Meereswissenschaftliche Berichte
MARINE SCIENCE REPORTS

No. 83

Germany and the investigation of the Baltic Sea hydrography during the 19th and early 20th century

by

Wolfgang Matthäus

Publications on the history of the marine research in Warnemünde/Germany

by

Wolfgang Matthäus

Leibniz Institute for Baltic Sea Research (IOW), Seestraße 15, 18119 Rostock, Germany

Corresponding address: wolfgang.matthaeus@io-warnemuende.de

Leibniz-Institut für Ostseeforschung
Warnemünde
2010

Meereswiss. Ber., Warnemünde 83 (2010)

MATTHÄUS, W.:

Germany and the investigation of the Baltic Sea hydrography during the 19th and early 20th century

Contents

Abstract

In the 19th and early 20th century, Germany played an important part in investigation of the hydrographic conditions of the Baltic Sea. The oldest individual measurements of temperature and salinity carried out in the late 18th and the 19th century and done by German scientists and scientists of German origin are compiled. The German Baltic Sea research is very closely connected with the Royal Prussian „Commission for the Scientific Investigation of the German Seas" in Kiel instituted in summer 1870, but its roots go back to the 1850s and 1860s. The contributions of the merchant and factory owner HEINRICH ADOLPH MEYER (1822 – 1889) to Baltic hydrography are summarized. In Kiel, he formed a circle of marine scientists and was one of the first who started systematic investigations in the western Baltic in the late 1850s. Moreover, he installed and maintained the first network of observation stations in the Belt Sea between 1868 and 1870 and developed measuring instruments. The first important expedition for investigation of the oceanographic conditions of the Baltic Sea on board of the steamer *Pommerania* in 1871 and the contributions of the cruises of the steamer *Holsatia* to Baltic hydrography in 1887 and 1901/1902 are described. The work of both the physicist GUSTAV KARSTEN (1820 – 1900) and the geographer OTTO KRÜMMEL (1854 – 1912) for Baltic oceanography as well as KRÜMMEL'S initiative for international cooperation in marine research in the 1890s are appreciated. WALTHER HERWIG (1838 – 1912) and also OTTO KRÜMMEL played a prominent role in foundation of the International Council for the Exploration of the Sea (ICES) in the late 19th and early 20th century. Germany's lead in establishing of a fixed station network in the Baltic is appreciated. Finally, the reflection of the Baltic Sea research in German natural history descriptions and oceanographic textbooks of the 19th century is summarized. A short view of the German Baltic Sea research during the 20th century completes the contribution.

Kurzfassung

Im 19. und Anfang des 20. Jahrhundert spielte Deutschland eine bedeutende Rolle bei der Erforschung der hydrographischen Bedingungen der Ostsee. Die ältesten Einzelmessungen von Temperatur und Salzgehalt, ausgeführt von deutschen Wissenschaftlern und Wissenschaftlern deutscher Abstammung im späten 18. und im 19. Jahrhundert, werden zusammenstellt. Die deutsche Ostseeforschung ist sehr eng verknüpft mit der im Sommer 1870 gegründeten Königlich Preußischen „Kommission zur wissenschaftlichen Untersuchung der deutschen Meere" in Kiel, deren Wurzeln auf die 1850er und 1860er Jahre zurückgehen. Die Beiträge des Kaufmanns und Fabrikanten HEINRICH ADOLPH MEYER (1822 – 1889) zur Hydrographie der Ostsee werden zusammenfassend dargestellt. In Kiel scharte er einen Kreis von Meereswissenschaftlern um sich und er war einer der ersten, der in den späten 1850er Jahren systematische Untersuchungen in der westlichen Ostsee begann. Darüber hinaus errichtete und unterhielt er zwischen 1868 und 1870 das erste Stationsnetz in der Beltsee und entwickelte Messinstrumente. Die erste bedeutende Expedition zur Erforschung der ozeanographischen Bedingungen der Ostsee an Bord des Dampfers *Pommerania* im Jahre 1871 und die Beiträge der Reisen des Dampfers *Holsatia* zur

Untersuchung der hydrographischen Bedingungen der Ostsee in den Jahren 1887 und 1901/02 werden beschrieben. Die Arbeiten des Physikers GUSTAV KARSTEN (1820 – 1900) und des Geographen OTTO KRÜMMEL (1854 – 1912) für die Ostseeozeanographie sowie KRÜMMELS Initiative für die internationale Zusammenarbeit in der Meeresforschung in den 1890er Jahren werden gewürdigt. WALTHER HERWIG (1838 – 1912) und auch OTTO KRÜMMEL spielten eine hervorragende Rolle bei der Gründung des Internationalen Rates für Meeresforschung (ICES) Ende des 19. und zu Beginn des 20. Jahrhunderts. Schließlich wird Deutschlands Rolle bei der Errichtung eines festen Stationsnetzes in der Ostsee gewürdigt. Abschließend wird die Reflexion der Ostseeforschung in deutschen naturhistorischen Beschreibungen und ozeanographischen Handbüchern des 19. Jahrhunderts zusammenfassend dargestellt. Der Beitrag wird komplettiert mit einem kurzen Ausblick auf die deutsche Ostseeforschung im 20. Jahrhundert.

1. Introduction

ADAM von BREMEN (before 1050 – 1081/1085), one of the most important historians of the Middle Ages, has obviously used the term "Baltic Sea" (Mare Balticum) for the first time (OTTO 1794). The oldest measurements of water temperature in the Baltic Sea handed down in scientific literature go back to the second half of the 18th century while the first observations of salinity were already recorded at the end of the 17th century.

In the 19th century, there took place a change in investigation of the seas. The oceanography separated from geography and instituted as an independent science. That was also the time from individual to cooperated investigations in marine research, in particular in the North Sea and the Baltic. Although Germany is not a maritime nation and only a minority of the population is sensible to marine problems, Germany along with Sweden was the pioneers in marine research of the Baltic Sea. Additionally, marine research in Germany was promoted by the foundation of the German „Reich" in 1871, which led to an increased interest in the seas and formed the basis for a favourable development of marine activities.

Already in summer 1870, the Prussian Minister for Agricultural Affairs, Domains and Forests instituted the Royal Prussian "Kommission zur wissenschaftlichen Untersuchung der deutschen Meere" in Kiel [Commission for the Scientific Investigation of the German Seas = Kiel Commission]. This Commission represents the oldest institution of that kind in Europe and has done an important work for hydrographic research in the Baltic Sea (see Section 3).

Only several short summarizing papers on the history of investigation of the Baltic Sea have been published so far, e.g. by GRASSHOFF (1974), KORTUM (1996), LEPPÄRANTA & MYRBERG (2009) and HUPFER (2010). SMED (1990a) and FONSELIUS (2002) have published more detailed contributions on the history of hydrographic investigations in the Baltic Sea before the foundation of the International Council of the Exploration of the Sea (ICES) in 1902. Short reviews on the history of fishery research in Germany are given by KÄNDLER (1962), WEGNER

(1995, 1998a) and HAHLBECK (1998). The "Geophysical Bibliography of the North Sea and the Baltic" compiled by MODEL (1966) and the "Bibliography on the History of German Marine Research" compiled by WATERMANN & WRZESINSKI (1989) contain numerous references on the investigation of the Baltic Sea by Germany.

A summarizing appreciation of the German contribution to the Baltic Sea research is lacking so far. The following contribution tries to close this gap, at least for the 19th and the turn to the 20th century and, as far as hydrographic investigations are concerned, mainly for temperature and salinity conditions.

2. The early observations

2.1 Measurements of water temperature

The oldest individual measurements of water temperature in the Baltic Sea recorded in scientific literature go back to the second half of the 18th century. The Swedish businessman and farmer PETER JOHAN BLADH (1746 – 1816) seems to be the first who measured the temperature of the Baltic along the Swedish coasts in the Åland Sea and the Gulf of Bothnia during voyages in 1773 and 1776 (BLADH 1776).

By the turn of the 18th to the 19th century, the foundation of seaside resorts started at the German coasts of the Baltic Sea. In 1793, the oldest German seaside resort was founded in Heiligendamm (near Doberan); Travemünde followed in 1801, Kolberg in 1802, Putbus in 1816 and Kiel and Zoppot in 1822. In this connection, the interest in water temperature (and also salinity conditions) of those locations increased (PFAFF 1822) and even regular observations have been started partly (see VOGEL 1819).

The physician SAMUEL GOTTLIEB VOGEL (1750 – 1837) (Fig. 1) – founder of the seaside resort in Heiligendamm, since 1789 professor of the medical faculty at the Rostock University – realized the importance of sea water for human health. He took care of measurements of water temperature[1] and analysis of salinity. In 1819, he wrote:

> "Im Badehause haengt … eine Tafel, auf welcher taeglich zweymahl die Temperatur der See und der Atmosphaere … angeschrieben werden. Mit der Zeit werden sich hieraus nuetzliche Folgerungen und Resultate ziehen lassen."
> ["In the bathing-house, there hangs out … a table, on which the temperature of the sea and the atmosphere … is written down two times a day. In future, useful conclusions and results can be drawn from this."[2]] (VOGEL 1819, p. 27).

---

[1] I did not find any original publications on regular measurements at Heiligendamm before 1853 (DOVE 1858a). But there are references to observations of temperature, at least in 1819, by BOLL: "…an der Küste bei Doberan stieg sie (die Wassertemperatur) am 6ten Juli 1819 selbst auf 25º,2;…" [„…at the coast near Doberan, it (the temperature) increased to 25.2º on 6 July 1819;…"] (BOLL 1847, p. 57).

[2] The translation of the German quotations into English is not a literal one but reflects the content of the German paragraph.

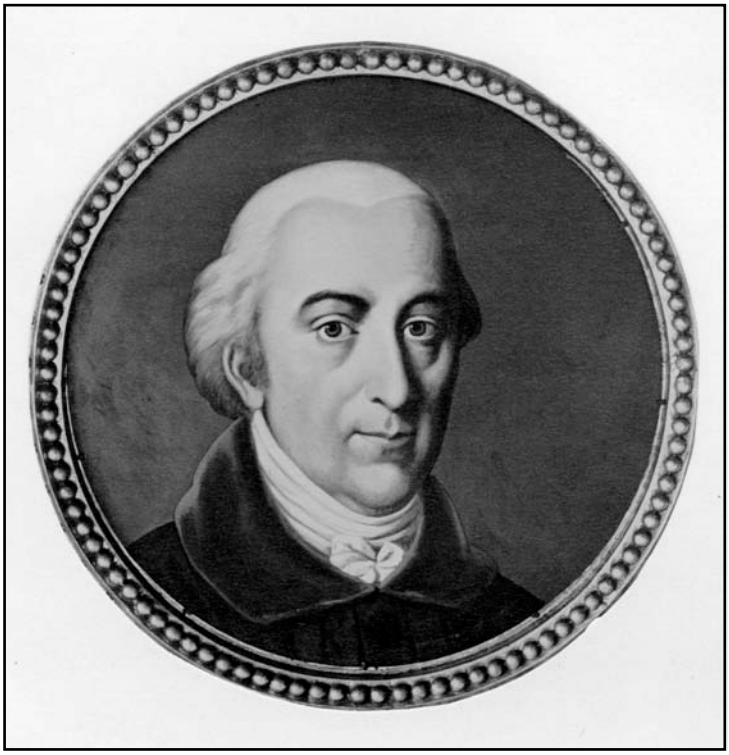


Fig. 1
SAMUEL GOTTLIEB VOGEL (1750 – 1837), professor of the medical faculty of the Rostock University and founder of the oldest German seaside resort in Heiligendamm in 1793 (Archive, Rostock University).

Abb. 1
Samuel Gottlieb Vogel (1750 – 1837), Professor der Medizinischen Fakultät der Universität Rostock und Gründer des ersten deutschen Seebades in Heiligendamm im Jahre 1793 (Archiv, Universität Rostock).

In 1828/1829, the Dane J. H. L. DAU carried out daily measurements of water temperature in the Sound near Copenhagen (DAU 1831) and recommended similar measurements at the German coast near Memel, Pillau and Stralsund (see also Section 9). The famous German naturalist and traveller ALEXANDER von HUMBOLDT (1769 – 1859) was aware of these measurements (see BIERMANN 1979) when he observed the Baltic Sea temperatures along the Prussian coast during a voyage from Stettin to Königsberg und return in August/September 1834 (v. HUMBOLDT 1834). He measured the water temperature at the surface by using a small "Bunsen thermometer". In a short report, he described for the first time (after BOLL 1847, p. 57) a phenomenon off the Prussian coast between Leba and Hela, today well known as upwelling:

> "Während die Luft am 24. August zwischen 21º,5 und 24º,6 … war, fand ich das Meer bei Swinemünde 23º,2 … Als wir am 25. das Vorgebirge zwischen Leba und Rixhofter umsegelten, … fiel plötzlich das Thermometer im Seewasser bis 11º,2 und 12º,o herab …

> Oestlicher von der Landzunge von Hela stieg wieder die Seetemperatur bis 22º,2 … Dieselben Erscheinungen zeigten sich bei der Rückfahrt."
> ["On 24 August, the air temperature was between 21.5º and 24.6º but I found the sea temperature near Swinemünde 23.2º, … on the 25th, we sailed around the foothills between Leba and Rixhöft, … the sea temperature decreased suddenly up to 11.2º and 12.0º … Easterly of the promontory of Hela, the sea temperature increased again to 22.2º … The same phenomena appeared on the way back."] (v. HUMBOLDT 1834; quoted after KORTUM & LEHMANN 1997, p. 56/57).

Humboldt did not explain this phenomenon:

> "Vielleicht sind andere Beobachter glücklicher, die Ursache dieser plötzlichen Erkältung zu entdecken."
> ["Maybe other observers are happier to discover the cause of this sudden cooling"] (v. HUMBOLDT 1834; quoted after KORTUM & LEHMANN 1997, p. 56).

A comprehensive description on HUMBOLDT's contribution to the temperatures in the Baltic Sea is given by KORTUM & LEHMANN (1997).

Only from 1853 onwards (at least until 1858), water temperatures in Heiligendamm were measured regularly two times a day. The physicist and meteorologist HEINRICH WILHELM DOVE (1803 – 1879), founder of modern meteorology and from 1849 onwards director of the Royal Prussian Meteorological Institute in Berlin, compared the water temperature conditions in Heiligendamm, Copenhagen and Reval (Tallinn) by using mean annual variations on the basis of monthly and seasonal means (DOVE 1858a, 1858b). He also calculated differences between water and air temperatures and stated:

> "…im Frühling … eilt die Erwärmung der Luft der des Meeres so weit voraus, daß … die Differenzen negative werden." It is „…wahrscheinlich, daß das Meer den in der jährlichen Periode veränderlichen Bedingungen der Insolation langsamer folge, als die Luft."
> [„…in spring … compared to the sea, the warming of the air is in advance so far, that the differences are negative." It is "…probable, that the sea followed more slowly the isolation conditions, variable in the annual period, than the air"] (DOVE 1859).

In 1863, the doctor of medicine G. THOMAS published a 12 years time series of water temperatures observed in Cranz at the coast of East Prussia (THOMAS 1863). From 1852 to 1863, he measured surface temperatures near the shore three times a day during the summer months (mid-June to mid-September). Comparing the measured data with observations in Heiligendamm (Doberan) and Copenhagen (see DOVE 1858a) he concluded:

> "Hiernach ist die mittlere Wärme der Ostsee im Sommer überall niedriger als die mittlere Luftwärme und sinkt mit der nordöstlichen Ausbreitung dieses Meeres,…"
> [„According to these measurements the mean heat of the Baltic Sea is everywhere lower during summer than the mean air heat and decreased with the extension of this sea in north eastern direction,…"] (THOMAS 1863, p. 170).

In 1863/1864, HEINRICH ADOLPH MEYER measured water temperatures in the Kiel harbour at the surface and in depths of 5 and 16 fathoms using his rubber isolated thermometer (cf. Section 3, Fig. 9a) (MEYER & MÖBIUS 1865). Annual variations of temperature at the surface and different depths were also measured by MEYER at eight fixed observation stations in the Belts and the Sound between 1868 and 1870 (MEYER 1871).

In 1870, the Kiel Commission (see Section 3) concluded the installation of an enlarged observation network of coastal stations for investigating variations in water temperature and salinity (MEYER et al. 1872). Fife permanent observation stations were established at the Prussian Baltic coast in 1871 and later extended to 12-13 stations at the whole German coast (KARSTEN 1875; see also Section 9).

2.2 Analyses and measurements of salinity

The interest in the saltness in the sea and its origin dates back to the Antiquity. However, analyses of the salts in sea water started in the 17th century (see WALLACE 1974). The oldest information on the salinity of the Baltic Sea goes back to the end of the 17th century. At the 6 February 1697, the professor of physics at the Kiel University SAMUEL REYHER (1635 – 1714) (Fig. 2), measured the salinity between the surface and a depth of 5 feet in the Kiel Fjord (REYHER 1697; see also BENEKE 2010) (Fig. 3). Above all KORTUM (1994) pointed to the importance of this measurement as starting point of the empirical marine research in Germany.

In 1771, the German-Swedish physicist JOHAN CARL WILCKE (1732 – 1796), born in the then Swedish town Wismar (today northern Germany), analyzed properties of sea water in the Sound (WILCKE 1771).

In November 1793, SAMUEL GOTTLIEB VOGEL analyzed the sea water at Heiligendamm at the Mecklenburg coast (Fig. 4), assisted by his colleague, the chemist and botanist HEINRICH FRIEDRICH LINK (1767 – 1851) – professor of natural history, chemistry and botany at the University of Rostock from 1792 – 1811. VOGEL (1794) wrote:

> "Ich war nun neugierig, mich durch eigene Versuche von der Beschaffenheit unseres Ostseewassers zu ueberzeugen, und unser Hr. Professor Link hatte die Gefaelligkeit, mich dabey treulich zu unterstuetzen."
> [„Now I was inquisitive to convince myself of the quality of our Baltic water by own investigations, and our Mr. Professor Link had the kindness to assist me truly"] (VOGEL 1794, p. 43).
> „Indessen werde ich ... dieselbe Pruefung mehrmals in verschiedenen Jahreszeiten, und mit dem Wasser aus verschiedenen Tiefen geschoepft, wiederholen..."
> [„Meanwhile I will ... repeat the same check several times during different seasons and using water sampled from different depths..."] (VOGEL 1794, p. 49/50).

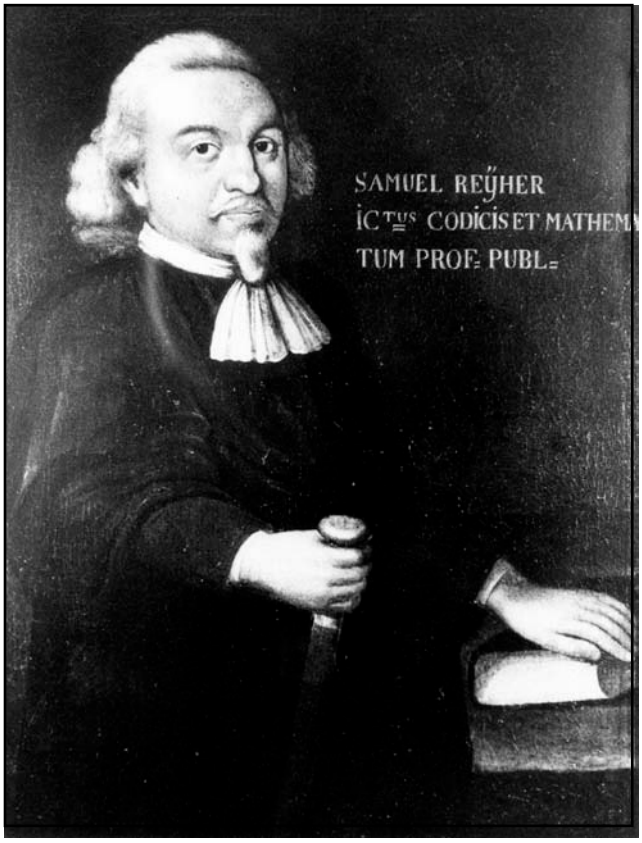


Fig. 2
SAMUEL REYHER (1635 – 1714), professor of mathematics at the Kiel University (Archive IfM-Geomar, Kiel).

Abb. 2
SAMUEL REYHER (1635 – 1714), Professor der Mathematik an der Universität Kiel (Archiv IfM-Geomar, Kiel).

Later VOGEL wrote on that:

> "Hr. Hofr. Link hat dieß Wasser zweymahl zu verschiedenen Zeiten chemisch untersucht; das eine Mahl wurde es nahe am Ufer geschoepft, und das andre Mahl in einer ansehnlichen Entfernung davon. Gleichwohl zeigte das Resultat nur eine unbedeutende Verschiedenheit,..."
> ["Mr. Privy Councillor Link has analyzed this water twice at different times; once sampled near the shore, the second time in a considerable distance of that. Nevertheless, the result showed only an insignificant difference,..."] (VOGEL 1819, p. 11).

VOGEL also knew the cause of the increase in salinity at the Mecklenburg coast:

> "Dagegen können starke Nordwinde aus der noch einmahl so salzigen Nordsee wohl eine große Menge Salztheile in die Ostsee treiben."

["On the other hand, strong north winds can transport a great amount of salt from the double-saline North Sea into the Baltic."] (VOGEL 1819, p. 12).

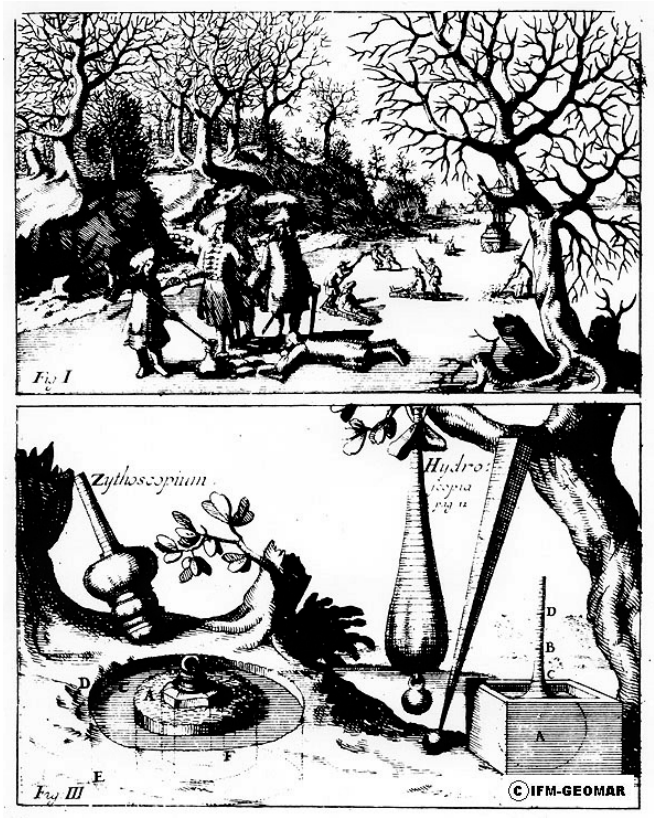
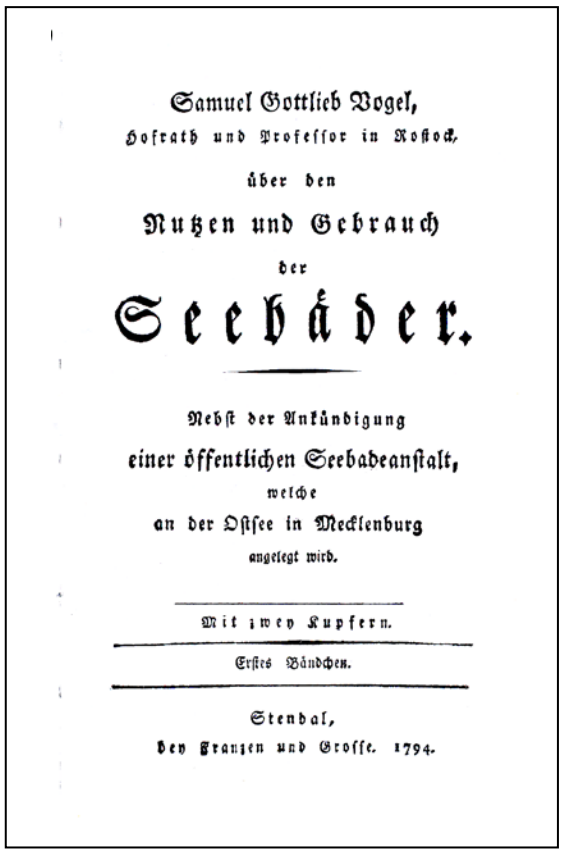


Fig. 3
Measurement of salinity by SAMUEL REYHER in the Kiel Fjord at the Düsternbrook shore in winter 1697 (Archive IfM-Geomar, Kiel).

