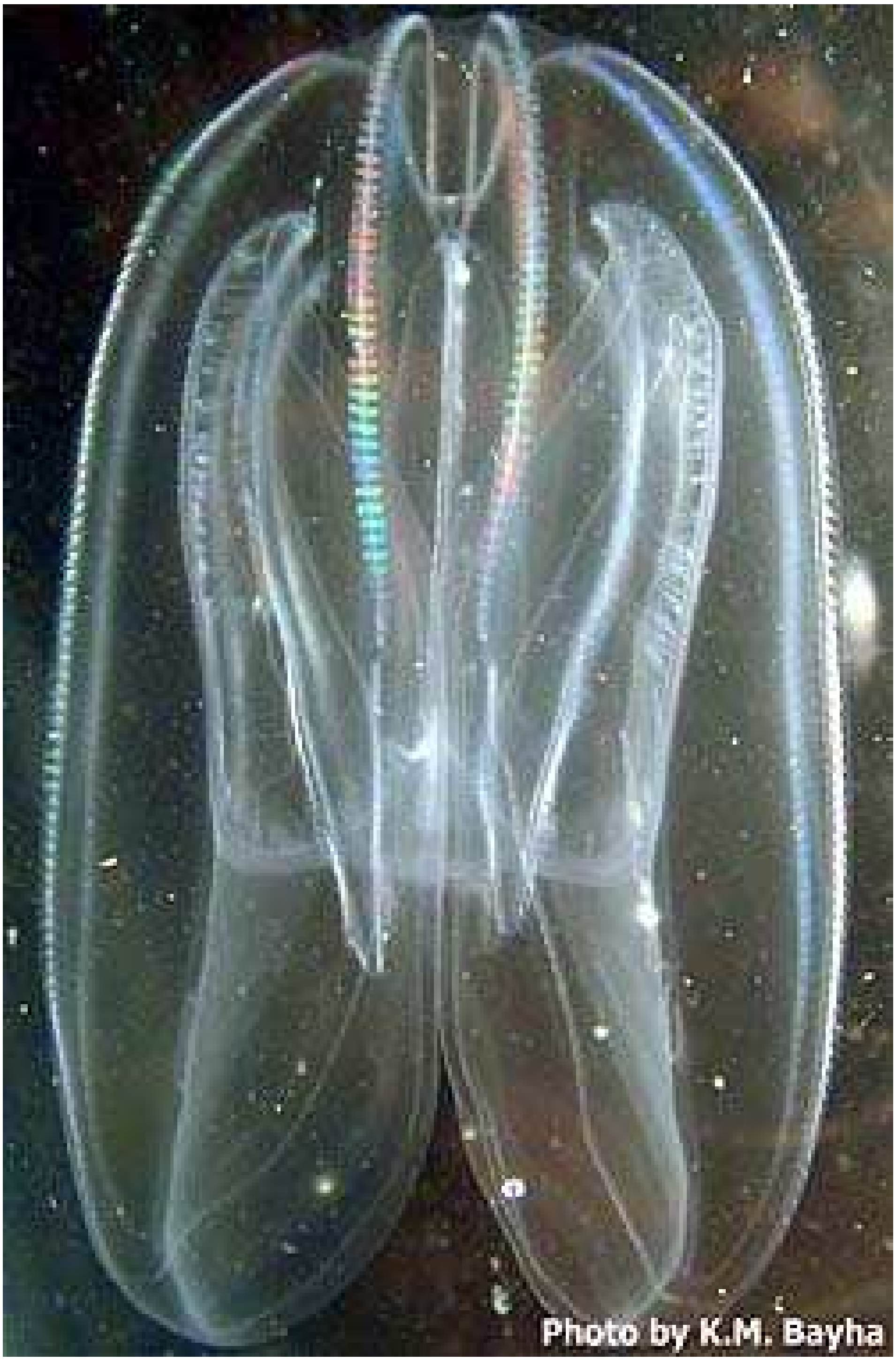
- When you are looking for possible invaders to the Baltic Sea one needs to know their osmoregulation capacities.
- Availability of resting stage is increasing the risk of invasion.
- Representatives of populations from the Sea of Azov have the most similar living conditions to those of the Baltic Sea and risk of their invasion is the highest.

In the Baltic Sea the following hydrobionts are widespread:
A3 ● – euryhaline marine hydrobionts (osmoconformers-III);
B1 ● – widely euryhaline marine hydrobionts (confohyperosmotics-I);
B2 ● – brackish water hydrobionts of marine origin (confohyperosmotics-II);
C1 ● – freshwater hydrobionts from estuaries of Baltic rivers (hyperosmotics-I);
C2 ● – brackish water hydrobionts of freshwater origin (hyperosmotics-II or secondary confohyperosmotics);
D1 ● – some Caspian brackish water hydrobionts (amphiosmotics-I) invaded Baltic Sea;
D3 ● – euryhaline hydrobionts of freshwater origin (amphiosmotics-III);
D4 ● – widely euryhaline hydrobionts of freshwater origin (amphiosmotics-IV);
E ● – euryhaline marine hydrobionts of freshwater origin (hypoosmotics).

- At present the main source of immigrants to the Baltic Sea from seas and lakes - remnants of Paratethys are: Black Sea, Sea of Azov, Caspian Lake.
- The average salinity of all this water bodies is very close to those of Baltic Sea: Black Sea – 18 ‰, Sea of Azov – 10 ‰, Caspian Lake – 12 ‰.



Zones of barrier salinities and tolerance ranges of hydrobionts from marine and continental waters: horizontal axis – salinity, ‰; over horizontal axis are given salinity tolerance ranges of hydrobionts from marine waters; below horizontal axis – for those from continental waters. Osmoconformers: *1* – I, *2* – II, *3* – III; confohyperosmotics: *4* – I, *5* – II; *6* – hyperosmotics I, *7* –hyperosmotics II or secondary confohyperosmotics; amphiosmotics: *8* – I, *9* – II, *10* – III, *11* – IV; *12* – hypoosmotics; Barrier salinities of marine waters: *I M* – first, *5* –8‰, *II M* – second, 16–20‰, *III M* – third, 26–30‰, *IV M* – fourth, 36–40‰, *V M* – fifth, 50–55‰; barrier salinities of continental waters : *I c* – first, 5–20‰, *II c* – second, 50–60‰, *III c* – third, 100–300‰ and more; *A* – marine brackish waters; *A** – before “critical salinity” 5–8‰, *A*** – after “critical salinity” 5–8‰, *B* – typical marine waters, *C* – marine hyperhaline waters, *D* – fresh waters, *E* – continental brackish waters, *E**– in the “critical salinity” zone 5–20‰, *E***– after the “critical salinity” zone, *F* – continental hyperhaline waters.



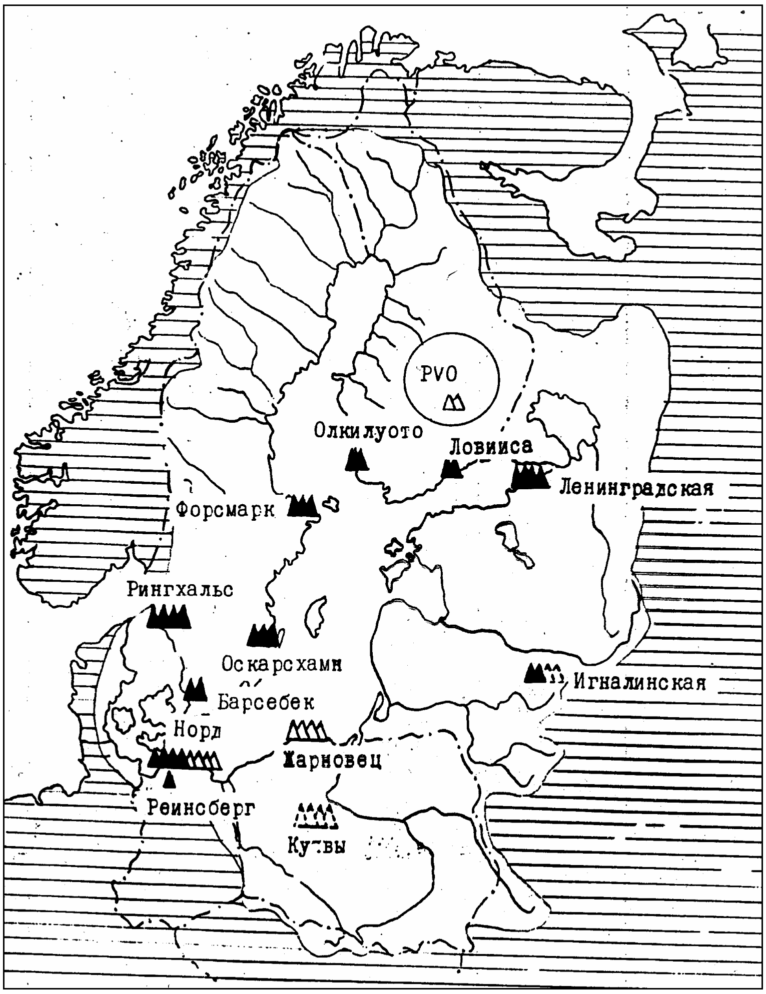
Mnemiopsis leidyi.