Abb. 3
Messung des Salzgehalts durch SAMUEL REYHER in der Kieler Förde am Düsternbrooker Ufer im Winter 1697 (Archiv, IfM-Geomar, Kiel).

Since the beginning of the 19th century, the German term "Salzgehalt" was already used in observations and investigations in Germany defined as sum of all salts in sea water (see e.g. LICHTENBERG 1811; SIVERS 1820; KARSTEN 1846; BOLL 1847; V. ETZEL 1859; V. BAER 1862; STRUVE 1864). In 1865, the Danish chemist JOHAN GEORG FORCHHAMMER (1794 – 1865) introduced the English term "salinity" as a bulk parameter in reference to the total salt content of sea water (FORCHHAMMER 1865).



Samuel Gottlieb Vogel,
Hofrath und Professor in Rostock,
über den
Nutzen und Gebrauch
der
Seebäder.

Nebst der Ankündigung
einer öffentlichen Seebadeanstalt,
welche
an der Ostsee in Mecklenburg
angelegt wird.

Mit zwey Kupfern.

Erstes Bändchen.

Stendal,
bey Franzen und Grosse. 1794.

Fig. 4
Title page of SAMUEL GOTTLIEB VOGEL's book – published in 1794 – which contains data of temperature and salinity at the oldest German seaside resort Heiligendamm (from VOGEL 1794).

Abb. 4
Titelblatt des Buches von SAMUEL GOTTLIEB VOGEL aus dem Jahre 1794, das Angaben zu Temperatur und Salzgehalt im ältesten deutschen Seebad Heiligendamm enthält (aus VOGEL 1794).

As early as the beginning of the 19th century, there were numerous analyses of salt content of sea water at the German coast and some from different regions of the open Baltic done by individual German scientists or travellers. The M.D. and chemist CHRISTOPH HEINRICH PFAFF (1773 – 1852) – professor of medicine and chemistry at the University of Kiel – performed a larger number of analyses on sea water in 1814, most of which dealt with Baltic Sea waters. In particular, he observed the salinity in the Kiel Fjord (PFAFF 1814, 1818). FRIEDRICH DAVID LICHTENBERG (1774 – 1847) – pharmacist in Danzig – analyzed the salt content of a sea water sample taken in 1810 at Zoppot in the Gulf of Gdańsk (LICHTENBERG 1811). He believed that there might be some relation between salt content and wind conditions. He suggested analyses from different areas under the same conditions and by the same manner (LICHTENBERG 1811, p. 257).

The physicist and editor of the "Annalen der Physik" LUDWIG WILHELM GILBERT (1769 – 1824) informed on observations of the salinity in the Baltic Sea (GILBERT 1820). The judge Mr. von SIVERS reported on observations of saltness of the open Baltic in the "Hamburgischer unparth. Correspondent" of 2 August 1820 (v. SIVERS 1820). He measured salinities by means of an aerometer and found salt contents of 7.5 ‰ near Reval and 4.25 ‰ near Pernau. During a voyage from Riga to Copenhagen and Helsingør in 1819, he observed salinities between 7 ‰ in the Gulf of Riga, by 8 ‰ near Gotland and about 15 ‰ in the northern part of the Sound.

In the 19th century, numerous German scientists and scientists of German origin interested in Baltic hydrography worked at the southern and eastern Baltic coast in university towns like Riga, Dorpat (Tartu) or St. Petersburg.

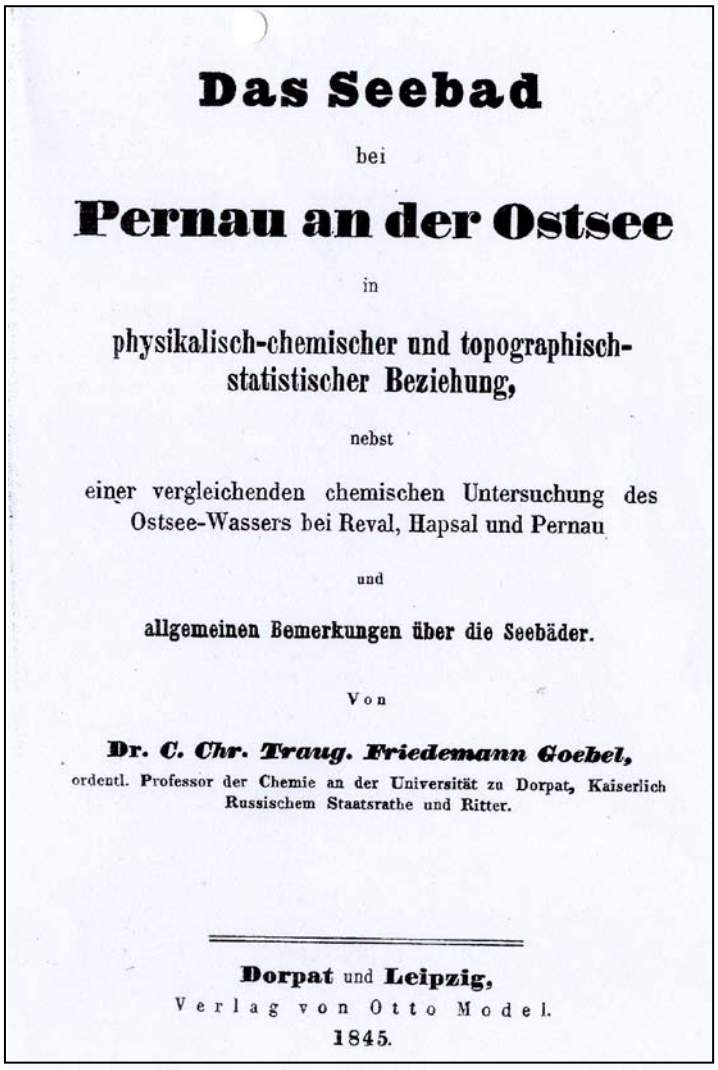
In 1842 and 1844, the chemist CARL CHRISTOPH TRAUGOTT FRIEDEMANN GOEBEL (1794 –1851) – 1824 professor of pharmacy in Jena, since 1828 professor of chemistry and physics in Dorpat – analyzed water samples taken from three locations at the Estonian coast (GOEBEL 1845; Fig. 5). He determined the total salt content by analysing the chemical components of the sea water. He compiled for the first time salinity observations of the Baltic Sea coastal areas available until 1845 (Fig. 6). These analyses were cited very often during the following decades (e.g. v. BAER 1862; BOLL 1847; MEYER & MÖBIUS 1865; v. SASS 1866b, 1866c) but nobody went back to the original sources.

In 1852, the naturalist KARL ERNST VON BAER (1792 – 1876) – professor in Königsberg, since 1834 professor of zoology and physiology in St. Petersburg – collected water samples of different areas of the Baltic Sea during a scientific journey from Riga to Sweden and Denmark (v. BAER 1862) which were later analyzed by HEINRICH STRUVE (cf. v. BAER 1862, p. 127). Moreover, von BAER compiled a total of 30 analyses of Baltic Sea salt content observed in different areas and during different seasons and published – for the first time – a map of the salinity condition of the Baltic Sea.

With regard to salinity he subdivided the Baltic Sea into three regions:

> "1) die östlichen und nördlichen Eingänge, nämlich den Bottnischen, den Finnischen und den Rigischen Busen,
> 2) das grosse oder mittlere Becken von diesen Eingängen bis … Schonen … und der Deutschen Küste,
> 3) die westliche Extremität von dieser Verengung bis zu den drei Ausgängen."
> [„1) the eastern and northern entrances, namely the Gulfs of Bothnia, Finland and Riga,
> 2) the large or central basin from these entrances to … Skåne … and the German coast,
> 3) the western part of this narrowing up to the three exits."] (v. BAER 1962, p. 119).

Von BAER described the salinity conditions, but in particular fauna and flora of the three regions.



Das Seebad

bei

Pernau an der Ostsee

in

physikalisch-chemischer und topographisch-statistischer Beziehung,

nebst

einer vergleichenden chemischen Untersuchung des Ostsee-Wassers bei Reval, Hapsal und Pernau

und

allgemeinen Bemerkungen über die Seebäder.

Von

Dr. C. Chr. Traug. Friedemann Goebel,

ordentl. Professor der Chemie an der Universität zu Dorpat, Kaiserlich Russischem Staatsrathe und Ritter.

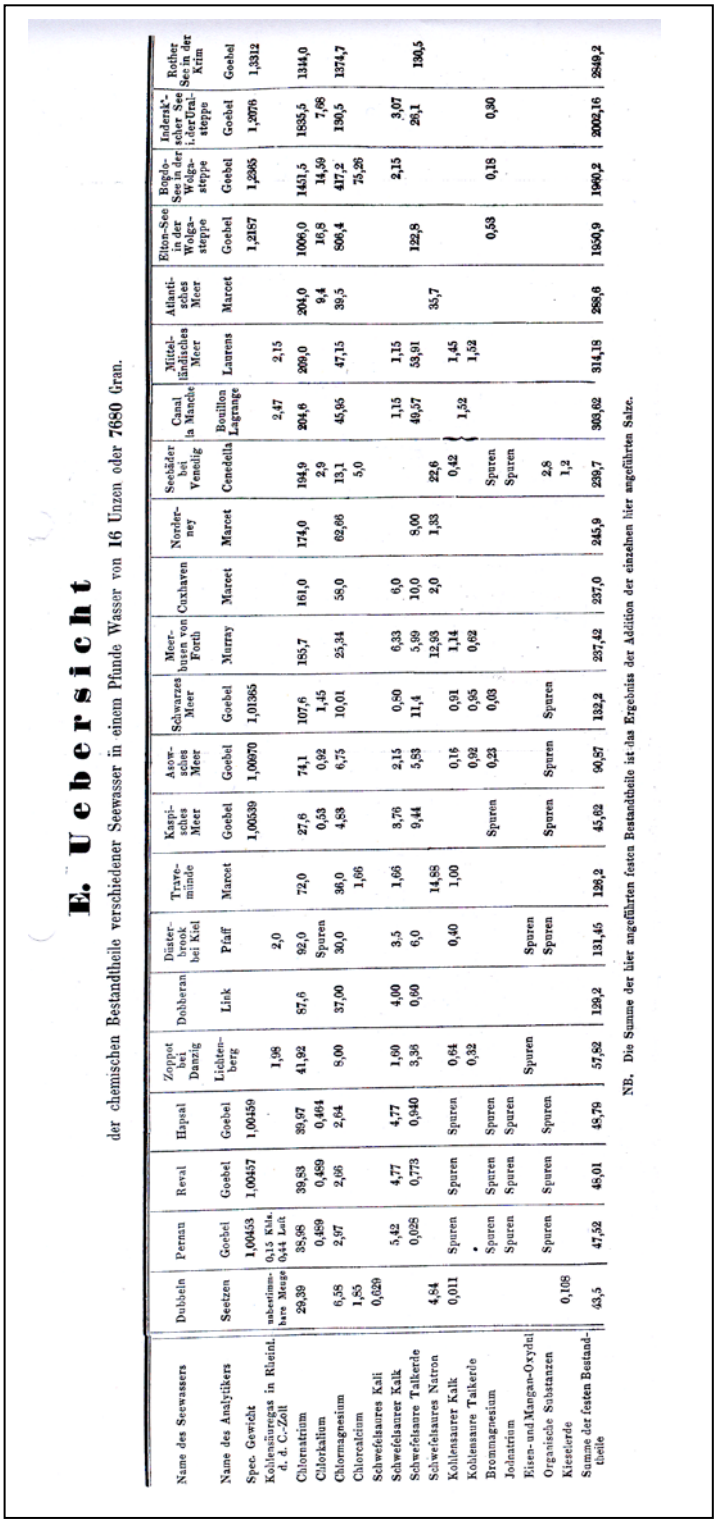
Dorpat und Leipzig,

Verlag von Otto Model.

1845.

Fig. 5
Title page of GOEBEL's paper containing analyses of composition of sea water at the Baltic Sea coast available until 1845 (from GOEBEL 1845).

Abb. 5
Titelseite von GOEBELs Arbeit aus dem Jahre 1845, die Angaben über die Zusammensetzung des Meerwassers an verschiedenen Küstenabschnitten der Ostsee enthält (aus GOEBEL 1845).



E. Uebersicht

der chemischen Bestandtheile verschiedener Seewasser in einem Pfunde Wasser von 16 Unzen oder 7680 Gran.

Name des Seewassers	Dubbein	Pernau	Reval	Hapsal	Zoppot bei Danzig	Dobberan	Dünter-brook bei Kiel	Travemünde	Kaspisches Meer	Asowsches Meer	Schwarzes Meer	Meerbusen von Forth	Cuxhaven	Norderney	Seebäder bei Venedig	Canal la Manche	Mittelländisches Meer	Atlantisches Meer	Elton-See in der Wolgasteppe	Bogdo-See in der Wolgasteppe	Indersk'scher See i. der Ural-steppe	Rother See in der Krim
Name des Analytikers	Seetzen	Goebel	Goebel	Goebel	Lichtenberg	Link	Pfaff	Marcet	Goebel	Goebel	Goebel	Murray	Marcet	Marcet	Cenedella	Bouillon Lagrange	Laurens	Marcet	Goebel	Goebel	Goebel	Goebel
Spec. Gewicht	1,00453	1,00457	1,00459						1,00539	1,00970	1,01365								1,2157	1,2365	1,2076	1,3312
Kohlensäuregas in Rheinl. d. d. C.-Zoll	0,15 Kbk. 0,44 Luft				1,96		2,0									2,47	2,15					
Chlornatrium	29,39	35,96	39,53	39,97	41,92	57,6	92,0	72,0	27,6	74,1	107,6	155,7	161,0	174,0	194,9	204,6	209,0	204,0	1006,0	1451,5	1835,5	1344,0
Chlorkalium		0,459	0,459	0,464			Spuren		0,53	0,92	1,45				2,9			9,4	18,8	14,59	7,66	
Chlormagnesium	6,58	2,97	2,66	2,64	9,00	37,00	30,0	36,0	4,58	6,75	10,01	25,34	56,0	62,66	13,1	45,65	47,15	39,5	508,4	417,2	130,5	1374,7
Chlorcalcium	1,55							1,66							5,0					25,26		
Schwefelsaures Kali	0,029																					
Schwefelsaurer Kalk		5,42	4,77	4,77	1,60	4,00	3,5	1,66	3,76	2,15	0,50	6,33	6,0			1,15	1,15			2,15	3,07	
Schwefelsaure Talkerde		0,028	0,773	0,940	3,36	0,60	6,0		9,44	5,53	11,4	5,99	10,0	9,00		49,57	53,91		122,8		29,1	130,5
Schwefelsaures Natron	4,54							14,66				12,93	2,0	1,33	22,6			35,7				
Kohlensaurer Kalk	0,011	Spuren	Spuren	Spuren	0,64		0,40	1,00		0,16	0,91	1,14			0,42	1,52	1,45					
Kohlensaure Talkerde		•			0,32					0,92	0,65	0,62					1,52					
Brommagnesium		Spuren	Spuren	Spuren					Spuren	0,23	0,03				Spuren				0,53	0,18	0,30	
Jodnatrium		Spuren	Spuren	Spuren											Spuren							
Eisen- und Mangan-Oxydul					Spuren		Spuren								2,8							
Organische Substanzen		Spuren	Spuren	Spuren			Spuren		Spuren	Spuren	Spuren				1,2							
Kieselerde	0,108																					
Summe der festen Bestandtheile	43,5	47,52	48,01	48,79	57,82	129,2	131,45	128,2	45,82	90,57	132,2	237,42	237,0	245,9	239,7	303,62	314,13	288,8	1650,9	1960,2	2002,16	2849,2

NB. Die Summe der hier angeführten festen Bestandtheile ist das Ergebniss der Addition der einzelnen hier angeführten Salze.

Fig. 6

Compilation of analyses of chemical composition of sea water at eight locations of the Baltic shore published by GOEBEL in 1845 (from GOEBEL 1845, Zweite Abth., Part E).

Abb. 6

Zusammenstellung der Analysen der chemischen Zusammensetzung des Meerwassers an acht Orten der Ostseeküste, veröffentlicht von GOEBEL im Jahre 1845 (aus GOEBEL 1845, Zweite Abth., Teil E).

In 1854, CARL ERNST HEINRICH SCHMIDT (1822 – 1894) – professor of chemistry at the Dorpat University – analysed the salt content of a sea water sample of the Estonian north coast (SCHRENK 1854-1857; BRAUN 1884).

In 1868, AUGUST FRIEDRICH CARL HIMLY (1811 – 1885), professor of chemistry at the Kiel University between 1846 and 1884, reported on analyses of common salt (NaCl) of 58 samples of water taken in the Kiel harbour (near Düsternbrook) in 1858 and seven samples taken during a cruise between Kristiania and Kiel (HIMLY 1868; see also BENEKE 2010). Himly found out that the salt content of the Kiel harbour varied dependent on wind direction.

In 1861, the magister of the University of Dorpat ADOLPH GOEBEL – the son of CARL CHRISTOPH GOEBEL – analyzed the salinity in water samples taken in the Gulf of Riga and near the islands of Hiiumaa and Saaremaa between 1854 and 1860 (see v. BAER 1862).

HEINRICH WILHELM STRUVE (1822 – 1908), chemist at the mountain department of the Caucasus administration, analyzed eight water samples collected by v. BAER along the coast between Helsinki and Landskrona (STRUVE 1864). He supplemented the table of salinity measurements compiled by v. BAER (1862) by further five samples from the Gulf of Bothnia.

Based on the data compiled by v. BAER and himself, STRUVE assumed that a „two-fold" current exists in the Baltic. His assumption based upon

> "…dass im Becken der Ostsee sich zwei Wasser vermischen, nämlich die Süsswasser aus den mächtigen Zuflüssen des Bottnischen und Finnischen Meerbusens … mit dem Meerwasser aus dem grossen Ocean, das durch den Sund und die beiden Belte hineinströmt…"
> [„…that two water masses mix in the Baltic basin, the fresh water of the huge runoff … with the sea water of the great ocean which flows in through the Sound and the two Belts…"] (STRUVE 1864, p. 9).

In another place, he stated that

> „…Strömungen in der Ostsee und zwar in dem eigentlichen grossen Becken derselben … durch den verschiedenen Salzgehalt im Wasser hervorgerufen werden…"
> [„…the currents in the Baltic Sea namely in the actual great basin … are caused by the different salinity…"] (STRUVE 1864, p. 11).

STRUVE was of the opinion that the existence of such currents can be verified only

> „…durch…Untersuchungen des Seewassers aus verschiedenen Tiefen"
> [„…by investigations of sea water from different depths"] (STRUVE 1864, p. 9).

But he criticized the use of simple glass bottles for water sampling from depths greater than 45 fathoms frequently used at that time.

Table 1
Analyses of sea water (chemical composition; A) and measurements of salinity (aerometer; M) in the Baltic Sea coastal areas carried out by German travellers and scientists [G] as well as scientists of German origin [GO] during the 18th and 19th century (*only common salt NaCl)

Tabelle 1
Analysen des Meerwassers (chemische Zusammensetzung; A) und Messungen des Salzgehaltes (Aräometer; M) im Küstenbereich der Ostsee, durchgeführt von deutschen Reisenden und Wissenschaftlern [G] und Wissenschaftlern deutscher Herkunft [GO] im 18. und 19. Jahrhundert (* nur Kochsalz NaCl)

Carried out by		Ana-lysis type	Year	Area	Reference
REYHER, S.	G	M	1697	Kiel Fjord	REYHER (1697)
WILCKE, J. C.	GO		1771	Sound	WILCKE (1771)
LINK, H. F.	G	A	1793	Mecklenburg Bight	VOGEL (1794, 1819)
LICHTENBERG, F. D.	G	A	1810	Gulf of Gdańsk	LICHTENBERG (1811)
PFAFF, C. H.	G	A	1814	Kiel Fjord	PFAFF (1814, 1818)
v. SIVERS	G	M	1819	Gulf of Riga, Baltic proper	v. SIVERS (1820)
GOEBEL, C. C. T. F.	G	A	1842-1844	Estonian coast	GOEBEL (1845)
STRUVE, H. W.	GO	A	1852	Swedish coast	v. BAER (1862), STRUVE (1864)
SCHMIDT, C.	GO	A	1854	Estonian coast	SCHRENK (1854-1857)
GOEBEL, A.	G	A	1854-1860	Estonian coast	v. BAER (1862)
HIMLY, C.	G	A	1858	Kiel harbour*, Kattegat*	HIMLY (1868)
STRUVE, H. W.	GO	A	1862	Gulf of Bothnia	STRUVE (1864)
MEYER, H. A.	G	M	1868-1870	Belt Sea	MEYER (1871)
KIEL COMMISSION	G	M	Since 1871	German Baltic coast	KARSTEN (1873b), ANON. (1874)
GLASENAPP, M. v.	GO	M	1877	Gulf of Riga	SCHWEDER (1884)
BRAUN, M.	G	M	1881-1883	Gulf of Finland	BRAUN (1884)
SCHWEDER, G.	G	M	1881-1887	Gulf of Riga	SCHWEDER (1881)
PFLAUM, H.	G	M	1896	Gulf of Riga	PFLAUM (1896)

In 1866, the farmer Dr. ARTHUR FERDINAND BARON von SASS (1837 – 1871) reported on the composition of Baltic Sea water (v. SASS 1866a, 1866b) and on variations of specific gravity and salinity in the Baltic Sea (v. SASS 1866c, 1867). He studied relations between salinity and wind direction and force, season and precipitation.

In summer 1877, professor Max von GLASENAPP (1845 – 1923) of the Riga Polytechnic School observed the salinity in the Gulf of Riga (SCHWEDER 1884). During his annual stay in Karlsbad at the shore of the Gulf of Riga, the director of the secondary school in Riga G. SCHWEDER observed regularly the salinity of the Gulf of Riga between June and August of the years 1881 – 1887 using instruments supplied by the Kiel Commission (SCHWEDER 1881). Carrying on the measurements of SCHWEDER, the teacher of physics HERMANN E. PFLAUM observed the salinity along the Gulf shore in 1896 (PFLAUM 1896).

Stimulated by the work of the Kiel Commission, in particular by the *Pommerania* Expedition in 1871, the zoologist MAXIMILIAN BRAUN (1850 – 1930) – professor in Dorpat, later in Rostock and Königsberg – intended to investigate the living conditions of flora and fauna in the Gulf of Finland in a similar way (BRAUN 1884). In the summers of 1881 and 1883, he carried out observations of temperature and specific gravity along the Estonian coast using, among others, the hard rubber thermometer and the glass bottle developed by H. A. MEYER (cf. Section 3, Fig. 9a, b).

All analyses and measurements of the Baltic Sea salinity carried out by German scientists and scientists of German origin during the 18th and 19th century are compiled in Table 1.

3. HEINRICH ADOLPH MEYER and the Baltic Sea research

The Hamburg merchant, factory owner and sponsor of marine biology HEINRICH ADOLPH MEYER (1822 – 1889) (Fig. 7) played a decisive role in the development of the German marine sciences in the second half of the 19th century. Moreover, in the 1860s he formed a circle of German scientists interested in marine research consisting of the zoologist KARL AUGUST MÖBIUS (1825 – 1908), the physiologist VICTOR HENSEN (1835 – 1924), the physicist GUSTAV KARSTEN (1820 – 1900) and himself (see Fig. 7).

During the commercial activity of his father in Hamburg and his own business in the United States and since 1848 in Hamburg, MEYER made a lot of money. He was always open for modern ideas. His interest and ***engagement in marine research*** arose in the 1850s. For further details on his life see Anon. (1890) or REDNAK (1994), and on his work for marine science see also KARSTEN (1890, 1893b).

MEYER had an excellent organizing talent and experimental skill. Mainly interested in physical oceanography, he initiated the start of marine biological studies in Kiel in the 1850s and 1860s (see also KÖLMEL 1990). In summer 1859, MEYER matriculated at the Kiel

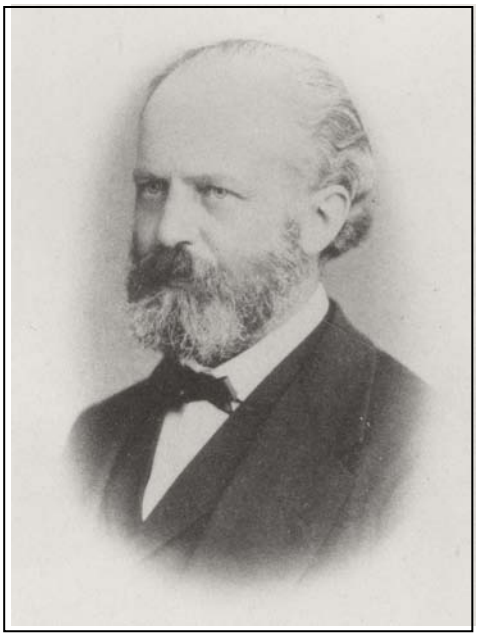
University and attended lectures on zoology and anatomy but especially on physics given by the physicist GUSTAV KARSTEN (see Section 5). As early as 1859 MEYER carried out hydrographic observations in the Kiel harbour and Kiel Fjord. Stimulated by investigations on the annual variations in faunal biodiversity observed in the Kiel Fjord (MEYER & MÖBIUS 1865) he started regular observations of the physical conditions in the western Baltic Sea.

In 1862, he caused the building of the small sailing-yacht *Marie* (GERLACH 2000) and investigated the physical conditions in the Kiel Bight and the Belt Sea. He invited K. A. MÖBIUS and V. HENSEN (see Fig. 7) – later professors at the Kiel University (HENSEN since 1864; MÖBIUS since 1868) – to take part in excursions and to carry out additionally marine biological investigations. MEYER & MÖBIUS (1865, 1872) published the physical and biological results in two volumes entitled "Fauna der Kieler Bucht". In 1866, MEYER was given an honorary doctorate by the Philosophical Faculty of the Kiel University in recognition of both his physical investigations of the sea and sponsoring of marine science in Kiel (KARSTEN 1893b).

Meyer was one of the first who started ***systematic investigations*** of the physical conditions in the western Baltic. In July 1868, he carried out two hydrographic cruises with his sailing-yacht *Marie* covering 151 stations in the Little Belt and the Great Belt in order to investigate the thermohaline stratification (Fig. 8). Between 1868 and 1870, he installed and maintained eight fixed observation stations in the Belt Sea at private venture (KARSTEN 1893b, 1896a) and caused to carry out regular measurements of temperature and specific gravity of sea water, current, sea level and wind (MEYER 1871). He studied the interaction between wind, current and salt transport in the transition area between the North Sea and the Baltic and investigated the causes of changes in salinity. Moreover, on the basis of his measurements MEYER showed the annual cycle of temperature and salinity at the fixed stations and calculated mean values. He published the results in a basic paper on the physical conditions in the western part of the Baltic Sea (MEYER 1871). The data measured at the fixed stations and during the cruises are compiled in a data supplement of 82 tables.

Already in 1868, MEYER identified two-layer currents in the Belt area: out-going currents at the surface and in-going currents in the deeper water layers. He concluded:

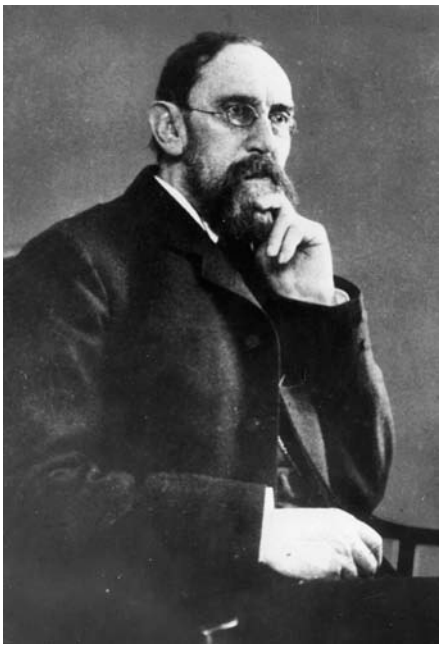
> "Der ungleiche Salzgehalt der Nordsee und Ostsee … ist die Ursache … in den, beide Meere verbindenden Wasserstrassen…" „Das salzreiche, specifisch schwerere Wasser der Nordsee dringt als Unterstrom in die Ostsee ein, das salzärmere, specifisch leichtere Wasser der Ostsee fliesst als Oberstrom in das Kattegat und die Nordsee"
> [„The cause of the two-layer currents in the straits connecting the two seas is the different salinity of the North Sea and the Baltic … The salt-rich, heavier water of the North Sea penetrates into the Baltic like an under current, the lower saline, lighter water of the Baltic flows into the Kattegat and North Sea as upper current"] (MEYER 1871, p. 46).



HEINRICH ADOLPH MEYER (1822 – 1889), merchant, factory owner and sponsor of oceanography; 1871 – 1880 chairman of the Kiel Commission (from ANON. 1890).

GUSTAV KARSTEN (1820 – 1900), professor of physics and mineralogy at the University of Kiel; 1880 – 1895 chairman of the Kiel Commission (Photo: Archive IfM-Geomar, Kiel).

KARL AUGUST MÖBIUS (1825 – 1908), professor of zoology at the Kiel University (Photo: Archive, IfM-Geomar, Kiel).



VICTOR HENSEN (1835 – 1924), professor of physiology at the Kiel University; 1895–1901 chairman of the Kiel Commission (Photo: Archive, IfM-Geomar,Kiel).

Fig. 7
Founding members of the Kiel Commission.

Abb. 7
Gründungsmitglieder der Kieler Kommission.

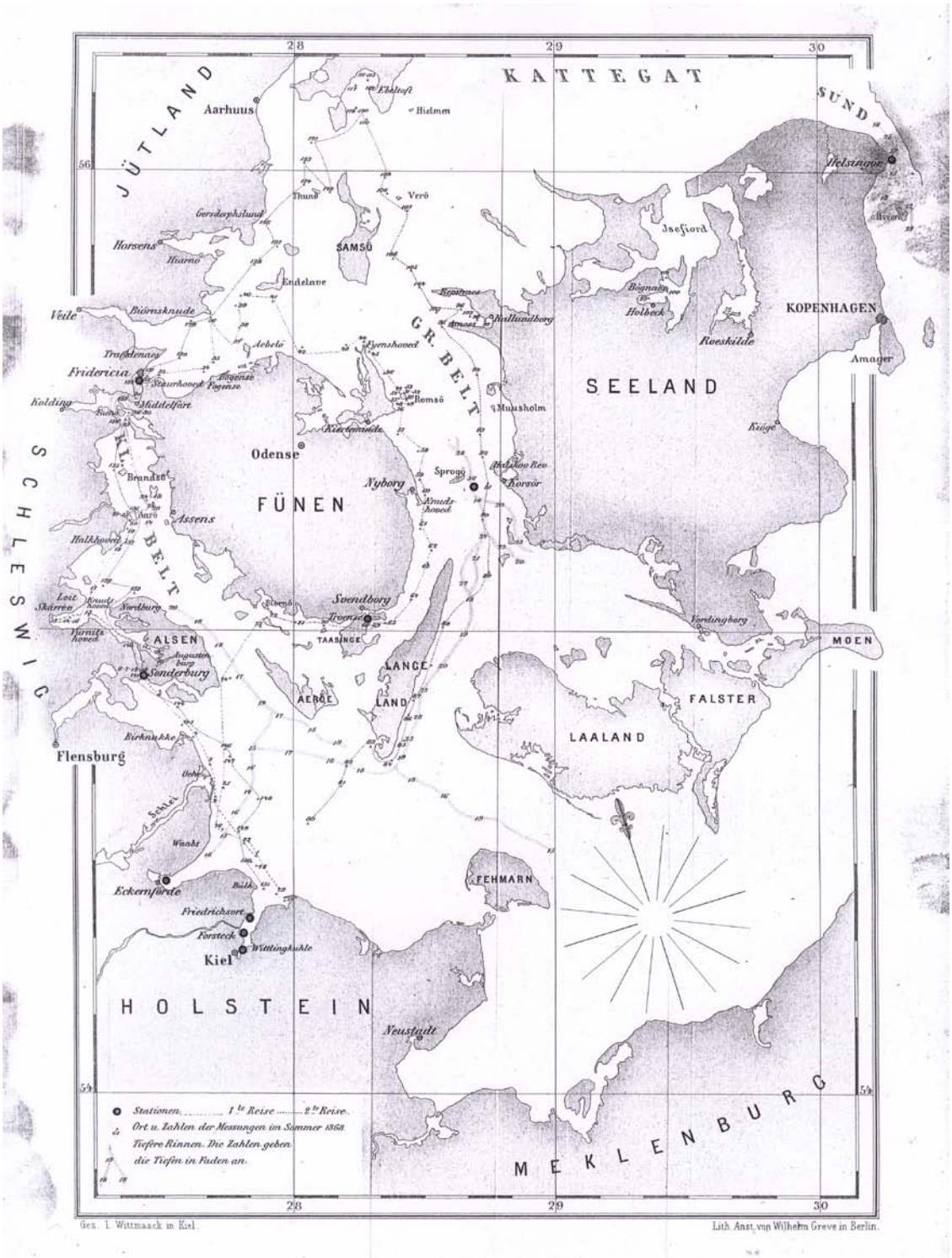


Fig. 8
Map of the two cruises of the sailing-yacht *Marie* in the Belt Sea area in 1868 and the eight fixed stations (heavy dots) installed by H. A. MEYER and operating between 1868 and 1870 (from MEYER 1871).

Abb. 8
Karte der beiden Reisen der Segeljacht *Marie* im Gebiet der Beltsee im Jahre 1868 und die acht Messstationen (hervorgehobene Punkte), die von H. A. MEYER errichtet und zwischen 1868 und 1870 betrieben wurden (aus MEYER 1871).

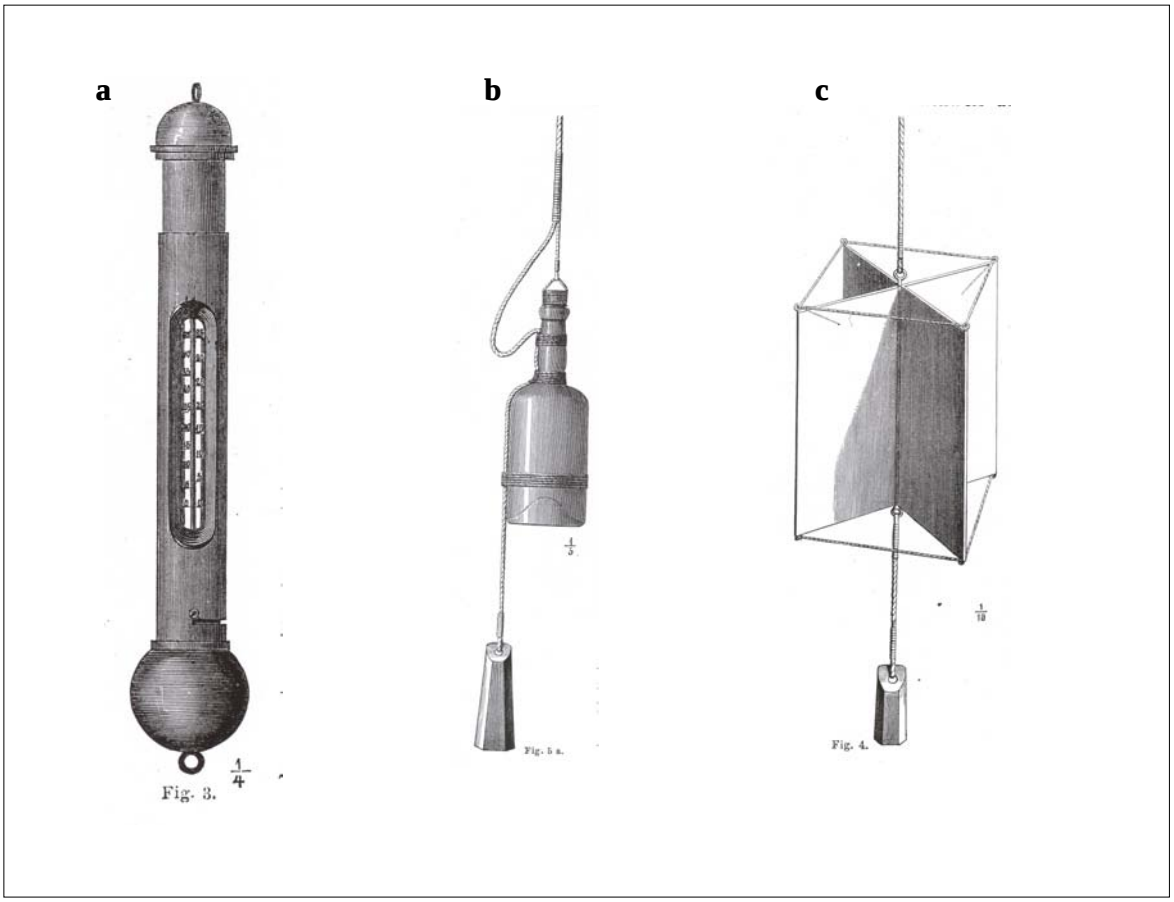


Fig. 9
Isolated Thermometer (a), glass bottle for water sampling at small depths (b) and current drifter (c) developed by H. A. MEYER and used both on board of his sailing-yacht *Marie* for observations during his cruises in July 1868 and at the fixed stations installed between 1868 and 1870 (from MEYER 1871).

Abb. 9
Isolier-Thermometer (a), Wasserschöpfer für geringe Tiefen (b) und Strömungsmesser (c), entwickelt von H. A. MEYER und benutzt auf seiner Segeljacht *Marie* während seiner Reisen im Jahre 1868 und an den zwischen 1868 und 1870 betriebenen Stationen (aus MEYER 1871).

With respect to the current observations, however, he complained that

> "...ein gleichmässiges Strommaass und die Erfindung eines für obere und untere Strömungen brauchbaren Geschwindigkeitsmessers..."
> [„...a uniform unit for currents and the invention of a current meter used both for upper and deep currents..."]

was still missing and he recommended that

> „...bei einigen meteorologischen Stationen schon eingeführte Instrumente zur Messung der Windstärke..."
> [„...instruments for measuring the wind force introduced already at several meteorological stations..."]

should be generally used (MEYER 1871, p. 33).

MEYER himself developed the ***measuring instruments*** for his cruises and the fixed stations (MEYER 1871; KARSTEN 1873a). He used a simple thermometer covered with thick hard rubber for temperature measurements (Fig. 9a). It had to be kept submerged for one hour before being quickly raised to the surface for reading. A glass bottle was used for water sampling from shallow depths (Fig. 9b). The closed bottle was submerged, opened at the sampling depth and lifted up after the air bubbles rising the surface. Current directions were observed by means of a large current cross made of zinc sheets (Fig. 9c). A special water bottle for deep sampling developed by Meyer (Fig. 10) was used during the North Sea cruise of the *Pommerania* in 1872 (JACOBSEN 1873b; MEYER 1875) and during routine measurements (see MAYER 1883; ANON. 1888; NATTERER 1892). Moreover, this bottle was tested with success during the famous *Challenger* circumnavigation (1872 – 1876) and used during the voyage of S.M.S. *Gazelle* (1874 – 1876) (see MEYER 1875; v. BOGUSLAWSKI 1884; KRÜMMEL 1886, 1907; ANON. 1889) and was also delivered to the United States and Russia (MEYER 1875).

Suggested by the "Deutscher Fischerei-Verein" (DFV) [German Fishery Association] (DFV 1870a; see also Section 8), influenced by the circle of the Kiel marine scientists[3] but initiated by HENSEN (KÖLMEL 1990) and MEYER (KARSTEN 1893b), the ***Kiel Commission*** was instituted by Prussia in summer 1870 (see KÖLMEL 1990, on the history of the Commission). In the beginning, the Commission's work was focussed on the improvement of fishery. But soon the founders realized that the knowledge of the hydrographic conditions have a specific importance for fishery research. The Commission acted as official body of the Prussian State. The German Baltic Sea research of the late 19th century was very closely connected with the Kiel Commission which contributed fundamental ideas and methods to modern biological and physical oceanography.

The Commission underlined in a memorandum that this initiative takes care

> "...dass endlich auch für die norddeutschen Meere ... energische wissenschaftliche Arbeiten in Angriff genommen werden..."
> ["...that at last ... vigorous scientific investigations start on for the northern German seas..."] (MEYER et al. 1871, p. 14).

---

[3] HEINRICH ADOLPH MEYER and KARL MÖBIUS were corresponding members of the German Fishery Association (DFV) from the beginning (DFV 1870b), later GUSTAV KARSTEN and VICTOR HENSEN became also members (MEYER-WAARDEN 1970).

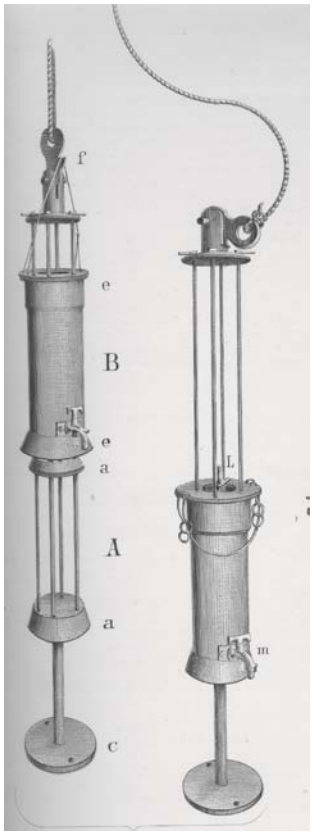


Fig. 10
Water bottle for deep sampling developed by H. A. MEYER (from MEYER 1875).

Abb. 10
Wasserschöpfer zur Gewinnung von Wasserproben aus größeren Tiefen, entwickelt von H. A. MEYER (aus MEYER 1875).

The activities of the Commission should include

> "…die Feststellung der physikalischen Grundbedingungen für das organische Leben im Meere und die davon abhängigen Erscheinungen des mannigfach wechselnden pflanzlichen und thierischen Lebens."
> [„…identifying of the basic physical conditions for the marine organic life and the variability in faunal and floral life depending from the physical conditions."] (MEYER et al. 1871, p. 14).

For this purpose, the observations should be focussed on the following parameters:

> "a) Tiefe, Wasserstand, Grundbeschaffenheit, Salz- und Gasgehalt, Strömungen und Temperatur des Wassers.
> b) Flora und Fauna des Meeres.
> c) Verbreitung, Nahrung, Fortpflanzung und Wanderung der nutzbaren Thiere."

> ["a) Depth, sea level, bottom condition, salinity and gas content, currents and temperature of the water.
> b) marine flora and fauna.
> c) distribution, food, reproduction and migration of the useful dears."] (MEYER et al. 1871, p. 14).

The studies should have the practical purpose to improve the fishery, but investigating the hydrographic conditions was the basic step for attaining the practical goals. According to the working plan of the Commission, a number of observation stations should be installed at the Prussian Baltic coast between the border to Denmark and Memel (today Klaipeda) and an expedition in the Baltic Sea should be carried out (MEYER et al. 1871).

MEYER became the first chairman of the Kiel Commission (between 1870 and 1880) and was later appointed as honorary member. MÖBIUS, HENSEN and also KARSTEN (see Fig. 7) became members. KARSTEN dealt with the hydrography of the Baltic Sea and the elaboration of the measurements of the Commission's coastal station network (see Section 5.2).

A first appreciation of the Commission's work was given by OTTO KRÜMMEL (see Section 7) who became professor of geography at the Kiel University in 1883. Despite his troubles with the Commission in the 1890s (see Section 7.3), he wrote on the contribution of the Commission to the physical investigation of the Baltic Sea in a letter to the Swedish oceanographer OTTO PETTERSSON (1848 – 1941):

> "Die Kommission ist die älteste Institution ihrer Art in Europa und hat vor 20 Jahren sehr Bedeutendes geleistet zur physikalischen Erforschung der Ostsee..."
> ["The Commission is the oldest institution of that kind in Europe and has done an important work for physical research in the Baltic 20 years ago..."] (SMED 1994, p.62).

Later the fishery biologists FRIEDRICH HEINCKE (1852 – 1929) and HERMANN HENKING (1858 – 1942) summarized the Commission's work for the fishery research:

> "Die Arbeiten dieser Kieler Kommission haben nicht nur die Fischereibiologie des Meeres in Deutschland begründet, sondern uns auch ... die führende Stellung auf diesem Forschungsgebiete verschafft."
> [„The work of this Kiel Commission has founded not only the fishery biology of the sea in Germany but also ... our leading position on this research field."] (HEINCKE & HENKING 1913, p. 113).

Basing on the measurements of the eight observation stations established in the Belt Sea MEYER's investigations showed considerable variations in temperature, salinity and sea level in the western Baltic Sea (MEYER 1871). For investigating these variations in more detail and in different time scales, the Commission concluded that long observation series are needed which can only be obtained by installation of an enlarged observation network (MEYER et al. 1873b). Thereupon, the Commission established permanent observation stations at the Prussian Baltic coast, later completed by stations at the Mecklenburg coast.

Mainly KARSTEN (e.g. 1873b, 1875, 1878a) but also MEYER (1884) dealt with the elaboration of the observation data (for details see Section 9).

4. The Baltic Sea expedition of the steamer *Pommerania* in 1871

4.1 The difficult preparatory work

The suggestion of the first Baltic Sea expedition goes back to the DFV founded in January 1870 and was supported by the referee in the Prussian Ministry for Agriculture CONRAD CARL GEORG EDUARD von MARCARD (1826 – 1892). One of the first decisions of the DFV was recommendation No. 2 written in the first Circular dated 7 March 1870:

> „Die Aufmerksamkeit … ist … auf die Nothwendigkeit wissenschaftlicher Vorarbeiten für die Hebung der Nord- und Ostsee-Fischerei gelenkt … Wir haben die Verwendung eines Kriegsfahrzeuges … während einiger Sommermonate … befürwortet und es als wünschenswerth bezeichnet, dass dem Kommandanten … geeignete Sachverständige beigegeben werden. Auch das Bedürfnis regelmässiger Untersuchungen über den Salzgehalt und die Temperatur des Meerwassers haben wir … geltend gemacht."
> [„Attention must be focussed on the requirement of scientific preparatory work for the development of the fishery in the North Sea and the Baltic … We supported the use of a Navy ship … during several summer months … and expressed our wish that the commander … should be accompanied by qualified experts. We also asserted the need of regular observations of salinity and temperature of sea water."] (DFV 1870a, p. 2).

The corresponding DFV member KARL MÖBIUS wrote on 4 April: From my point of view it is

> „…nöthig, zunächst nur in der Ostsee Untersuchungen vorzunehmen." …
> The priority area „…einer Untersuchung … ist das östliche Becken, weil es die grössten Tiefen hat … Das Seewasser ist zu untersuchen auf seinen Gehalt an Salzen und Gasen, auf seine Temperatur und Strömungen … Ich empfehle, die Leitung der Expedition einer Commission zu übertragen, welche aus dem Commandeur des Schiffes und den Naturforschern derselben besteht."
> ["…necessary to start investigations in the Baltic Sea." …
> The priority area "…of investigation … is the eastern basin, because it has the biggest depths … The content of salts and gases of the sea water, temperature and currents should be investigated … I recommend that the expedition is in charge of a commission consisting of the ship's commander and scientists." (DFV 1870c, p. 8).