The native habitat of the ctenophore *Mnemiopsis leidyi* is in temperate to subtropical estuaries along the Atlantic coast of North and South America, where it is found in an extremely wide range of environmental conditions. Winter low and summer high temperatures of 2ºC and 32ºC, respectively, and salinities of < 2 to 39 g/l.

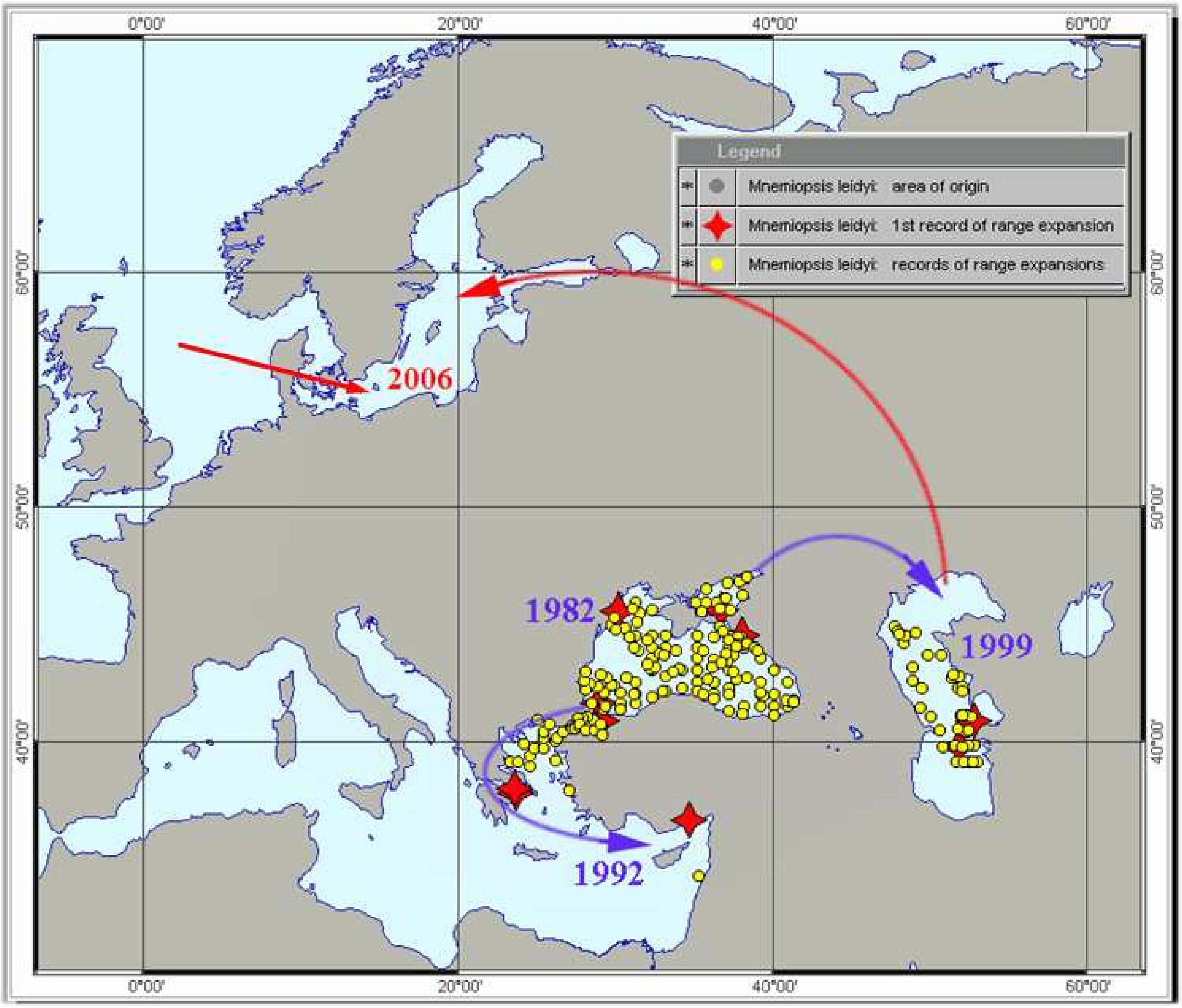
Records of Mnemiopsis in the Northern Europe in 2006 (from: Hansson, 2006).