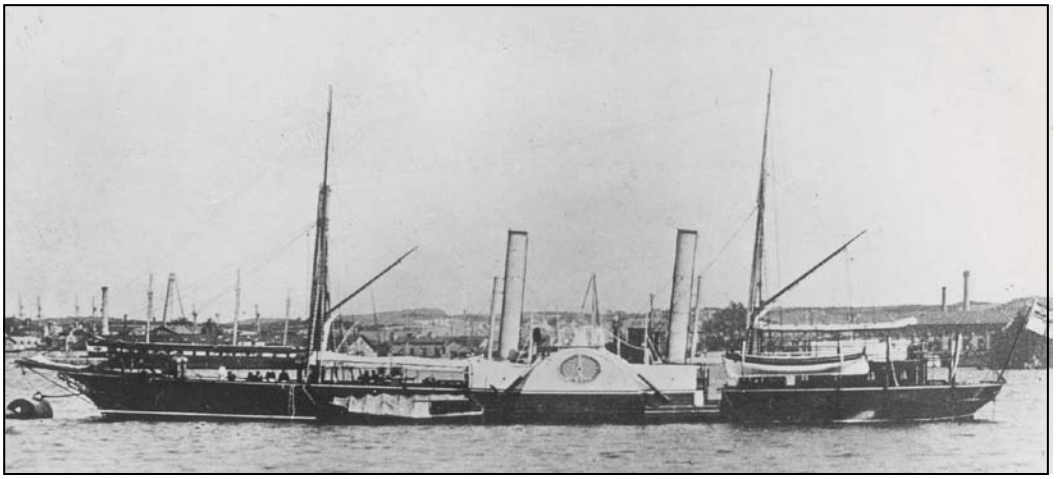


Fig. 11
Paddle-wheel steamer S. M. Aviso *Pommerania,* which carried out the first important expedition for investigation of the oceanographic conditions of the transition area, the western and central Baltic Sea in 1871 (Photo from about 1880, reproduced with the kind permission of Bilddienst Wilhelmshavener Zeitung).

Abb. 11
Raddampfer S. M. Aviso *Pommerania,* der die erste bedeutende Expedition zur Erforschung der ozeanographischen Bedingungen des Übergangsgebietes sowie der westlichen und zentralen Ostsee im Jahre 1871 durchführte (Foto etwa 1880, reproduziert mit freundlicher Genehmigung des Bilddienstes der Wilhelmshavener Zeitung).

The corresponding DFV member H. A. MEYER proposed scientists participating in the expedition (DFV 1870d) and wrote on one objective of the expedition on 6 April:

> It should be „…eine Hauptaufgabe dieser Expedition…, einige feste Stationen zu errichten, damit fortdauernde Beobachtungen über Salzgehalt, Temperatur, und Strömung nicht nur … an der Wasseroberfläche, sondern auch in mässigen Tiefen gemacht werden. Die Sommerbeobachtungen werden erst durch regelmässige Jahresbeobachtungen dauernden Werth erhalten, weil die in der Ostsee so bedeutenden Schwankungen einzelne Beobachtungen immer höchst unzuverlässig erscheinen lassen."
> It should be [„…a main objective of this expedition…, to install several fixed stations in order to observe salinity, temperature and current, not only … at the surface but also in moderate depths. The summer observations gain in importance by regular annual measurements because isolated observations seem to be highly unreliable owing to important fluctuations in the Baltic Sea."] (DFV 1870d, p. 10).

The DFV charged K. MÖBIUS and H. A. MEYER (along with three fishery experts) with the elaboration of an instruction on the performance of the preparatory work and to propose qualified experts (DFV 1870e, p. 2). Later, the Kiel Commission underlined the objectives of the Baltic expedition in a memorandum dated April 1871 (MEYER et al. 1871; see also Section 3).

4.2 The expedition

As a first initiative, the Kiel Commission prepared an investigation of the Baltic Sea on board of the gunboat *Comet* in July 1870 but the German-French War in 1870/1871 prevented the cruise (MEYER et al. 1871). After the war – from June to August 1871 – the expedition took place in the sea area between the Skagerrak and the central Baltic (MEYER et al. 1873a). This expedition went down in history as the first important cruise for investigation of the oceanographic conditions of the Baltic Sea.

The expedition was carried out on board of the paddle-wheel steamer S. M. Aviso[4] *Pommerania* of the Imperial Navy (Fig. 11) commanded by naval lieutenant RUDOLF HOFFMANN (BA-MA 1). The vessel was built in 1864 as dispatch steamer between Stralsund and Stockholm (55 m length, 322 GRT; for German research vessels cf. REINKE-KUNZE 1986, and WEGNER 2000) and was requisited by the Navy in 1870 (HILDEBRAND et al. 1979). The *Pommerania* was put into commission in Stralsund in April 1871 (BA-MA 2), early in May transported to Kiel and placed at disposal for the Baltic expedition (BA-MA 3).

The direct leader of the expedition was the commander of *Pommerania*. He has to make

> "…seine Dispositionen nach Benehmung mit den ihm beigegebenen Fachmännern selbstredend so …, dass der Zweck derselben – eine möglichst reiche wissenschaftliche Ausbeute – erfüllt wird."
> [„…one's arrangements in agreement with the accompanying experts in such a manner …, that the objective of the expedition – the best scientific output – can be fulfilled." (BA-MA 4, p. 11R).

On the participants of the expedition, it is only written:

> "Die Ausführung der physikalischen, zoologischen und botanischen Untersuchungen ist einer Mehrzahl von Fachmännern übertragen, welche mit dem erforderlichen Hilfspersonal die Expedition begleiten werden. Außerdem werden sich die Mitglieder der wissenschaftlichen Commission in Kiel bei der Expedition nach ihrem Ermessen zeitweilig beteiligen."
> [„The physical, zoological and botanical investigations have to be carried out by several experts which will accompany the expedition supported by required auxiliary personnel. Moreover, the members of the scientific Commission in Kiel will participate temporarily at one's discretion."] (BA-MA 4, p. 11V/11R).

A short trip into the Great Belt – scientifically in charge of G. KARSTEN – was carried out from 16 to 18 June 1871 in order to test the measuring instruments and fishing gears. From 21 to 29 June, a second trial run was in charge of H. A. MEYER. This cruise reached the Kattegat and Skagerrak covering 46 stations (cf. Fig. 12). The task was again testing and handling of the instruments (MEYER et al. 1873b), but first hydrographic and biological measurements

[4] fast, little armed warship.

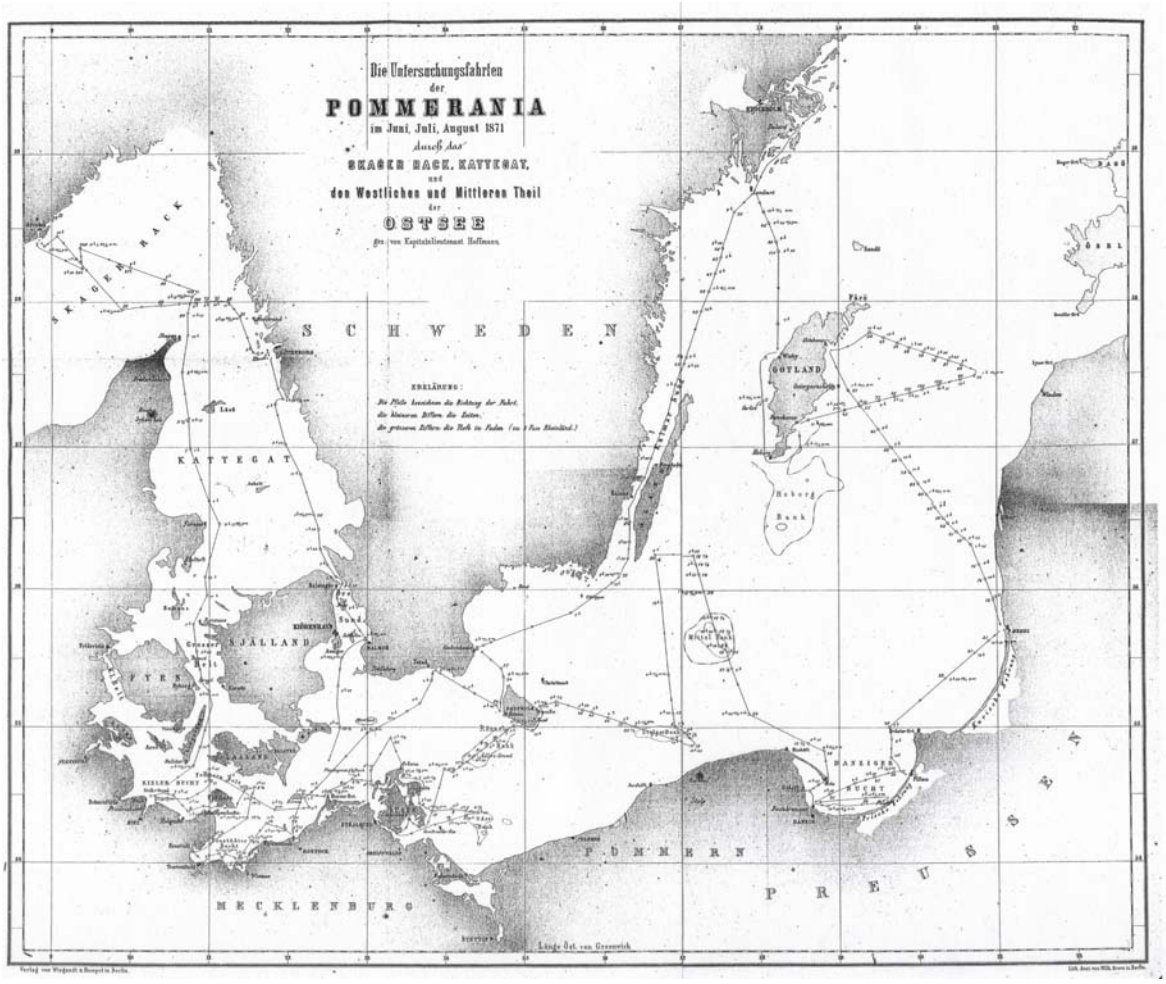


Fig. 12
Map of the cruises of the steamer *Pommerania* showing transects and stations at which observations were carried out in June – August 1871 (from MEYER et al. 1873a).

Abb. 12
Reiserouten des Dampfers *Pommerania* zwischen Juni und August 1871 sowie die durchgeführten Schnitte und Stationen (aus MEYER et al. 1873a).

were also carried out (MEYER et al. 1872). The main cruise of *Pommerania* was carried out between 6 July and 23 August and was led scientifically by H. A. MEYER (6 to 14 July) and K. MÖBIUS (from 14 July onwards). During the main expedition, covering the central Baltic as far north as Stockholm, measurements at 170 stations and, additionally, numerous physical observations were carried out covering the western and central Baltic (Fig. 12).

Main objectives of the expedition were:

- Investigation of the boundaries between North Sea and Baltic Sea waters by means of salinity, currents, temperature or marine fauna and flora;

- Exploration of current and future fishing areas in the Baltic and its physical and chemical conditions;
- Investigation of hydrographic conditions in the deeps of the Baltic Sea and the vertical distribution of marine fauna and flora (MEYER et al. 1873b).

OSCAR GEORG FRIEDRICH JACOBSEN (1840 – 1889) – at that time assistant at the Chemical Laboratory of the Kiel University, from 1873 onwards professor at the Rostock University (Fig. 13) – was the chemist of the expedition. He was familiar with the analysis of salt and gases dissolved in water and he was asked to deal with the hydrographic-hydrochemical observations (on contributions of JACOBSEN to chemical oceanography see MATTHÄUS 2010). JACOBSEN formulated the topic of the physical-chemical investigations. It should be investigated

> "…welches Wasser … durch Sund und Belte in die Ostsee … eintreten kann … und … der Verlauf der Verdünnung bis in das … östliche Gotlandbecken…"
> [„…which water … can penetrates into the Baltic Sea through the Sound and the Belts … and how is the course of dilution on the way to the … eastern Gotland Basin…"] (JACOBSEN 1873a, p. 39).

4.3 Results of the hydrographic observations

The expedition was successful especially with respect to the hydrographic investigations and gave – for the first time – a survey of the thermohaline conditions of the open Baltic Sea between the Kattegat and the central Baltic (Fig.14). JACOBSEN (1872, 1873a, 1873b) reported on the salinity distribution and currents in the Danish Straits and in the Baltic and informed on the gas analyses. KARSTEN (1873a) analyzed the data measured at the coastal stations.

The measurements of salinity showed:

> "Die salzärmsten Wasserproben – mit 0,648 pCt.[5] Salz – wurden … nordwestlich von Gotland geschöpft, während … Wasser mit mehr als 3 pCt. sich nicht nur im Kattegat, sondern auch … in der Tiefe der Belte und der Sundstrasse vorfand."
> ["The water samples – having the lowest salinity of 0.648 per cent – were taken north westerly of the island of Gotland, while … water with more than 3 per cent was found not only in the Kattegat but also … in the deep water of the Belts and the Sound."] (JACOBSEN, 1872, p. 21).

On 17 June, observations in the Great Belt showed

> "…die eingehende Unterströmung schwereren Wassers in besonders deutlicher Weise." (Jacobsen 1873a, p. 39). "In der Cadettenrinne zwischen Darserort und Gjedser trafen wir am 7. Juli schon in 6 Faden Tiefe auf einen starken südwestlichen, der Oberflächenströmung entgegenlaufenden Unterstrom. Das Wasser der Oberfläche enthielt

[5] pCt = Prozent [per cent] (%).

0.751 Proc., das aus 14 Faden ... geschöpfte ... 1.637 Proc. Salz. Bei einer späteren dortigen Messung (18. August) ... betrug [der Salzgehalt] an der Oberfläche 0.874, am Grund in 15 Faden Tiefe 2.467 Proc."
[„...especially clear the in-going under current of heavier water." (Jacobsen 1873a, p. 39). „On 7 July, we found a strong south westerly under current already in a depth of six fathoms of the Kadet Trench between Darsser Ort and Gedser flowing in opposite direction to the surface current. The surface water had 0.751 per cent and the water taken from 14 fathoms ... 1.637 per cent. During a later measurement on 18 August ... the surface [salinity] was 0.847 per cent and 2.467 per cent at the bottom in a depth of 15 fathoms."] (JACOBSEN 1873a, p. 41).

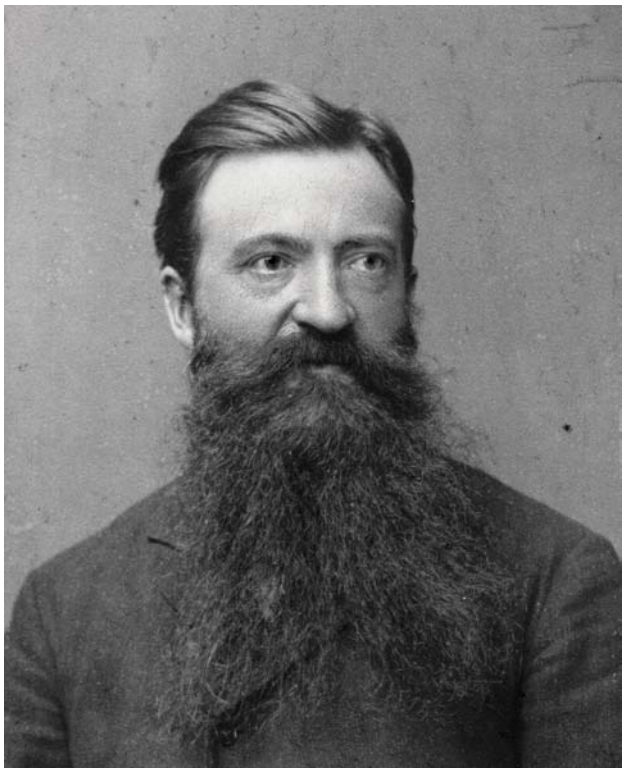
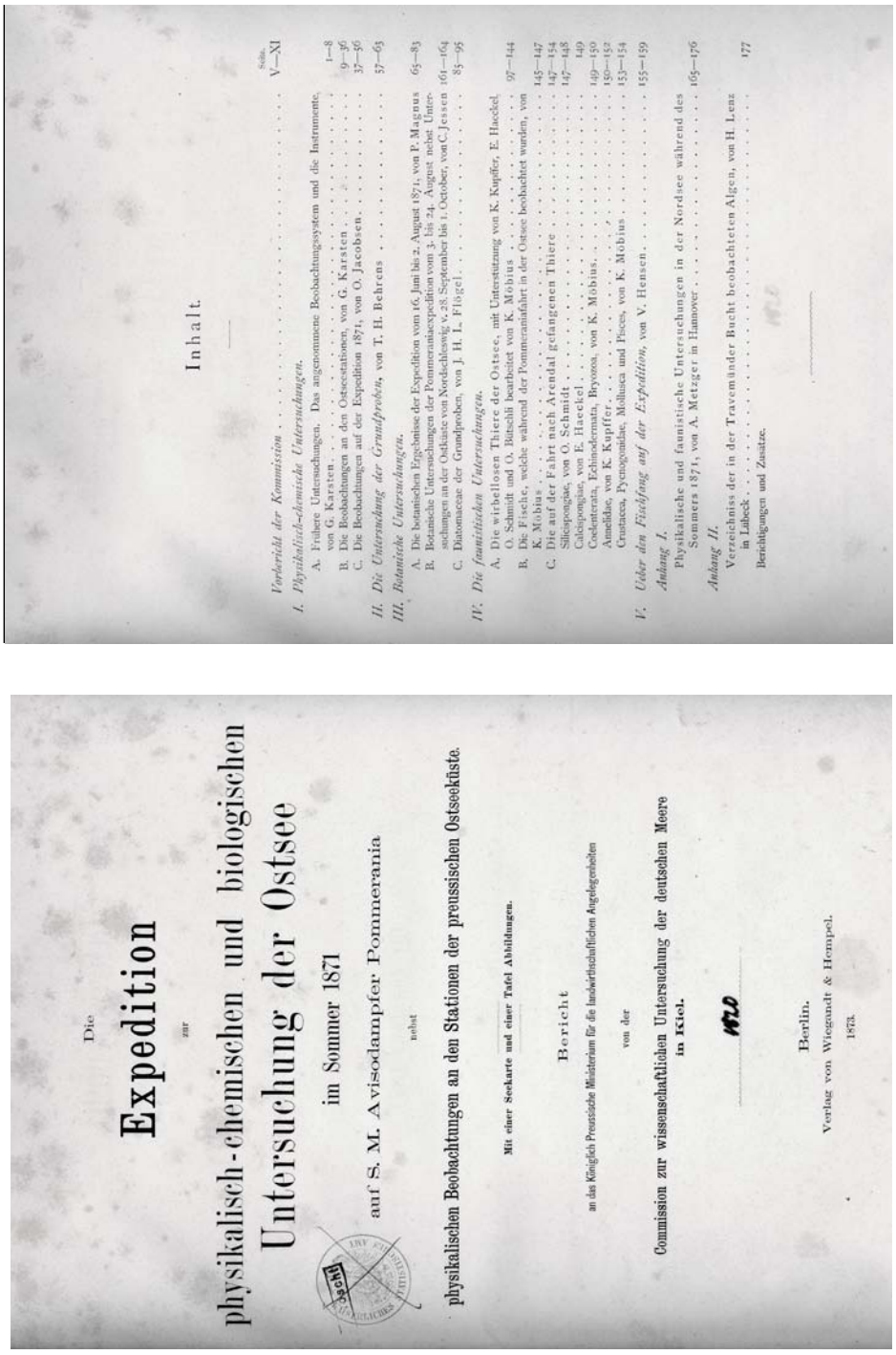


Fig. 13
OSCAR GEORG FRIEDRICH JACOBSEN (1840 – 1889), chemist of the *Pommerania*-Expedition in 1871 (Photo: Archive, Rostock University).

Abb. 13
OSCAR GEORG FRIEDRICH JACOBSEN (1840 – 1889), Chemiker der *Pommerania*-Expedition 1871 (Foto: Archiv, Universität Rostock).



Die

Expedition

zur

physikalisch-chemischen und biologischen Untersuchung der Ostsee

im Sommer 1871

auf S. M. Aviso Pommerania.

nebst

physikalischen Beobachtungen an den Stationen der preussischen Ostseeküste.

Mit einer Seekarte und einer Tafel Abbildungen.

Bericht

an das Königlich Preussische Ministerium für die landwirthschaftlichen Angelegenheiten

von der

Commission zur wissenschaftlichen Untersuchung der deutschen Meere in Kiel.

Berlin.

Verlag von Wiegandt & Hempel.

1873.

Inhalt.

Fig. 14
Title page and contents of the report of the Kiel Commission on the Baltic Sea expedition of S. M. Aviso *Pommerania* in 1871 (from MEYER 1873a).

Abb. 14
Titelblatt und Inhaltsverzeichnis des Berichtes der Kieler Kommission über die Ostsee-Expedition des S. M. Aviso *Pommerania* im Jahre 1871 (aus MEYER 1873a).

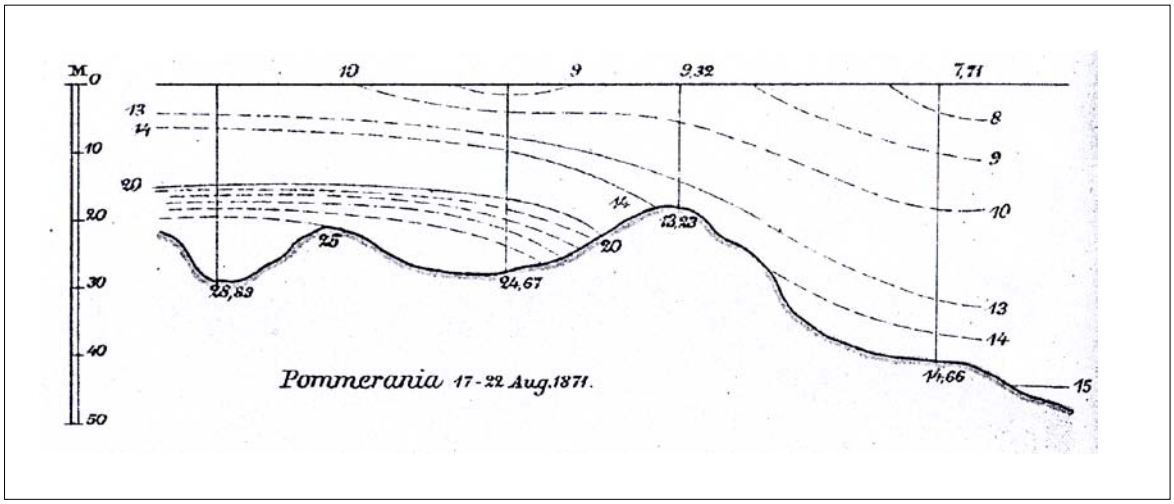


Fig. 15
Longitudinal transect of salinity (in ‰) from the Fehmarn Belt (left) to the Arkona Basin carried out on board of *Pommerania* in August 1871 (from EKMAN & PETTERSSON 1893, Table IV).

Abb. 15
Längsschnitt des Salzgehaltes (in ‰) zwischen Fehmarnbelt (links) und Arkonabecken gemessen von der *Pommerania* im August 1871 (aus EKMAN & PETTERSSON 1893, Tab. 4).

Fig. 15 shows the salinity distribution (in ‰) between Fehmarn Belt and the Arkona Basin in August 1871.

The results of the expedition showed on the further penetration of the saltwater:

> „…tiefere Schichten salzreichen Wassers, wie sie besonders durch den grossen Belt und zeitweise ohne Zweifel auch durch den Sund eintreten, erstrecken sich bis weit in die Ostsee hinein, – nur langsam durch allmälige Mischung mit schwächerem Oberflächenwasser an Salzgehalt verlierend und im Allgemeinen den Rinnen der grössten Tiefen als vorgeschriebenen Strombetten folgend."
> [„…deeper layers of saline water penetrating particularly through the Great Belt and occasionally - no doubt - through the Sound, extend far away into the Baltic, – their salinity decreases only slowly by gradual mixing with the surface water and, in general, the inflowing water uses the deepest channels as pathways"] (JACOBSEN 1872, p. 22; 1873a, p. 40).

Investigation of hydrographic conditions of the Baltic deep water in the eastern Gotland Basin gave rise to assume that

> "Die vorherrschende Strömung des Tiefenwassers … in diesem weiten östlichen Meerestheile … der vorherrschenden Oberflächenströmung entgegengesetzt, d. h. … von Südwest nach Nordost gerichtet sein [muss], um durch solchen Zufluss immer wieder den

> Verlust auszugleichen, den das nördliche Tiefenwasser durch Abgabe von Salz an verdünntere Wasserschichten beständig erleidet."
> [„the predominant current of the deep water … in this far easterly sea area [must go] in opposite direction to the predominant surface current, i.e. from … south west to north east, in order to compensate by such supply again and again the loss which the northern deep water suffers permanently by delivery of salt to levels with lower salinity."] (JACOBSEN 1873a, p. 42/43).

The observations of the oxygen content done by JACOBSEN should also be mentioned. He found hydrogen sulphide smell of the near-bottom water of a trough-shaped deep in the Little Belt (JACOBSEN 1873b). JACOBSEN presumed the cause in a longer stagnation of the bottom water combined by interaction with the sediment (for more details see MATTHÄUS 2010).

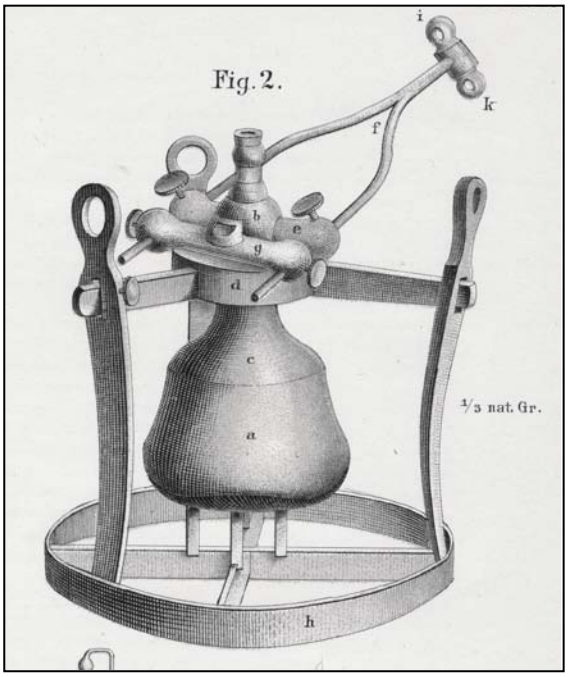


Fig. 16
Rubber bottle for deep sampling of water for analysis of gases developed by O. JACOBSEN and H. BEHRENS and improved by the mechanic L. Steger (from JACOBSEN 1875).

Abb. 16
Kautschuk-Schöpfapparat zur Gewinnung von Wasserproben aus größeren Tiefen zur Analyse der Gase im Meerwasser, entwickelt von O. JACOBSEN und H. BEHRENS und verbessert vom Mechaniker L. Steger (aus JACOBSEN 1875).

In general, the results of the expedition were unsatisfactory regarding the analysis of dissolved gases, mainly due to unsuitable water samplers (JACOBSEN 1873b). Therefore, JACOBSEN assisted by HEINRICH BEHRENS (1842 – 1905) developed a special rubber water sampler in order to take samples for analysis of gases in sea water (Fig. 16). The water bottle worked successfully during the North Sea cruise of *Pommerania* in 1872 (JACOBSEN 1873b, 1875), was used by BUCHANAN during the *Challenger* Expedition 1872 - 1876 (BUCHANAN 1878) and was also explained in textbooks (MAYER 1883). Later JACOBSEN analyzed successfully the quantity of dissolved gases in sea water (JACOBSEN 1873b, 1875, 1888) and his results and the method used were appreciated internationally (TORNØE 1880; DITTMAR 1884; KNUDSEN 1903).

On the basis of the *Pommerania* results, KARSTEN (1874a) summarized the knowledge of that time on the hydrographic conditions of the Baltic Sea in an overview paper. As far as salinity is concerned he wrote:

> "...in der Ostsee ... lässt sich ... eine Zunahme des specifischen Gewichtes von Oben nach Unten nachweisen. Da ein Abnehmen des Salzgehaltes vom atlantischen Ocean ... zur Ostsee ... von Westen nach Osten vorhanden ist,... findet ... eine Bewegung des Wassers ... der Art statt, dass sich das schwerere Wasser unten ... von West nach Ost, das leichtere oben ... von Ost nach West bewegt."
> ["...in the Baltic, an increase in specific gravity can be proved from top to bottom. Since there is a decrease in salinity from the Atlantic Ocean ... to the Baltic Sea ... from west to east, ... a water movement takes place ... in such a way that the heavier water moves below ... from west to east and the lighter one above ... from east to west"] (KARSTEN 1874a, p. 513).

Covering the *Pommerania* results and the measurements carried out at the German coastal stations, KARSTEN supplemented the knowledge on the Baltic Sea hydrography in 1878 (KARSTEN 1878a; see the next Section).

The *Pommerania* Expedition showed the necessity of further expeditions in order to investigate the Baltic Sea hydrography in more detail. In the "General Report" dated 21 October 1871, the Kiel Commission stated on the cruise:

> "Die ... Expedition ... sollte ... nicht mehr sein als eine Recognoscirungsfahrt, um einen Blick über das ganze Forschungsgebiet zu werfen und die bathymetrischen, chemisch-physikalischen und biologischen Verhältnisse desselben cursorisch zu prüfen, besonders aber um sichere Anhalspunkte für weitere wissenschaftliche Untersuchungen ... zu finden."
> ["The ... expedition ... should be no more than a general cruise in order to obtain an overview on the whole area with respect to the bathymetric, physical-chemical and biological conditions, but in particular to find reliable support for further scientific investigations..."] (MEYER et al. 1872, p. 11).

Therefore, the Commission recommended seasonal cruises in special German sea areas as e.g. the Gulf of Gdańsk, the Bay of Lübeck or the Kiel Bight:

> „Wenn ... die ... Untersuchungen zu einer klaren Einsicht in die Lebensverhältnisse der Fische führen sollen, so ist es unerlässlich, dieselben in den verschiedenen Gebieten unserer Meere durch alle Jahreszeiten fortzusetzen."
> [„If ... the ... investigations shall give a clear understanding of the living conditions of fish, then it is indispensable to continue these investigations in different areas of our seas and during all seasons."] (MEYER 1872, p. 11).

Moreover, the Commission recommended to the Prussian Minister for Agricultural Affairs a similar scientific investigation of the North Sea during the summer of 1872 in order to have a basis for a better explanation of the Baltic hydrography:

> "Erst durch eine wissenschaftliche Untersuchung der Nordsee werden wir auch eine befriedigende Grundlage zur Erklärung der Eigenschaften des baltischen Meeres erlangen können…"
> ["We can only obtain a satisfactory basis for the explanation of the properties of the Baltic Sea by a scientific investigation of the North Sea..."] (MEYER et al. 1872, p. 11).

5. Activities of GUSTAV KARSTEN in Baltic Sea research

GUSTAV KARSTEN (1820 – 1900) (Fig. 7) was the physicist among the leading German marine scientists of the 19th century. He graduated and habilitated at the Berlin University in 1843 and 1845, respectively, and was one of the co-founder of the German Physical Society in 1845. After his time at the Berlin University KARSTEN accepted the professorship of physics and mineralogy at the University of Kiel in 1847. A detailed appreciation of his life and scientific work is given by WEBER (1900). This part is focussed on the work of GUSTAV KARSTEN for Baltic oceanography.

5.1 KARSTEN's way to oceanography

In the 1840s, the "Royal Prussian Privy Councillor" and mineralogist CARL JOHANN BERNHARD KARSTEN (1782 – 1853) – father of GUSTAV KARSTEN – worked at a two-volume "Lehrbuch der Salinenkunde" (KARSTEN 1846/1847) which also covered a chapter on salt in the sea. Possibly stimulated by his father, GUSTAV KARSTEN was interested in salt solutions and sea water. During his time at the Berlin University, he started an extensive experimental investigation in specific gravity of common salt solutions (KARSTEN 1846) which formed the basis of his later work in oceanography (see below). He investigated maximum density and freezing point of common salt solutions as function of temperature and salinity (specific gravity). He developed both empirical equations of the temperatures of freezing point and maximum density as function of salinity, and an equation of specific gravity as function of temperature and salinity. KARSTEN used the results especially for sea water with salinities between 0 and 40 ‰.

Another point was KARSTEN's organizational talent and ability. He organized the installation of a network of meteorological observation stations in the duchy of Schleswig-Holstein between 1849 and 1869. Moreover, he was very active in reorganization of the standards of gravities and measures in Schleswig-Holstein and became director of the Bureau of Standards in 1860.

His interest in the sea was the reason that KARSTEN was one of the four founding members of the Kiel Commission in 1870 (see Section 3) and there responsible for hydrography. From the foundation onwards KARSTEN was also manager of the Commission, succeeded MEYER as chairman in 1880 and chaired the Commission until 1896 (SMED 1994). According to KÖLMEL (1990; see also WEBER 1900), KARSTEN resigned as chairman and member of the Kiel Commission in 1895. In a letter to PETTERSSON dated 16 March 1896, KRÜMMEL wrote that KARSTEN left the Commission not before 1 April 1896 (see SMED 1994). However, HENSEN followed him in chairmanship.

KARSTEN's interest in oceanography was mainly focussed on the physics of the Baltic Sea and on the elaboration of the meteorological and hydrographic measurements of the Commission's coastal station network. But he had no time to participate in cruises. In preparation of the *Pommerania* Expedition, he participated obviously only in a short trip into the Great Belt from 16 to 18 June 1871, being scientifically in charge of testing measuring instruments and fishing gears.

In the 1840s, he was aware of the water exchange between the North Sea and the Baltic, especially on the in-going under current in the Sound reported e.g. by BOYLE (1670), SMITH (1684) or BREWSTER (1821) after observations carried out by seamen. KARSTEN explained the physical background of this process in his book on common salt solutions:

> "Aus der Ostsee geht ein Oberstrom in den atlantischen Ocean, ein Unterstrom in umgekehrter Richtung … wegen des geringen spec. Gew. des Ostseewassers. Daß, bei diesem Austausch des Wassers, der Salzgehalt der eingeschlossenen weniger salzhaltigen Meere nicht zunimmt, wird man aus der Menge des in sie einströmenden süßen Wassers erklären können."
> [„There is an upper current from the Baltic Sea into the Atlantic Ocean, an under current in opposite direction … because of the low spec. gravity of the Baltic water. The salinity of enclosed lower saline seas does not increase under these exchange conditions. That can be explained by the amount of fresh water discharged into these seas."] (KARSTEN 1846, p. 90/91).

He paid special attention to the importance of the density maximum in sea water of different salinity, in particular for the Baltic Sea:

> „Da ... das Ostseewasser von geringem Salzgehalte ist und ein Maximum der Dichtigkeit oberhalb des Gefrierpunktes hat, so können die tiefsten Schichten nicht unter die Temperatur der Maximi abgekühlt werden."
> [„Since ... the Baltic water has a low salinity and a maximum density above the freezing point, the deepest layers can not cooled down below the temperature of the maxima."] (KARSTEN 1846, p. 92).

Later KARSTEN animated his pupil and son-in-law LEONHARD WEBER (1848 – 1919) – who started as an assistant of the Physical Institute in 1876, since 1894 professor of theoretical physics at the Kiel University – to deal with this problem. In his thesis (KARSTEN 1877), WEBER dealt with the maximum density of pure water and sea water as function of temperature and salinity (WEBER 1878; see also ANON. 1878a). He investigated Baltic Sea water of the Adlergrund (Arkona Sea) and the Kiel harbour and found density maxima at salinities of 7.9 ‰ and temperatures of 2.43 ºC and 17.7 ‰ and 0.45 ºC, respectively.

From his own measurements and the investigation of WEBER, KARSTEN (1888, 1896a) stated on the importance of the density maximum for vertical mixing in the Baltic:

> "Indem ... in der kalten Jahreszeit das bis zum Maximum der Dichte abgekühlte salzärmere Wasser nach unten sinkt und dieser Prozess sich bei den an die Stelle tretenden nächstliegenden Schichten sich fortwährend erneuert, muss allmählig eine Verdünnung der unteren Schichten bewirkt werden."
> [„In the cold season, there must occur gradually a dilution of the lower layers because the lower saline water sinks downwards due to its cooling down to the density maximum, and this process goes on continuously in the neighbouring layers that replace the water."] (KARSTEN 1896a, p. 175).

5.2 KARSTEN's oceanographic interests and the German coastal station network

In 1874, KARSTEN summarized the knowledge of that time on the hydrographic conditions of the Baltic Sea in an overview paper using the *Pommerania* measurements (KARSTEN 1874a). On the basis of the *Pommerania* results and the measurements carried out at the German coastal stations, he supplemented the knowledge on the Baltic Sea hydrography in 1878 (KARSTEN 1878a; see also ANON. 1878a). Generally, earlier results were confirmed but there were considerable annual peculiarities. He wrote on the surface water:

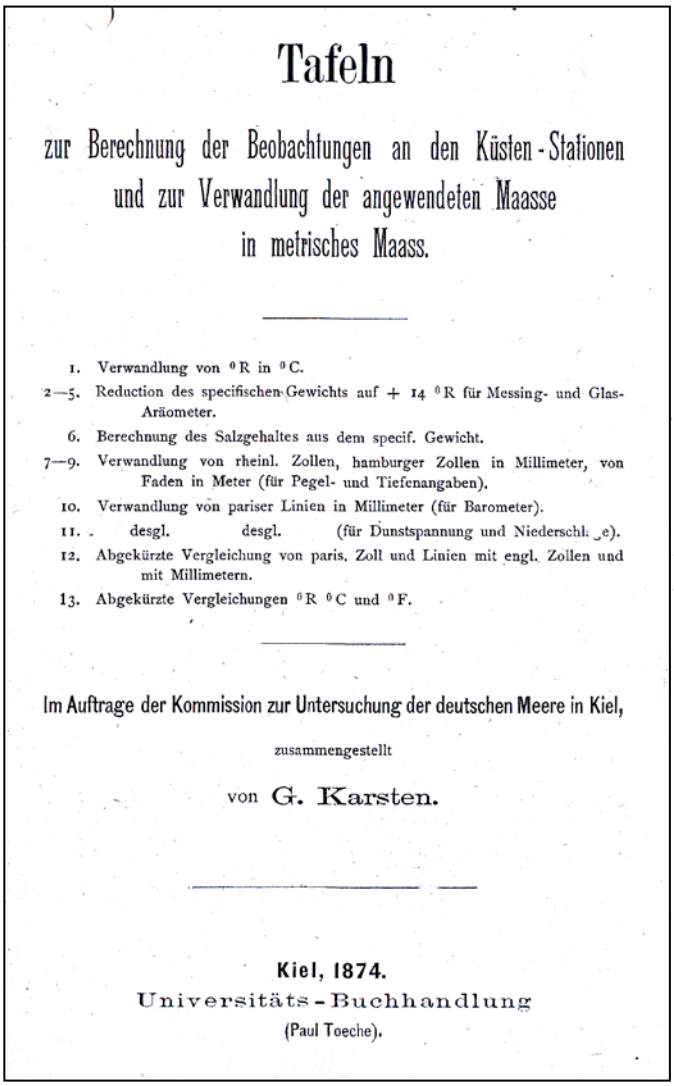
> "In dem weitaus grössten Theile der Ostsee ... findet sich ein ... unter 1 Prozent bleibender Salzgehalt. Von Rügen ab westwärts nimmt derselbe stetig zu ... der kleine Salzgehalt der östlichen Abtheilung [ist] in den einzelnen Jahren viel geringeren Schwankungen unterworfen ..., als der grössere der westlichen Abtheilung ... In der westlichen Abtheilung unterscheiden sich einzelne Jahrgänge ... sehr wesentlich von einander,..."
> [„In the largest part of the Baltic ... there is ... the salinity below 1 per cent. Salinity increased continuously westerly of the island of Rügen ... the low salinity of the eastern part

is subject to much smaller annual fluctuations …, than the higher one of the western part… In the western part, variations from year to year differ … considerably from each other,…"] (KARSTEN 1878a, p. 269).

KARSTEN stated for the deep water:

„...der Unterschied zwischen Oberflächen- und Tiefenwasser ist ... im westlichen Becken bedeutender und namentlich treten grosse Verschiedenheiten sowohl der Jahreszeiten als der verschiedenen Jahre hervor ... bedingt durch den Bewegungsmechanismus des Wassers … Sehr andauernde und intensive Westwinde können den abfliessenden Strom hemmen und den einfliessenden salzreichen Unterstrom fördern. Dann wird nicht allein das gesamte westliche Ostseebecken mit ungewöhnlich salzreichem Wasser erfüllt werden, sondern dasselbe kann ... in den tieferen Wasserschichten viel weiter nach Osten vordringen."

["…the difference between surface and deep water is … more important in the western basin. There are large differences both between the seasons and from year to year … caused by the moving mechanism of the water … Persistent and intensive westerly winds can hamper the out-going current and support the in-going saline under current. In that case, not only the total western Baltic basin will be filled by unusual salt-rich water, but it can … penetrate much far to east in the deeper water layers."] (KARSTEN 1878a, p. 269).



Tafeln

zur Berechnung der Beobachtungen an den Küsten-Stationen und zur Verwandlung der angewendeten Maasse in metrisches Maass.

1. Verwandlung von ⁰R in ⁰C.
2—5. Reduction des specifischen Gewichts auf + 14 ⁰R für Messing- und Glas-Aräometer.
6. Berechnung des Salzgehaltes aus dem specif. Gewicht.
7—9. Verwandlung von rheinl. Zollen, hamburger Zollen in Millimeter, von Faden in Meter (für Pegel- und Tiefenangaben).
10. Verwandlung von pariser Linien in Millimeter (für Barometer).
11. desgl. desgl. (für Dunstspannung und Niederschl.ge).
12. Abgekürzte Vergleichung von paris. Zoll und Linien mit engl. Zollen und mit Millimetern.
13. Abgekürzte Vergleichungen ⁰R ⁰C und ⁰F.

Im Auftrage der Kommission zur Untersuchung der deutschen Meere in Kiel,

zusammengestellt

von G. Karsten.

Kiel, 1874.
Universitäts-Buchhandlung
(Paul Toeche).

Fig. 17
Title page of the tables for both calculation of coastal station observations and conversion of different European measures into the metric system published by GUSTAV KARSTEN in 1874 on behalf of the Kiel Commission (from KARSTEN 1874b).

Abb. 17
Deckblatt der Tabellen zur Berechnung der Beobachtungen an den Küstenstationen und der Umrechung verschiedener europäischer Maße in das metrische System, veröffentlicht von GUSTAV KARSTEN im Jahre 1874 im Auftrage der Kieler Kommission (aus KARSTEN 1874b).

In March 1878, KARSTEN presented the results obtained by investigations of the Kiel Commission between 1871 and 1876 to the German Geographical Society (KARSTEN 1878b). During another presentation to the Society in May 1878, he explained – for the first time – the physical cause of the upper and lower currents in the transition area between the North Sea and the Baltic:

> "Die Unterschiede des hydrostatischen Druckes … können in zwei mit einander communicirenden Meeren einen Ober- und einen Unterstrom erzeugen (wie die Ost- und Nordsee…) … Die Ursachen für eine solche Bewegung sind … ungleiches specifisches Gewicht und ungleicher Salzgehalt, wie es z. B. bei der Ost- und Nordsee … der Fall ist."
> ["Between two communicating seas (like the Baltic and North Seas…), the differences in hydrostatic pressure … can generate an upper and lower current … The causes for such movement are … unequal specific gravity and unequal salinity, as it is the case … e.g. for the Baltic and the North Sea."] (KARSTEN 1878c, p. 162/163).

He also ensured that the results of the investigations were accessible to interested people in the public in particular to the fishermen (KARSTEN 1880).

By reason of his experience in hydrographic data KARSTEN was also asked to work with the physical observations collected during the first German circumnavigation on board of S.M.S. *Gazelle* in 1874 – 1876, which were handed over to the Kiel Commission by the Imperial Admiralty (KARSTEN 1878a, 1888).

On behalf of the Kiel Commission 12 - 13 observation stations were established at the Prussian Baltic coast between Sonderburg to Hela (for details see Section 9). The observations at the German coastal station network were regularly published (ANON. 1874). KARSTEN had special interest in the results, worked at the data and published monthly and seasonal means of specific gravity, salinity and temperature at the stations. At the instance of KARSTEN German and foreign sailors were equipped with thermometers, areometers and water bottles made available by the Commission in order to do observations in the open sea for supplementing the coastal station measurements. For applying to the observations of the coastal stations KARSTEN (1874b) published tables (Fig. 17) in order to reduce the specific gravity to 17.5 ºC, to calculate the salinity from specific gravity and to converse the used values into metric measures. In the late 19th century, these tables were the mostly used in Germany (v. BOGUSLAWSKI 1884; KRÜMMEL 1886) and were also well-known among marine scientists (see e.g. TORNØE 1880).

In the late 1890s, KARSTEN (1896b) summarized the task of the physics in the German Seas. Animated by KARSTEN, WEBER developed and tested a current meter with electrical recording in 1893 (KARSTEN 1896b; SMED 1994, see also Section 7.3). Later WEBER investigated the electrical conductivity of sea water (KARSTEN 1896b) but KARSTEN thought that this method could hardly be of practical use for determination of salinity.

Finally it should be mentioned that KARSTEN has done early preparatory works for the Kiel Canal in the early 1860s owing to his hydrological knowledge of the region (WEBER 1900). The memorandum on the Kiel Canal published in 1865 is attributed to him (KARSTEN, 1865).

6. The Baltic Sea cruises of the steamer *Holsatia* in 1887 and 1901/1902

In September 1887, the chartered cargo-steamer *Holsatia* (Fig. 18; built in 1868, length 40 m, 300 GRT) carried out a cruise in the Baltic Sea (HENSEN 1893) ordered by the Section for "Coastal and High Seas Fisheries" of the "Deutscher Fischerei-Verein" (DFV) (see Section 8) and led by VICTOR HENSEN. The main objective was the exploration of herring stocks and their food conditions in the central Baltic but temperature and salinity conditions also were measured during the cruise (cf. Fig. 19).

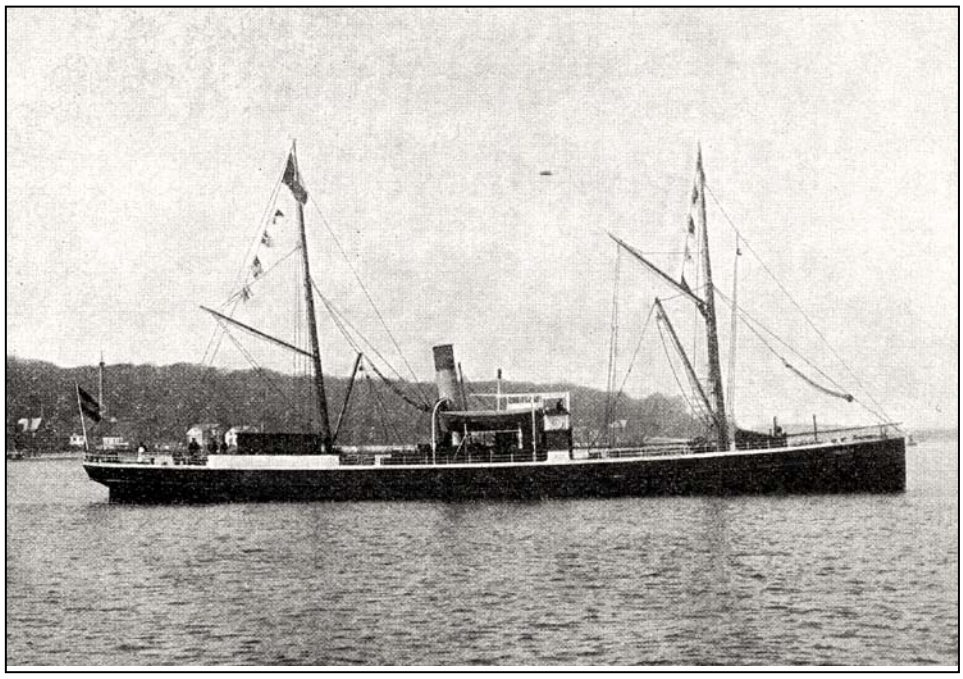


Fig. 18
Cargo-steamer *Holsatia* chartered by the German Sea Fishing Association (DSV) in 1887 and 1901 for investigations in the Baltic Sea, and operating during the first regular seasonal cruise in the framework of ICES in 1902 (from REIBISCH 1902).