Location	Record coordinates		Record date	Species abundance (ind./plankton haul)	Collector (data source)
	Latitude, °N	Longitude, °E			
Skagerrak	58°52.10'	11°06.20'	late August 2006	"thousands"	Jan Karlsson "lobed ctenophore in surface waters" (pers. comm.)
Skagerrak	58°52.10'	11°06.20'	mid September 2006	? 4 (in plankton haul)	Own observation
Skagerrak	58°52.10'	11°06.20'	08.10.2006 and 14.10.2006	8-10 (in plankton haul) and "thousands"	Own observation and Video by L.-O. Loo
Skagerrak	58°52.10'	11°06.20'	23.11.2006	>20 (in plankton haul)	Own observation
Kiel Bay, SW Baltic	54°40'	10°30'	October and November 2006	29-92 individuals per cubic meter	Javidpour et al. 2006
coasts of the Netherlands	-	-	beginning of September	”large numbers”	Faasse and Bayha 2006
Oslofjord	no data	no data	late autumn 2006	unknown	T. Falkenhaug and A. Jelmert, pers. comm.
near Bergen	no data	no data	late autumn 2006	unknown	T. Falkenhaug and A. Jelmert, pers. comm.

Underwater photo of a *Mnemiopsis leidyi* bloom near Bommenede in the Grevelingen (26.08.2006). Photo of A. Rijsdijk.



Mnemiopsis could survive in Baltic Sea waters with high thermal pollution.



Distribution of *Mnemiopsis leidyi* in Europe. Some scientists including us believe that *Mnemiopsis* could invade Baltic Sea from via Baltic Straits.

What we have to do now?

- To control ballast waters of coming ships.
- To decrease thermal pollution of the Baltic Sea.
- To monitor biodiversity of thermal polluted and harbor zones.
- To study all parameters natural history and life cycle of *Mnemiopsis*.
- To monitor invasion.
- To compare chronology of previous invasions with those to the Baltic Sea.
- To find mechanical, chemical or biochemical, or even biological ways to stop or at least decrease invasion.
- To find the most “fragile” part of *Mnemiopsis* life cycle and use it for attack.
- And many other things.

1. Risk of *Mnemiopsis* invasion is very high due to intensive traffic between Baltic Sea and water areas that are rich with *Mnemiopsis*.
2. Risk of *Mnemiopsis* invasion is going to be higher due to global warming process and process of Baltic Sea possible salinization.
3. *Mnemiopsis* could survive at low temperatures up to 4°C and at low salinities up to 3 g/l. In winter time *Mnemiopsis* could survive in warm waters near power plants which release water to Baltic Sea.
4. Negative experience of *Mnemiopsis* invasion to Black, Azov and Caspian Seas should be studied.
5. Baltic Sea littoral states should discuss in advance possible measures of *Mnemiopsis* abundance control (including introduction of *Beroe*). It could happen that in the case of Baltic Sea *Beroe* couldn't help because in many water areas of this sea salinity and temperature are too low for *Beroe* naturalization.

References

Aladin N.V., 1986a. Hemolymph osmoregulation peculiarities in Ostracoda and Branchiopoda from Thalassic and athalassic brackish waters // Proceedings Zool. Inst., 141: 75-97 (in Russian)

Aladin N.V., 1986b. Qualitative and quantitative prognostication of Ostracoda and Branchiopoda faunas composition in thalassic and athalassic water of fluctuate salinity // Proceedings Zool. Inst., 141: 98-113. (in Russian)

Aladin N.V., 1988. The concept of relativity and plurality of barrier salinity zones // Zhurn. Obsch. Biol. 49(6): 825-833. (in Russian)

Aladin N.V., 1989. Critical character of the biological influence of the caspian water with the salinity 7-11 ‰ and the aral water with the salinity 8-13 ‰ // Proceedings Zool. Inst., 196: 12-21 (in Russian)

Khlebovich V.V., 1962. Peculiarities of aquatic fauna composition depending on salinity // Zhurn. Obsch. Biol. 23(2): 90-97. (in Russian)

Khlebovich V.V. The critical salinity of biological processes. Leningrad: "Nauka", 1974. 236 pp. (in Russian)

Khlebovich V.V., 1989. Critical salinity and horohalinicum: modern analysis of concepts // Proceedings Zool. Inst., 196: 5-11. (in Russian)

Kinne O., 1971. Salinity – Invertebretes. In: Marine Ecology. (Ed. By O. Kinne). L.-N.Y-Sydney-Toronto. Viley-Interscience: 821-995.

Remane A., 1934. Die Brackwasserfauna //Zool. Anz. (Suppl.). Bd. 7: 34-74.

Zenkevich L.A., 1963. Biology of the seas of the USSR. – London, Allen & Unwin.