Abb. 18
Frachtdampfer *Holsatia*, in den Jahren 1887 und 1901 vom Deutschen Seefischerei-Verein für die Forschungen in der Ostsee gechartert und 1902 für die erste reguläre Terminfahrt im Rahmen des ICES eingesetzt (aus REIBISCH 1902).

Thermometer and areometer were used for observing temperature and specific gravity. The depth-temperatures were measured by means of reversing thermometers designed by NEGRETTI (1874) and later by means of CASELLA thermometers (MATTHÄUS 1966). The water bottle developed by MEYER (cf. Fig. 10) was used for deep sampling.

On 16 September, HENSEN investigated the thermohaline stratification in the eastern Gotland Basin down to 146 m depth (stations see Fig. 19). He found minimum temperatures of 2.8 ºC in 90 and 100 m depth and temperatures of 4.7 ºC near the bottom. The near-bottom salinity was 13.1 ‰. HENSEN realized that the temperatures in the deep water of the central Baltic depend on the season of the inflow of saline water across the sills:

> "Die höchste Temperatur … scheint herrühren zu müssen von … Wasser, welches im Sommer die flache Region des Westens verliess, die niederste von Wasser, welches im Winter in den Unterstrom einfloss."
> ["The highest temperature … seems to originate from water, which left the shallow western area during summer, the lowest originate from water, which penetrates the under current during winter."] (HENSEN 1893, p. 121).

He also stated that the driving force for the diapycnal transport of salt is not diffusion but vertical mixing. He wrote on the vertical salt exchange:

> "Sicher kann von einem Austausch durch Diffusion nicht die Rede sein, denn dieser Prozess geht … äusserst langsam vor sich,… Damit die unterliegende schwere Flüssigkeit sich mit der überliegenden leichteren mischt, muss ein Antrieb gesetzt werden, welcher beide Flüssigkeiten in etwas v e r s c h i e d e n e r Weise in Bewegung setzt … Dann wird die schwere Flüssigkeit in Folge ihres Beharrungsvermögens in die leichte hineinlaufen, es werden Wirbel entstehen,… und es wird eine Durchmischung … erfolgen."
> [„Obviously, exchange by diffusion is out of question since this process takes place … extremely slowly,… The mixing of the lower heavy liquid with the upper lighter ones needs a driving force which moves both liquids in a slightly d I f f e r e n t way … Then the heavy liquid will move into the light by its inertia, eddies occur,… and a mixing takes place."] (HENSEN 1893, p. 122).

In 1901, the Second International Conference for the Exploration of the Sea in Kristiania (Oslo) (see Section 8) suggested to start seasonal cruises already in 1901. Each member country should provide a steamer specially constructed for scientific fishery research. From August to October 1901, the DSV, supported by the "Deutsche Wissenschaftliche Kommission für die Internationale Meeresforschung" (DWKIM) [German Scientific Commission for the International Marine Research], again chartered the steamer *Holsatia* for the investigation of fishery conditions in the Baltic Sea. That cruise was carried out in preparation of the international seasonal cruises agreed in Kristiania (ANON. 1902), but the hydrographic investigations were restricted to measurements of temperature and salinity (REIBISCH 1902). A total of 64 stations were investigated between the western Baltic and the Gotland Deep (Fig. 20) most of them hydrographic stations. Water samples were taken by means of KRÜMMEL's water bottle equipped with a reversing thermometer for measuring the deep-water temperatures (cf. Fig. 22). Specific gravity was measured by means of an

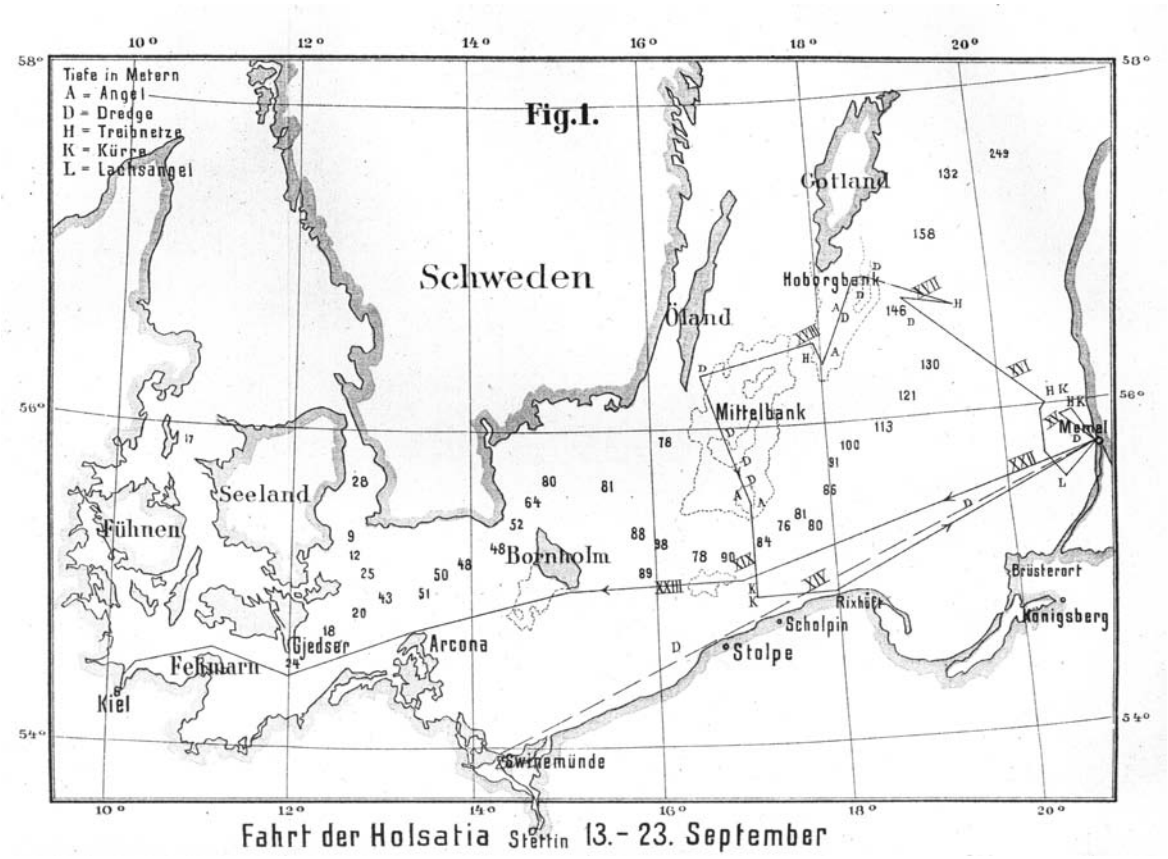


Fig. 19
Map of the cruise of the *Holsatia* showing the transects carried out in September 1887 (from HENSEN 1893).

Abb. 19
Reiseroute der *Holsatia* mit den im September 1887 ausgeführten Schnitten (aus HENSEN 1893).

areometer checked by KRÜMMEL and provided with correction tables required for calculation of salinity (REIBISCH 1902).

Once more in 1902, the steamer *Holsatia* operated for hydrographical research in the Baltic. The first regular, internationally agreed seasonal cruise in the Baltic Sea in August 1902 must be carried out again by the *Holsatia* due to problems with the new research steamer *Poseidon*. Later, *Poseidon* (see Section 8) carried out all seasonal cruises on behalf of the Commission (cf. HERWIG 1905, 1906, 1908).

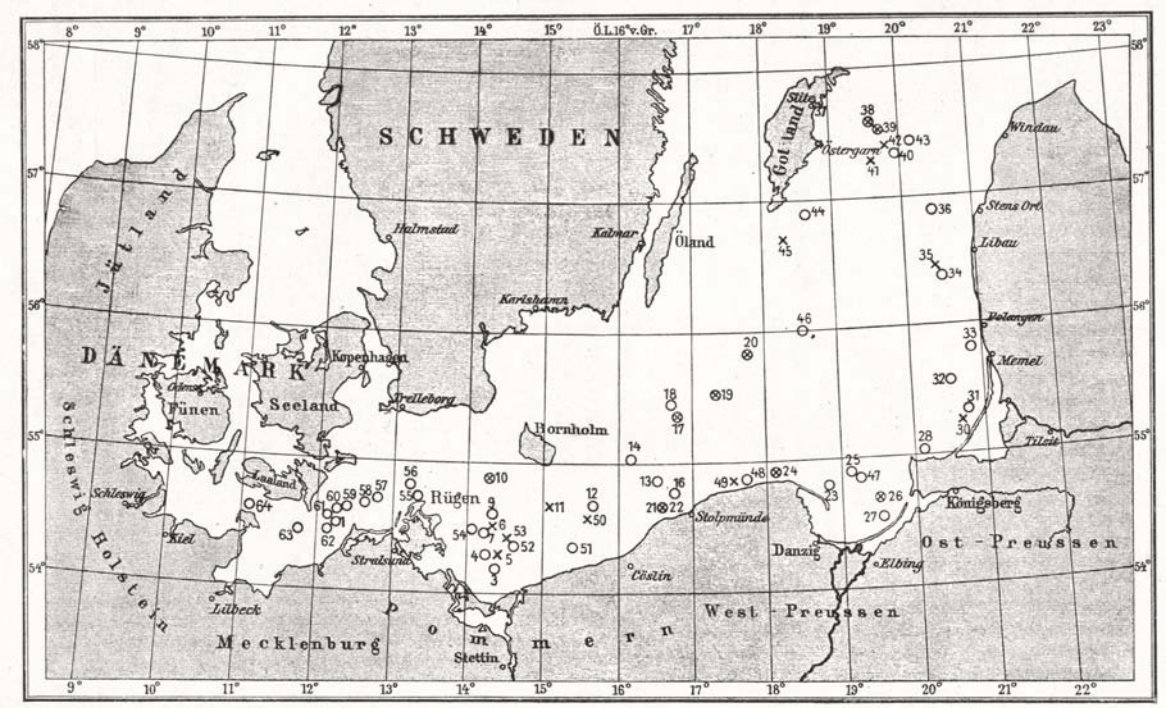


Fig. 20
Map of the cruise of the *Holsatia* showing the measurements carried out between August and October 1901 (from REIBISCH 1902).

Abb. 20
Reiseroute der *Holsatia* mit dem im August und Oktober 1901 bearbeiteten Stationsnetz (aus REIBISCH 1902).

7. OTTO KRÜMMEL's contributions to Baltic Sea research

This part describes the work of the geographer JOHANN GOTTFRIED OTTO KRÜMMEL (1854 – 1912) for investigation of the Baltic Sea. An extensive appreciation of his life, work and merits for geography and oceanography was given by ULRICH & KORTUM (1997).

7.1 His oceanographic activities in Kiel

KRÜMMEL (Fig. 21) was the pioneer of the modern oceanography in Germany. Starting his work as scientific assistant at the "Deutsche Seewarte" [German Marine Observatory] in Hamburg in 1882 (on the activities of KRÜMMEL at the Observatory see KORTUM 1993) KRÜMMEL accepted a professorship of geography at the University of Kiel in 1883 (MATTHÄUS 1967a, 1967b). On his call to Kiel, he wrote that he

"…kaum eine andere Professur mit solcher Begeisterung … antreten würde als gerade die Kieler, die mich dem Meere so nahe bringt, dessen Erforschung ich zur Aufgabe meines Lebens gemacht habe…"
[„…would hardly accept another professorship with such enthusiasm … as that one in Kiel, which takes me so close to the sea, the research of that I have dedicated to my purpose in life…"] (GStA PK 1).

Fig. 21
OTTO KRÜMMEL (1854 – 1912), pioneer of the modern oceanography in Germany, professor of geography at the Kiel University (Photo: Archive IfM-Geomar, Kiel).

Abb. 21
OTTO KRÜMMEL (1854 – 1912), Wegbereiter der modernen Ozeanographie in Deutschland, Professor der Geographie an der Universität Kiel (Foto: Archiv, IfM-Geomar, Kiel).

KRÜMMEL had experimental interest and organizational skill. Beside his activity in academic teaching he was engaged in marine research. He already had dealt with oceanographic problems in his PhD thesis in Göttingen (KRÜMMEL 1877) and during the preparation of the oceanographic part of the Atlantic Ocean Sailing Directions in Hamburg (see KORTUM 1993) but his deeper interest in the oceanography of the Baltic Sea started only in Kiel in the early 1890s. He has evaluated in detail the observations of the great Baltic expeditions carried

out by Germany (Meyer et al. 1873a), by Sweden in 1877 (EKMAN & PETTERSSON 1893) and by Russia in 1886/1889 (MAKAROFF 1894), and investigated the problem of renewal of the Baltic deep water at the end of the 19th century.

In the second half of the 1880s, KRÜMMEL published the popular book "Der Ozean" (KRÜMMEL 1886) and finished the second volume of the first oceanographic textbook after the passing away of GEORG von BOGUSLAWSKI (v. BOGUSLAWSKI & KRÜMMEL 1887). In these books, he summarized the scientific knowledge of that time also on the Baltic Sea. In 1899, he participated in the German "Plankton-Expedition" – led by HENSEN – on board of the steamer *National* in the northern part of the Atlantic Ocean and was responsible for the geophysical observations (KRÜMMEL 1892, 1893).

KRÜMMEL also dealt with oceanographic instruments. The water sampler with reversing thermometer, introduced in 1893 by H. L. EKMAN and O. PETTERSSON (PETTERSSON 1894a) and tested by FRIDTJOF NANSEN (MILL 1900), was modified by KRÜMMEL in 1905 for use by the Kiel Hydrographic Laboratory (KRÜMMEL 1907; Fig. 22). This water bottle had a no isolated cylinder and a sampler volume larger than that of the PETTERSSON water bottle. The KRÜMMEL sampler was used, for instance, during the voyage of S.M.S. *Planet* in 1906/1907 (BRENNECKE 1909) and was still used in the 1920s (SCHOTT 1928).

KRÜMMEL was very much interested in using areometers for measuring specific gravity on board in order to determine salinity and he dealt with the accuracy of areometers (KRÜMMEL 1890, 1894a, 1896b, 1901). Later he also dealt with the conductivity of sea water. On the basis of measurements by the chemist ERNST RUPPIN, assistant at the Kiel Hydrographic Laboratory, he published a table in order to interpolate the conductivity from temperature and salinity (KRÜMMEL 1908).

Among the 10 doctor theses on oceanographic problems, suggested and supervised by KRÜMMEL between 1888 and 1910, three of those dealt exclusively with Baltic oceanography (KORTUM & PAFFEN 1979). RUDOLF ENGELHARDT (1899) investigated currents by calculating the density level in the Baltic Sea on the basis of temperature and salinity measurements, mainly from the Swedish expedition in 1877 (EKMAN & PETTERSSON 1893). ENGELHARDT calculated the sea level of the Baltic easterly of Bornholm to be 33 cm above the level of the Skagerrak. He also found that the Baltic surface water moved cyclonically. The theses of E. F. PICCARD (1904) and R. KOHLMANN (1905) dealt with the physical geography of the Gulf of Finland and the currents of the western Baltic, respectively.

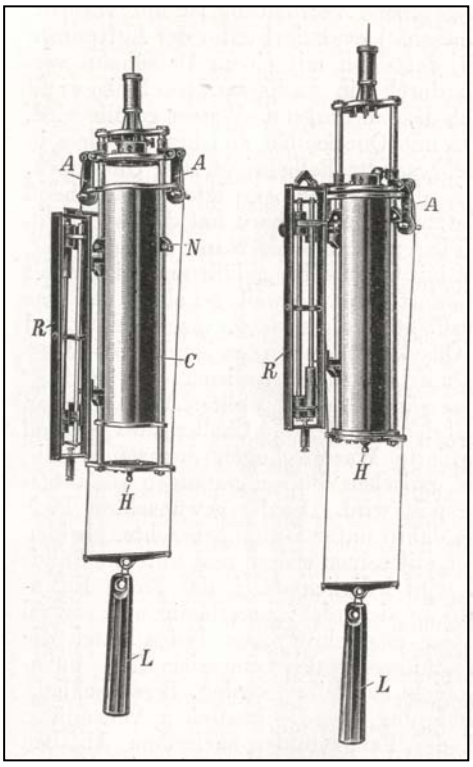


Fig. 22
Water bottle with reversing thermometer frame. The bottle was introduced by O. PETTERSSON and modified by KRÜMMEL in 1905 for use by the Hydrographic Laboratory in Kiel (from KRÜMMEL 1907).

Abb. 22
Wasserschöpfer mit Kippthermometerrahmen. Der Schöpfer wurde von O. PETTERSSON entwickelt und von Krümmel im Jahre 1905 für die Zwecke des Hydrographischen Labors in Kiel modifiziert (aus KRÜMMEL 1907).

Already in 1900, the "Reichsamt des Innern" [Imperial Office of the Interior] established the DWKIM (from 1919 onwards "Deutsche Wissenschaftliche Kommission für Meeresforschung", DWK) as link to the 1902 formed ICES in Copenhagen. BAHR (1962), SAHRHAGE (1982) and WEGNER (1990, 1998b) published details on the history of the DWK. The president of the DSV, WALTHER HERWIG (1838 – 1912), became chairman of the DWKIM from 1900 to 1908. KRÜMMEL became a prominent and active member and he led the hydrographic and meteorological investigations. Two laboratories – the Hydrographical and Biological Laboratory – were established in Kiel in 1902, affiliated to the Kiel Commission. In spring of 1902, the Hydrographical Laboratory started its work which was directed by KRÜMMEL from 1902 to 1911 (BRANDT 1928).

KRÜMMEL (1894b) underlined the importance of the measurements carried out by the *Pommerania* Expedition in 1871 but criticized that there was no standardized observation programme at the stations. Up to the 1890s, the knowledge on physical processes in the German part of the Baltic Sea mainly based on the regular observations at the 12 coastal stations maintained by the Kiel Commission. Therefore, KRÜMMEL criticized the lack of investigations into the Baltic deep water from German side:

> "Die … Kieler Ministerial-Kommission hat anscheinend diesen Theil ihrer Aufgaben vorerst zurückstehen lassen gegenüber ihren epochemachenden Untersuchungen über das Plankton der Ostsee, und sich darauf beschränkt, die physikalischen Prozesse nur an den Küstenstationen möglichst regelmäßig beobachten zu lassen."
> ["Compared with their epoch-making investigations in the plankton of the Baltic Sea the … Kiel Ministerial-Commission has obviously put on the back this part of their tasks, and has confined to observe regularly the physical processes at the coastal stations only."] (KRÜMMEL 1894b, p. 133).

In the 1890s, Sweden and Denmark performed joint synoptic investigations in the Skagerrak/Kattegat area (PETTERSSON & EKMAN 1891; PETTERSSON 1894b, 1894c). Moreover, regular seasonal cruises were carried out in the Kattegat, the Belts and the Sound by Danish ships from 1891 onwards (RØRDAM 1896; WANDEL 1896). In contrast to that, only single incomplete observations of the open Baltic Sea were carried out by Germany since 1871, e.g. by the warships *Rhein* in 1878 and *Niobe* in 1887, or – on behalf of the DSV – by the steamer *Holsatia* in 1887 (see KRÜMMEL 1894b).

KRÜMMEL also criticized that Germany did not start larger efforts in order to investigate the physical conditions of the Baltic Sea. In August 1893, for instance, he complained of the small amount of money that the Kiel Commission made available for physical research:

> "Seitdem … G. Karsten alt geworden und namentlich seit H. A. Meyer gestorben ist, liegt das Schwergewicht der Arbeiten auf dem Gebiet der Planktonforschung, …sodass wenig Mittel für die physikalischen Aufgaben übrig sind."
> ["Since … G. Karsten has been old and especially since H. A. Meyer passed away, the work is focussed on plankton research, and only a small amount of money is left for physical tasks."] (SMED 1994, p. 62: Letter of KRÜMMEL to O. PETTERSSON, dated 7 August 1893).

After the renouncement of KARSTEN in 1896, HENSEN followed him as Commission's chairman. KRÜMMEL expected to became member but his membership was confirmed as late as 1899 (GStA PK 2).

Despite his activities in academic teaching and administration in Kiel KRÜMMEL participated in cruises. His most important voyage was aboard of the steamer *National* during the German „Plankton-Expedition" in 1899 (KRÜMMEL 1892, 1893). In 1893/1894, he took part in short cruises in the Eckernförde Bay, the Fehmarn Belt and the Little Belt, and he carried out observations on board the *Nautilus* and *Pelikan* during cruises in the western Baltic

(KRÜMMEL 1894b, 1895). He also participated in one of the German seasonal cruises on board the *Poseidon* in the North Sea in August 1903 (KRÜMMEL 1905b).

7.2 KRÜMMEL's investigation in Baltic hydrography

KRÜMMEL's interest in Baltic Sea research arose soon after his start in Kiel. He was especially interested in the inflows of salt water. Already in his book „Der Ozean", published in 1886, he reported on the frequency of salt water inflows that

> „...die submarine Einströmung salzigen Wassers durch die Belte nicht in jedem Jahre gleich intensiv auftritt."
> [„...the near-bottom inflow of salty water through the Belts does not occur every year with the same intensity."] (KRÜMMEL 1886, p. 140).

In this connection he stated:

> „Hier wären systematische Untersuchungen gerade in der tiefen Mulde zwischen Gotland und Kurland besonders erwünscht; fehlt es doch sogar an regelmäßig beobachtenden Küstenstationen in diesem Teile der Ostsee."
> [„Systematic investigations would be welcome especially in the deep trough between Gotland and Kurland, since there are missing even regular measuring coastal stations in that part of the Baltic Sea"] (KRÜMMEL 1886, p. 140).

KRÜMMEL (1894b, 1895) summarized the knowledge of that time in two general papers on the physics of the Baltic Sea. He analyzed the international data and the German measurements available up to 1894 which based on observations on board the *Pommerania* in 1871 and measurements carried out by the Swedish oceanographer Fredrik Laurentz EKMAN (1830 – 1890) in 1877 (published by EKMAN & PETTERSSON 1893), by the Russian admiral and oceanographer S. O. MAKAROFF in 1886 and 1889 (MAKAROFF 1894) and his own measurements on board of the navy ships *Nautilus* and *Pelikan*.

KRÜMMEL described the stratification of temperature and salinity in the Baltic Sea and their variations from the Baltic entrance into the inner parts of the Gulfs. He explained the penetration of salty water into the central Baltic and described the importance of the sills between the different basins for the propagation:

> „Das Vordringen dieses Tiefenwassers ins Innere der Ostsee wird ... wesentlich reguliert durch die Schwellen- oder Zugangstiefen, welche die einzelnen Trogmulden voneinander trennen"
> ["The propagation of this deep water into the inner part of the Baltic Sea is ... essentially controlled by the sill or entrance depths, which separates the trough-shaped basins from each other"] (KRÜMMEL 1895, p.85/86).

He also explained the role of the Bornholm Basin for salt water inflows into the central Baltic:

> "Es kann … in diese "Bornholmer Mulde" Wasser von solchem Salzgehalt eindringen, wie er auf die Darßer Schwelle kommt. Das in dieser Mulde enthaltene Tiefenwasser bleibt dann darin … wenn keine neue Zufuhr erfolgt,…"
> [„Water of such salinity like at the Darss Sill can penetrate into this „Bornholm Trough". The deep water present in the trough remained there … if there is not a new supply,…"] (KRÜMMEL 1895, p. 86).

KRÜMMEL analyzed the inflow situation into the Bornholm Basin at the end of the 19th century:

> "Zwischen 1871 and 1877 hat vielleicht eine Zufuhr neuen Wassers aus der Beltsee stattgefunden … Dagegen hat von 1877 bis 1893 eine deutlich erkennbare Aussüßung…stattgefunden, während bis Juli 1894 … wieder eine Zufuhr neuen Wassers über die Darßer Schwelle erfolgt ist…"
> [„Between 1871 and 1877, perhaps an inflow of new water from the Belt Sea has taken place … On the contrary, a distinct recognizable freshening has occurred from 1877 to 1893, while an inflow of new water across the Darss Sill again occurred up to July 1894…"] (KRÜMMEL 1895, p. 86).

Summarizing, KRÜMMEL described the basic inflow mechanism and the renewal of the central Baltic deep water in his lecture "Die Deutschen Meere im Rahmen der internationalen Meeresforschung", presented in the Institut für Meereskunde in Berlin in 1903 (KRÜMMEL 1904). He stated that inflows of saline water into the Baltic

> "…nicht kontinuierlich, sondern unregelmäßig, stoßweise erfolgen und das zugeführte Quantum in jedem Fall verschieden groß ausfallen"
> ["…does not occur continuously but irregularly, intermittently and the supplied amount is definitely different"] (KRÜMMEL 1904, p. 27).

He reported on the renewal process of the Baltic in 1902/1903 by the increase in oxygen in the Gdańsk Deep:

> "Daß es sich … um eine Erneuerung des Wassers gehandelt hat, wird … erwiesen durch den Sauerstoffgehalt…; er betrug im November 1902 nur 6 Prozent, dagegen im Mai 1903 … 25 Prozent … und maß im Februar 1904 nur 9 Prozent."
> ["That it concerned a renewal of water … is demonstrated by the oxygen content…; it was only 6 per cent in November 1902, but 25 per cent in May 1903 … and was only 9 per cent in February 1904"] (KRÜMMEL 1904, p. 31).

KRÜMMEL remarked for the first time the different importance of the various indicators for a renewal of the deep water:

> "…der Salzgehalt gewährt dafür … nur ein Merkmal, ein empfindlicheres … die Temperatur, am deutlichsten sprechen aber die gelösten Gase"
> ["…salinity is for that … only one indicator, temperature … is a more sensitive one, but clearest are the dissolved gases"] (KRÜMMEL 1907, p. 352).

ERNST RUPPIN (1905) also used the oxygen concentration of the water penetrated during Baltic inflow events for characterizing the renewal process in the central deep basins.

One interesting result of the Swedish Baltic expedition in the summer of 1877 (EKMAN & PETTERSSON 1893) was the discovery of the Baltic intermediate layer with minimum temperatures existing at a certain depth below the warm surface water during summer. KRÜMMEL (1895) explained that phenomenon by vertical convection of the surface water in winter and warming of the surface water during spring and summer. In summer, cold surface water from the previous winter is preserved between the thermocline and the halocline.

The observations show that

> "…alle jahreszeitlichen Schwankungen der Temperatur sich … nur in der homohalinen Deckschicht abspielen, dass … die winterliche Abkühlung nur bis an deren untere Grenze vordringt."
> ["…all seasonal variations in temperature … take place only in the homohaline upper layer and … the winter cooling reach only their lower border."] (KRÜMMEL 1895, p. 114).

The

> „…großen jahreszeitlichen Schwankungen der Lufttemperatur über der Ostsee … verdankt die Oberfläche … ihre im Sommer oft bis 18º ansteigende Erwärmung, … Die innere Wärmeleitung von einem Wasserteilchen zum andern ist so gut wie ganz auszuschalten,…Wichtiger ist der vertikale Austausch zwischen den Wasserschichten durch Konvektion,…"
> [„…great seasonal variations of air temperature over the Baltic Sea … cause the warming of the sea surface which often increases up to 18º during summer time,… The inner heat transport from water particle to water particle can nearly be neglected,… the vertical mixing between the layers by convection is more important,…"] (KRÜMMEL 1895, p. 115).
> „Die unterhalb 70 m liegenden Tiefenschichten werden … kaum … von diesen mechanischen Vorgängen der Konvektion oder Durchmischung beeinflußt;"
> [„The layers below 70 m depth are hardly influenced by these mechanical processes of convection or mixing;"] (KRÜMMEL 1895, p. 117).

By means of the observations made by MAKAROFF (1894) easterly of Gotland, GERHARD SCHOTT (1866 – 1961) – since 1894 at the "Deutsche Seewarte" in Hamburg – calculated the in situ density of the water in different depths and has shown the vertical stability of the stratification both in the area with cold intermediate water layer in the central Baltic and in the northern Baltic (SCHOTT 1896).

KRÜMMEL also dealt with the importance of the physical conditions to fishery. In a summarizing paper, he reported – among others – on the dependence of the herring catches in the northern Kattegat (Bohuslän coast) on seasonal variations of physical conditions caused by the interaction between North Sea and Baltic waters (KRÜMMEL 1896a).

For investigating the physics of the Baltic Sea KRÜMMEL (1895) recommended urgently: By means of

> „...Küstenbeobachtungen allein, wie sie die Kieler Ministerialkommission seit 25 Jahren unterhält...“ we will „...niemals hinter das Geheimnis kommen, sondern durch häufig wiederholte, auf alle Jahreszeiten und mehrere Jahresreihen ausgedehnte Hochseefahrten, die allein geeignet sind, die physikalischen Zustände und Veränderungen des Ostseewassers aufzuklären.“
> [„...coastal stations like those that are in operation by the Kiel Commission since 25 years...“ we will „...never solve the secret but only by frequent open sea cruises which have to be carried out during all seasons and several years. Only such cruises are suitable for investigating the physical conditions and variations of the Baltic Sea waters”] (KRÜMMEL 1895, p. 118).

On the basis of the measurements carried out during the German seasonal cruises in 1902 and 1903, KRÜMMEL (1905a) reported on the conditions before the strong salt water inflow in December 1902 and on the effect of that inflow (for a historical survey on investigations in salt water inflows see MATTHÄUS 2006a). He wrote on the haline stratification:

In August 1902 (see Fig. 23a), there is

> “...an der Oberfläche ... die nach Westen ausfließende ... Deckschicht, mit 7,5 bis 8 Promille Salzgehalt, an der schwedischen Seite bis 25 m, an der Rügenschen bis 10 m hinab; in der Tiefe das aus der Beltsee ostwärts einströmende salzigere Wasser, das sich normaler Weise rechts an die deutsche Seite drängt und in Station 8 seinen größten Salzgehalt mit 14,40 Promille besitzt.”
> [„...at the surface ... the upper layer of 7.5 to 8 ‰ salinity, out flowing towards west, reaching down to 25 m at the Swedish side and down to 10 m depth at the Rügen side; in the depth, there is the eastward inflowing more saline water from the Belt Sea which is usually on the right at the German side and has its highest salinity of 14.40 ‰ at station 8.“] (KRÜMMEL 1905a, p. 27).

Oktober 1902 (Fig. 23b):

> “...Das Bodenwasser zeigt seinen größten Salzgehalt in der nördlichen Station 7, und die hier gefundenen 15,97 Promille sind wahrscheinlich ... über die ... Drogdenschwelle aus dem Sund herübergekommen,...”
> [„...The bottom water shows its highest salinity at the northern station 7, and the measured values of 15.97 ‰ are likely caused by water penetrated ... from the Sound across the Drogden Sill...”] (KRÜMMEL 1905a, p. 27/28).

The condition was „especially striking“ in February 1903 (Fig. 23c):

> “Die Deckschicht hat 8,2 bis 9,0 Promille Salzgehalt, ist also um 1 Promille salziger als gewöhnlich. Außerdem aber war auch der Unterstrom unerhört salzreich und am Boden in Station 8 mit 23,50 Promille so salzig, wie sonst wohl im Großen Belt. Dieses ... recht kalte Wasser (2º) ist offenbar durch die starken und anhaltenden Weststürme über die Darßer Schwelle hinübergedrängt worden...”
> [„The upper layer has a salinity of 8.2 to 9.0 ‰, which means by 1 ‰ more saline than usual. Besides that the under current was very salt rich and near the bottom of station 8 with 23.50 ‰ as salty as normally in the Great Belt. This ... relative cold water (2º) was

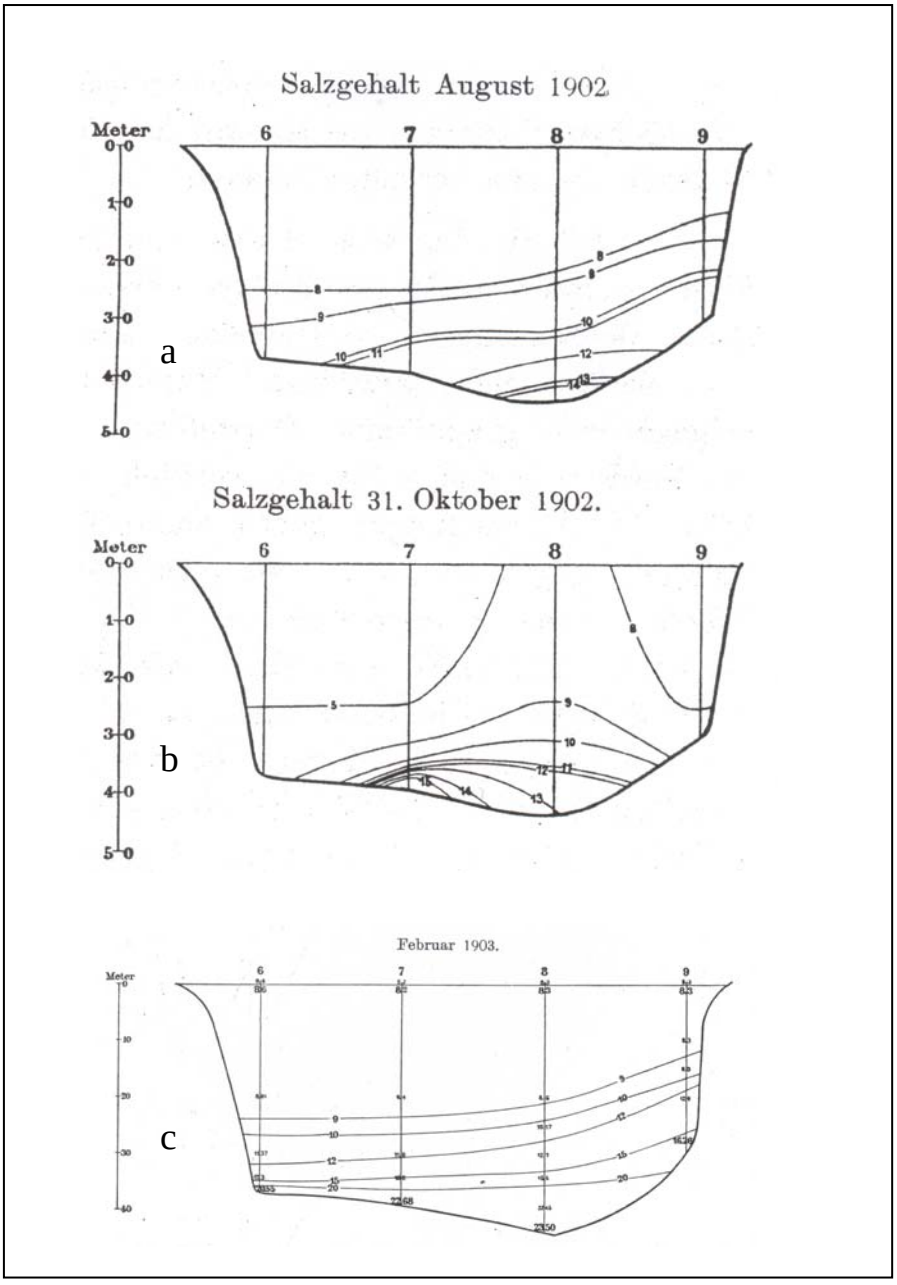


Fig. 23
Salinity stratification (in ‰) between Trelleborg (left) and Arkona measured during the seasonal cruises in 1902 (a,b) and 1903 (c). Positions see Fig. 26. (from KRÜMMEL 1905a).

Abb. 23
Salzgehaltsschichtung (in ‰) zwischen Trelleborg (links) und Arkona, gemessen auf den Terminfahrten in den Jahren 1902 (a,b) und 1903 (c). Positionen s. Abb. 26 (aus KRÜMMEL 1905a).

(2º) was pushed across the Darss Sill caused obviously by the strong and persistent westerly gales…"] (KRÜMMEL 1905a, p. 28).

7.3 OTTO KRÜMMEL and the international cooperation

International cooperation in the Baltic Sea started in the Scandinavian countries and Scotland. Already in 1878, measurements and observations of different parameters in air and water at coastal stations and light vessels were discussed during a Nautical-Meteorological Conference of the Scandinavian countries in Copenhagen (ANON. 1878b). In 1890, OTTO PETTERSSON AND GUSTAF EKMAN (1852 – 1930) initiated a quasi-synoptic investigation of the Skagerrak and northern Kattegat by means of five vessels (PETTERSSON & EKMAN 1891). In order to continue the successful observations they organized a joint investigation between Sweden, Denmark, Norway and Scotland in 1893/1894 (PETTERSSON 1894b, 1894c; PETTERSSON & EKMAN 1897).

The cause of the Scandinavian initiative seems to be obvious: Scandinavian countries have huge coastlines compared to Germany, on the one hand, and they have a close connection from their history also among marine scientists, on the other hand. Therefore it was relatively easy to establish cooperation between them if both a professional scientific programme and skilled, energetic and acknowledged scientists were available. These scientists were OTTO PETTERSSON and GUSTAF EKMAN.

OTTO KRÜMMEL was the first marine scientist in Germany who contacted the cooperation partners in Scandinavia and tried to push forward the cooperation from the German side. KRÜMMEL, an energetic young man (compared with the members of the Kiel Commission) who has dedicated the research of the sea to the purpose of his life (GStA PK 1), was looking for new ways also for investigating the Baltic Sea. When he came to Kiel, the Kiel Commission was established since more than one decade, founded by scientists tied friendly to each other since two decades. He represented a new generation, 25-30 years younger than the members of the Commission. So it was difficult for him as a newcomer to be accepted by the inner circle. Moreover, there was obviously a certain personal antipathy between the physicist KARSTEN and the young geographer KRÜMMEL (see also SMED 1994).

When KRÜMMEL read about the Scandinavian project in the newspapers he intended to participate by observations in the Baltic Sea (KRÜMMEL 1894b, 1895). He got in touch with OTTO PETTERSSON, both skilled organizers and productive scientists and nearly in the same age.

Because the Kiel Commission was not invited to join the cooperation, the then chairman GUSTAV KARSTEN (from 1880 to 1895) did not support KRÜMMEL's initiative. The Commission

financed only a few small days' cruises in summer 1893 since the Commission's budget was exhausted. KRÜMMEL was disappointed:

> "Die Ministerial-Kommission hätte wohl noch Mittel gehabt für zwei Fahrten, wenn nicht Professor Karsten erhebliche Summen zur Construction und Erprobung eines Tiefenstrom-Messers (mit elektrischer Registrirung) durch seinen Schwiegersohn Prof. Leonhard Weber hätte verbrauchen lassen"
> ["The Ministerial-Commission had possibly had money for two additional cruises but Professor Karsten had spent considerable money for construction and test of a deep-current meter (with electrical recording) carried out by his son-in-law Prof. Leonhard Weber."] (SMED 1994, p. 62: Letter of KRÜMMEL to O. PETTERSSON, dated 11 October 1893).

But KRÜMMEL (1895) was thoroughly convinced:

> „Daß ... eine Kooperation mit den anderen beteiligten Uferstaaten ... ökonomisch vorteilhaft sein müsste ... [und] bedarf wohl kaum einer besonderen Erörterung."
> [„A cooperation with the other interested states bordering the Baltic ... should be economically favourable ... and needs hardly special discussion." (KRÜMMEL 1895, p.118).

Consequently, he started – on his own initiative – cooperation with Danish and Swedish marine scientists on the water exchange between the North Sea and the Baltic. He asked the Imperial German Navy for participating in cruises. In 1893/1894, the survey steamer *Nautilus* and the training ship *Pelikan* undertook cruises in the Baltic Sea (KRÜMMEL 1895). That was the beginning of international cooperation in the Baltic from the German side.

Only when the chairmanship of the Commission changed from KARSTEN to HENSEN in 1896 Germany's participation in international cooperation got under way by larger activities. SMED (1994) reported in detail on KRÜMMEL's trouble with the Kiel Commission.

OTTO KRÜMMEL has made important contributions to the international cooperation in the framework of foundation and the first years of ICES between 1899 and 1911. He was member of the Central Bureau in Copenhagen from 1902 to 1911. Owing to his special interest in physical oceanography he paid strong attention to the organization and realization of international agreed regular seasonal cruises by Germany. KRÜMMEL appreciated the international cooperation in a lecture in 1903 and emphasized the importance of oceanography and biology:

> "...dies Ziel kann nur erreicht werden mit Hilfe der Wissenschaften der Oceanographie und Biologie, ... Diese ... internationale Erforschung ... wird mit einer musterhaften Gründlichkeit, Vielseitigkeit und Schärfe der Methoden betrieben und mit einem bis dahin unerhörten Aufwand von Mitteln ..., so dass sie in jeder Hinsicht zu einem Wendepunkt der wissenschaftlichen Meeresforschung ... geführt hat."
> [„...this objective can only be achieved by means of the sciences of oceanography and biology, ... This international investigation ... is carried out using exemplary thoroughness, versatility and accuracy of the methods and at a high expense of money so far ..., that it has led, in every respect, to a turning-point of the scientific marine research..."] (KRÜMMEL 1904, p. 1/2).

8. The role of Germany in the foundation of ICES

At the beginning, marine research in Germany was mainly focussed on fishing interests and fishery research. As early as the middle of the 19th century, German scientists initiated systematic investigations of the physical conditions in the Baltic Sea. MEYER, KARSTEN (see Sections 3 and 5) and later KRÜMMEL (see Section 7) called attention to the importance of the hydrographic conditions for the life, spawning and recruitment of fish.

At the end of the 19th century, marine scientists realized that international cooperation in marine investigations was highly desirable (SMED 1990a) and is the only way to learn about the sea and its inhabitants. The German marine research played an essential role in laying the basics for international collaboration. In this connection the contribution of WALTHER HERWIG (1838 – 1912) – an administrative jurist in the Prussian civil service – must be appreciated. HERWIG (Fig. 24) studied law and administration and entered the governmental services in 1864. He dedicated his active life to the advancement of German sea fisheries. An extensive appreciation of the life and work of WALTHER HERWIG is given by HEINCKE & HENKING (1913). His contribution to international collaboration in the marine field is described in detail by WENT (1972) and SMED (1990b).

In January 1870, the "Deutscher Fischerei-Verein" was founded in Berlin (MEYER et al. 1871), from which the "Sektion für Küsten- und Hochseefischerei" [Section for Coastal and High Seas Fisheries] separated in 1885 chaired by HERWIG. He developed a programme in order to promote the German coastal and deep-sea fishing. In 1894, the "Deutscher Seefischerei-Verein" [German Sea Fishing Association] was instituted and led by HERWIG until 1907 (see MEYER-WAARDEN 1970, on the history of the German Fishery Association).

From the early beginning, WALTHER HERWIG participated in the discussion on the collaboration in the marine field (see also ROZWADOWSKI 1999). A discussion with his colleagues in other countries during the sea fisheries exhibition held in Berlin in 1896 led to the agreement that international cooperation is necessary for progress in hydrography, marine biology and fisheries research. In March 1897, German scientists and a Dutch representative, the marine zoologist PAULUS PERONIUS CATO HOEK (1851 – 1914), met during a confidential conference in Dortmund/Germany (DSV 1904; v. BENNEKOM et al. 2002). They envisaged joint international investigations and drafted a programme for international fishery research. HEINCKE & HENKING (1913) reported on a meeting in Dortmund in fall 1898, where W. HERWIG, H. HENKING and F. HEINCKE met P. HOEK of the Netherlands and made proposals for an international conference (see also WENT 1972). The task of this meeting should be to establish an international commission for scientific investigation of the North Sea and the Baltic. Meanwhile, the activities of OTTO PETTERSSON resulted in an invitation of the Swedish Government for the First International Conference for the Exploration of the Sea in Stockholm in June 1899. HERWIG, HENSEN, KRÜMMEL and HEINCKE already cooperated in this preparatory conference. From the early beginning, special attention was paid to the North Sea and the Baltic.

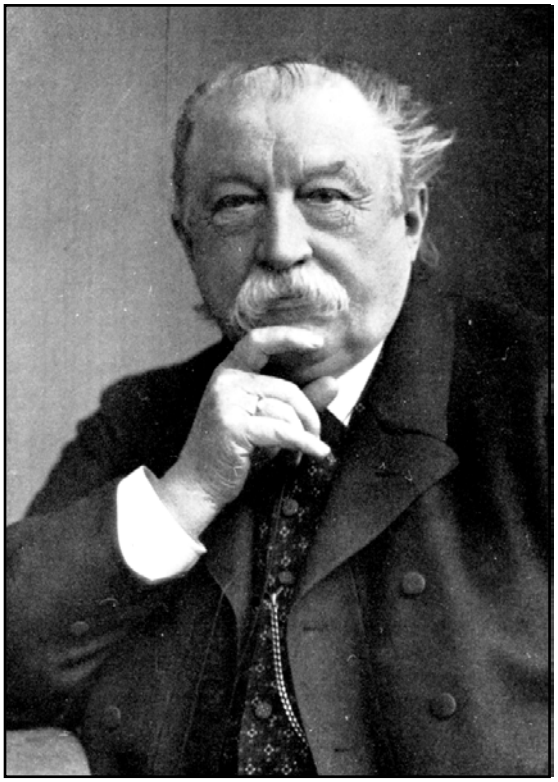


Fig. 24
WALTHER HERWIG (1838 – 1912), 1894 – 1907 president of the German Sea Fishing Association (DSV), 1902 – 1908 first president of the International Council for the Exploration of the Sea (ICES) (Photo: Archive Fach-Informationszentrum des vTI, Hamburg).

Abb. 24
WALTHER HERWIG (1838 – 1912), 1894 – 1907 Präsident des Deutschen Seefischerei-Vereins (DSV), 1902 – 1908 erster Präsident des Internationalen Rates für Meeresforschung (ICES) (Foto: Archiv des Fach-Informationszentrums des vTI, Hamburg).

In general, oceanographers played an essential part in founding of ICES, among them OTTO KRÜMMEL. The first Preparatory Conference agreed that the relationship between the quantity of halogen contained in sea water and the density of water should be investigated. This investigation should be undertaken under the direction of a committee consisting of physical oceanographers like JOHN MURRAY (1841 – 1914), MARTIN KNUDSEN (1871 – 1949), OTTO PETTERSSON, FRIDTJOF NANSEN (1861 – 1930), HENRY N. DICKSON (1866 – 1922), STEPAN O. MAKAROFF (1849 – 1904) and also OTTO KRÜMMEL. Moreover, the conference stated that it is desirable to start international investigations already in May 1901.

In May 1901, the Second International Conference for the Exploration of the Sea, held in Kristiania, recommended that W. HERWIG should be honorary President of the International Council and Central Bureau and P. HOEK General-Secretary. The oceanographers O. PETTERSSON and F. NANSEN should be honorary Vice-President and director of the International Laboratory, respectively. It was also recommended to start seasonal cruises already in 1901. Each member country should provide a steamer specially constructed for scientific fishery research. In preparation of these international agreed seasonal cruises the chartered German steamer *Holsatia* carried out a cruise in the Baltic Sea between August and October 1901 (see Section 5).

The Third International Conference for the Exploration of the Sea took place in Copenhagen in July 1902. ICES – the oldest international scientific organization – was formally founded and W. HERWIG was elected as first President (1902 – 1908). W. HERWIG and O. KRÜMMEL were the representatives of Germany at the Copenhagen meeting (for details of the foundation of ICES cf. WENT 1972, and ROZWADOWSKI 2002). Already in 1902, a detailed programme for hydrographic investigations could be implemented without delay owing to the experience of the member countries from national observation programmes in the late 19th century. Since its inception, the scientific work in the Baltic has been conducted through an ICES Committee, but the function of which has evolved over the years (WENT 1972).

HERWIG was not a scientist by education but a skilled administrator with diplomatic ability. He was greatly interested in the advancement of marine science and reported regularly on the German participation in international marine research (HERWIG 1905, 1906, 1908). Although re-elected president in 1907, his age and the state of his health forced him in 1908 to resign the ICES presidency.

WALTHER HERWIG died in 1912. His work for ICES was appreciated at the 11th Council Meeting in September 1913 in Copenhagen with the words:

> "President Herwig, who enjoyed the entire confidence … of the members of the Council, possesses a clearness of insight, a talent for organisation, and a diplomatic ability, which enabled him always to most successful conduct the business of the Council…" (ANON. 1913, p. 10).

OTTO PETTERSSON supplemented:

> "Dr. Herwig, who lived and worked to such a high degree for our aims, and always with confidence in their future, will ever be kindly remembered." (ANON. 1913, p. 10).

KRÜMMEL was a delegate to the Preparatory Conferences in Stockholm and Kristiania and played an important role in establishing the programme of ICES work. Until 1911, when he left the Kiel University, he participated in ICES meetings as a delegate of Germany on the meetings of the Central Committee.

As early as 1900, Germany established the DWKIM as national body for the international cooperation in marine research and fishery affairs (see also Section 7.1). By order of the "Reichsamt des Innern", the imperial research steamer *Poseidon* (Fig. 25) was built in 1901/1902 (length 49 m, 453 GRT). She carried out nearly all seasonal cruises in the framework of ICES on behalf of the DWKIM between 1902 and 1914 and on behalf of DWK between 1919 and 1939 (see also SCHULZ 1956). In particular, the cruises before the First World War (Fig. 26) led to essential knowledge on seasonal variability of different parameters of the Baltic Sea.

Fig. 25
Imperial research steamer *Poseidon* off Helgoland**,** operating for the German Scientific Commission for the International Marine Research (DWKIM/DWK) between 1902 and 1939 (Photo: AWI/BAH, Bremerhaven).

Abb. 25
Reichsforschungsdampfer *Poseidon* vor Helgoland, der zwischen 1902 und 1939 für die Deutsche Wissenschaftliche Kommission für die internationale Meeresforschung (DWKIM/DWK) im Einsatz war (Foto: AWI/BAH, Bremerhaven).

KRÜMMEL coordinated the German hydrographic investigations with r/v *Poseidon*. From 1902 onwards, he was responsible for the organization and leading of the seasonal cruises which, in general, were carried out for hydrographical purposes (KRÜMMEL 1905a) in February, May, August and November each year. The equipment of the laboratories and living rooms aboard the *Poseidon* was his special interest (KRÜMMEL 1905a).

During the seasonal cruises, the KRÜMMEL water bottle with reversing thermometer developed by C. RICHTER (Berlin) (cf. Fig. 22) was used for temperature measurements and water sampling in the beginning, later NANSEN bottles were used (KRÜMMEL 1905c).

In the Kiel Hydrographic Laboratory, which KRÜMMEL directed from 1902 to 1911, and on board, there worked the chemists ERNST RUPPIN (from 1902) and Paul KEMNITZ (from 1903).

OTTO KRÜMMEL passed away in 1912. During the 11th ICES Meeting in Copenhagen, the Council appreciated KRÜMMEL's work for ICES:

> "His extensive hydrographical knowledge, his continual zeal for the work, and his rare kindliness, were known to all,... the Council has ... suffered a great loss..." (ANON. 1913, p. 10).

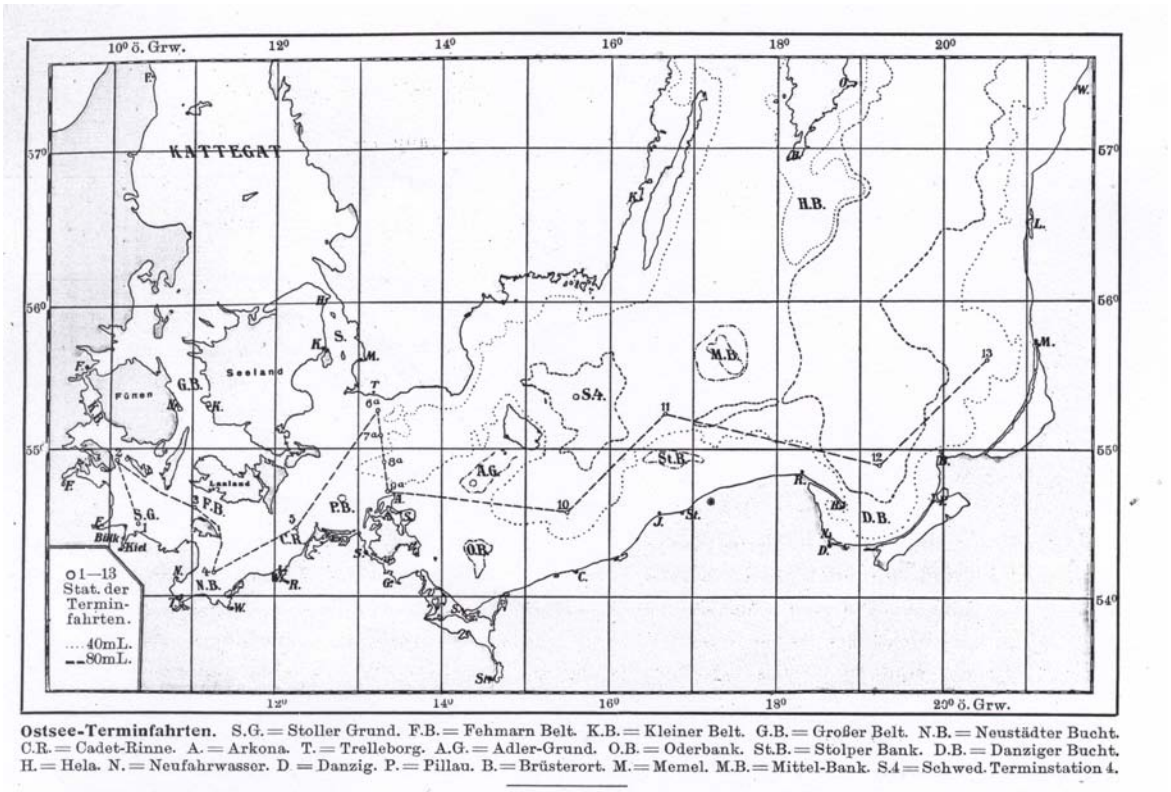


Fig. 26
Map of the international agreed German seasonal cruises of the research steamer *Poseidon* carried out between 1902 and 1914 (from KRÜMMEL 1905a).

Abb. 26
Stationskarte der international abgestimmten deutschen Terminfahrten mit dem Reichsforschungsdampfer *Poseidon*, durchgeführt zwischen 1902 und 1914 (aus KRÜMMEL 1905a).

9. Germany's part in establishing a permanent coastal station network and the use of light vessel observations in the Baltic Sea

One of the oldest time series of water temperature in coastal areas of the Baltic Sea was carried out on behalf of the Danish Admiralty. In 1828/1829, temperatures were measured every day over one year in the shallow channel in Copenhagen between the islands of Sealand and Amager about 2 km south of the Fort Trekroner (DAU 1831). Obviously, the German naturalist HUMBOLDT was asked by the Danish Admiralty to express his opinion to the importance of these measurements for the Sound. He seemed to be familiar with the knowledge of that time on the Baltic Sea and wrote in a letter to the German astronomer HEINRICH CHRISTIAN SCHUMACHER (1780 – 1850):

> "…ich möchte nicht gern zu mühevollen Beobachtungen verleiten, über deren Resultate, bei der geringen Tiefe von 8 Fuß, viele gerechte Zweifel bleiben müssten."
> [„…I do not like to tempt to hard observations when there are a lot of reasonable doubts on the results received in the small depth of 8 feet."] (BIERMANN 1979, p. 83).

But HUMBOLDT recommended:

> „Es wäre schon viel gewonnen, wenn 2-3mal in jedem Monate, besonders wenn grosse Änderungen des Windes und der Witterung statt gefunden haben, die Temperatur des Sundes … an tiefen, von der Küste entfernten Stellen beobachtet werden könnte. Giebt alsdann Vergleichung mit gleichzeitig angestellten Beobachtungen bei der Batterie Trekroner dasselbe, so wäre immer noch Zeit, sich auf letztere zu beschränken und dort täglich zwei mal 6 oder 7 Uhr Morgens und 2 Uhr Nachm die Temperatur aufzuzeichnen."
> [„It should already be a success if the temperature of the Sound could be observed 2 - 3 times a month at deep places far from the shore, in particular after considerable changes in wind and weather conditions. If then the comparison with simultaneous observations at the Fort Trekroner results in the same values, it is always time enough to restrict to the latter and to measure there the temperature two times a day, 6 or 7 o'clock in the morning and 2 o'clock in the afternoon."] (BIERMANN 1979, p. 83).

Germany was the first country in the Baltic region that started the installation of a permanent station network for measurements of hydrographic parameters. Between 1868 and 1870, MEYER installed and maintained eight fixed observation stations in the Belt Sea at private venture (KARSTEN 1893b, 1896a) and caused to carry out regular measurements of temperature and specific gravity of sea water, current, sea level and wind (MEYER 1871). His investigations showed considerable variations in temperature, salinity and sea level.

K. MÖBIUS and H. A. MEYER also underlined the necessity of fixed stations in letters to the DFV in 1870 and recommended for the *Pommerania* Expedition:

> "Die Expedition sollte Auftrag erhalten, Beobachtungsstationen zu bezeichnen und einzurichten …"
> [„One task of the expedition should be to fix and install observation stations …"] (DFV 1870c, p. 8).

It should be

> „…eine Hauptaufgabe dieser Expedition…, einige feste Stationen zu errichten, damit fortdauernde Beobachtungen über Salzgehalt, Temperatur, und Strömung nicht nur … an der Wasseroberfläche, sondern auch in mässigen Tiefen gemacht werden."
> [„…a main objective of this expedition…, to install several fixed stations in order to observe salinity, temperature and current, not only … at the surface but also in moderate depths."] (DFV 1870d, p. 10).

The Kiel Commission (see Section 3 and Fig. 7) concluded that long observation series are needed for investigating the considerable variations observed by MEYER (1871) in more detail and different time scales. Such series can only be obtained by installation of an enlarged observation network (MEYER et al. 1873b). Thereupon, fife permanent observation stations were established at the Prussian Baltic coast in 1872. The *Pommerania* cruise (see Section 4) gave some idea where there was a need for additional coastal stations, among others at Darsser Ort and in Hela. The network was completed by further stations at the Mecklenburg coast (KARSTEN 1874a) and finally extended to 12-13 stations at the whole German coast from Sonderburg to Hela (Fig. 27). At this stations, mainly water temperature and specific gravity, but also current and wind directions were measured (MEYER et al. 1872).

From 1871 onwards, the observations are regularly published (Fig. 28), early by KARSTEN (1873b, 1875) and since 1873 by the Kiel Commission (ANON. 1874). In the introductory remarks, KARSTEN expressed the hope that other countries will publish their observations at the coastal stations in the same manner (KARSTEN 1874c). Moreover, he recommended publishing the data in standardized measures.

KARSTEN worked at the data and published monthly and seasonal means of specific gravity, salinity and temperature at the stations (KARSTEN 1873b, 1875, 1878a, 1884, 1887, 1893a, 1896b).

On the basis of the station measurements MEYER (1884) concluded that

> „…Schwankungen im Salzgehalte, welche sich mit abnehmender Stärke vom Westen bis zum Osten, aber selbst in dem grossen Becken der Ostsee noch deutlich durch längere Zeiträume erstrecken, …wohl aperiodischer Natur…" sind.
> [„…fluctuations in salinity, which decrease from west to east but are still clearly noticeable in the large Baltic basins over longer periods, are presumably aperiodically in kind…"] (MEYER 1884, p. 7).

Therefore, he recommended extending the observations to stations in the offshore waters in order to investigate the periods of decrease and increase in salinity in the deeper layers which is important for the living conditions of the animal world in the Baltic Sea (MEYER 1884).

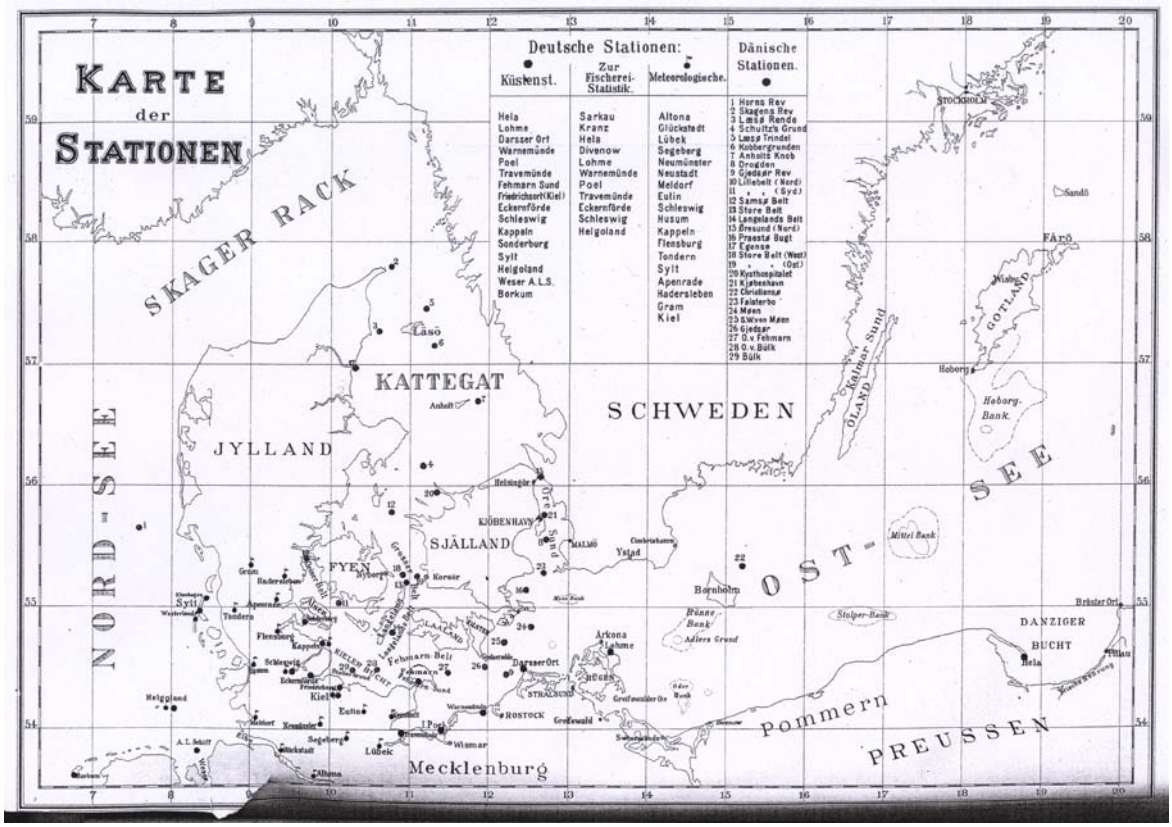


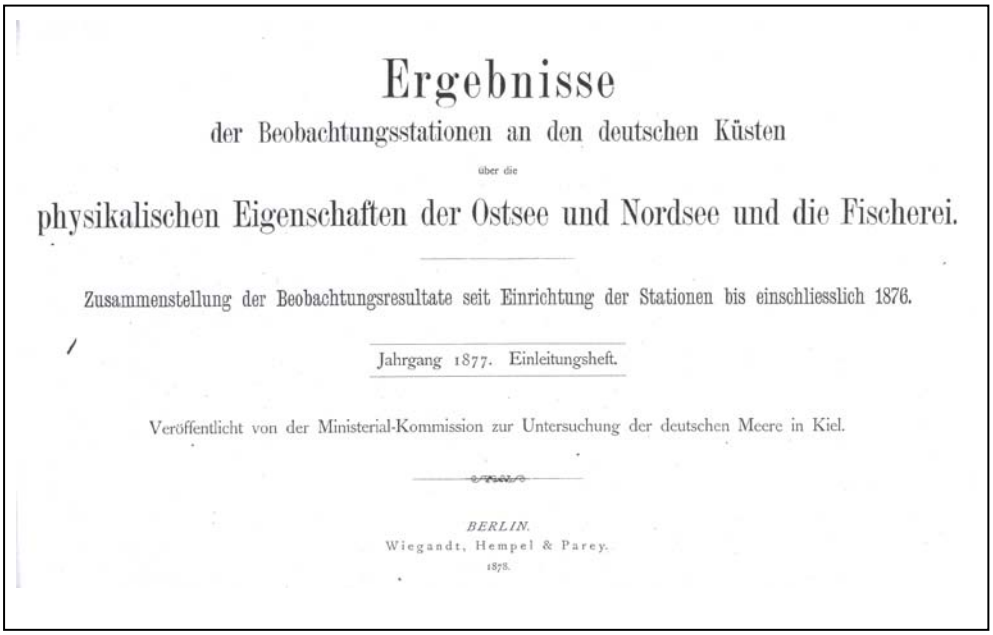
Fig. 27
Map of the German and Danish stations for hydrographic observations. The German stations are marked by the names, the Danish by numbers (from KARSTEN 1884).

Abb. 27
Karte der deutschen und dänischen Stationen für hydrographische Beobachtungen. Die deutschen Stationen sind durch ihre Namen gekennzeichnet, die dänischen durch Ziffern (aus KARSTEN 1884).

As far as the station network is concerned the Kiel Commission stated already in its first report in 1871 (MEYER et al. 1872): The countries bordering the Baltic Sea should be contacted, especially Denmark, Sweden and Russia,

> "…wo möglich dieselben Beobachtungen dort zu veranlassen, wie sie an den Preussischen Stationen angestellt werden,…"
> ["…to arrange there – if possible – the same observations like at the Prussian stations,…"]
> (MEYER et al. 1872, p. 10).

From 1876 to 1883, 28 hydrographical stations (see Fig. 27) were gradually established in Denmark between Bornholm and Skagen (MEYER 1884; FONSELIUS 2002). In 1879, Sweden



Ergebnisse

der Beobachtungsstationen an den deutschen Küsten

über die

physikalischen Eigenschaften der Ostsee und Nordsee und die Fischerei.

Zusammenstellung der Beobachtungsresultate seit Einrichtung der Stationen bis einschliesslich 1876.

Jahrgang 1877. Einleitungsheft.

Veröffentlicht von der Ministerial-Kommission zur Untersuchung der deutschen Meere in Kiel.

BERLIN.
Wiegandt, Hempel & Parey.
1878.

Fig. 28
Title page of the data compilation of 1878, containing the observations at the stations along the German coasts including 1876 published by the Kiel Commission (from ANON. 1878c).

Abb. 28
Deckblatt des Datenbandes aus dem Jahre 1878, in dem die an den Stationen entlang der deutschen Küsten beobachteten Werte einschließlich 1876 durch die Kieler Kommission veröffentlicht wurden (aus ANON. 1878c).

established five stations along the coasts of the Baltic proper and the Gulf of Bothnia. By 1897, there were 14 Swedish stations, of which 10 were on light vessels (FONSELIUS 2002).

First time series of salinity and specific gravity were published by MEYER (1884). He calculated annual means of salinity and specific gravity in the surface water on the basis of permanent measurements at German and Danish stations of the western and central Baltic Sea between 1872 and 1881 (Fig. 29).

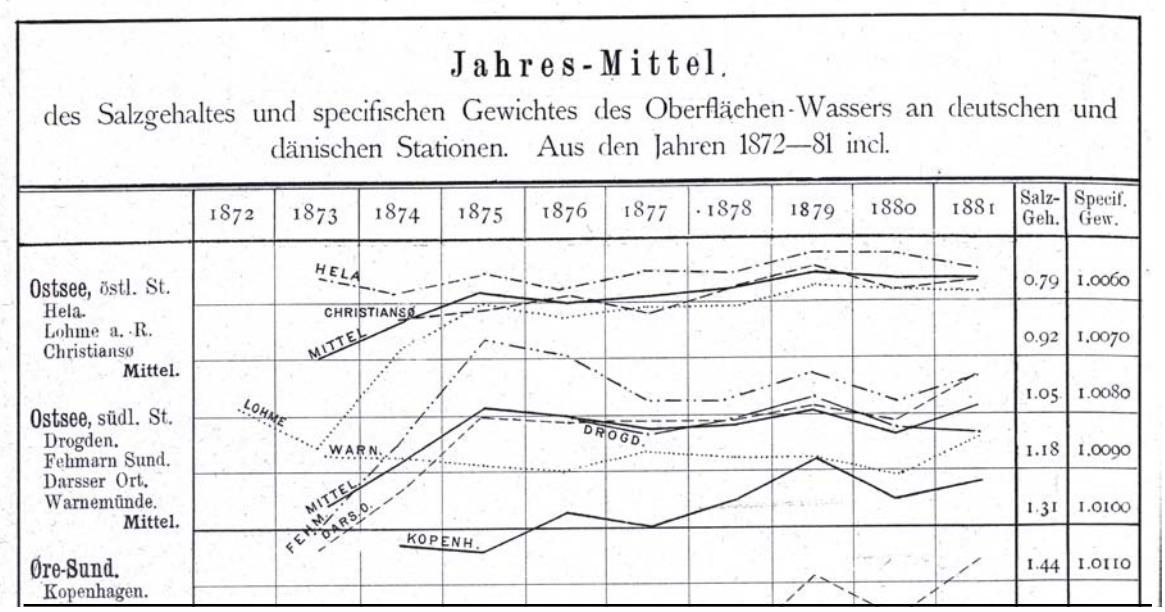


Fig. 29
Annual means of salinity and specific weight in the surface water at German and Danish stations of the western and central Baltic Sea between 1872 and 1881 (from MEYER 1884).

Abb. 29
Jahresmittel des Salzgehalts und des spezifischen Gewichts im Oberflächenwasser an deutschen und dänischen Stationen der westlichen und zentralen Ostsee zwischen 1872 und 1881 (aus MEYER 1884).

In the second half of the 19th century, a lot of light vessels have been installed by Denmark, Sweden and Germany in the Kattegat, the Belt Sea and the Baltic. As early as 1850, current observations were carried out on Danish light vessels (FONSELIUS 2002). Since August 1868, the Danish Navy-Ministry caused regular observations of air and water temperatures, current and wind direction at fife light vessels in the Kattegat and in the Sound (PETERMANN 1870). In 1880, a major number of Danish and Swedish light vessels started with regular daily measurements of temperature and salinity in the off-shore area (see e.g. NILSSON & SVANSSON 1974).

Until the turn to the 20th century, the following German light vessels have been installed: l/v Kalkgrund (Flensburg Fjord) in 1876, l/v Adlergund (Arkona Sea) in 1884, l/v Stollergrund (Kiel Bight) in 1892 and l/v Fehmarnbelt in 1902 (MACHOCZEK 2009, pers. comm.). Since summer 1900, the Kiel Commission organized hydrographic observations two times a day at l/v Adlergrund and Stollergrund, and since 1903 at l/v Fehmarnbelt (KOHLMANN 1905).

10. The German investigations in Baltic Sea hydrography reflected in natural history descriptions and oceanographic textbooks

By the turn of the 18th to the 19th century, the Prussian Privy Secretary JOHANN FRIEDRICH WILHELM OTTO (1743 – 1814) published the most comprehensive hydrography of that time in particular with respect to the sea. He presented a short paragraph on the Baltic Sea hydrography in his book "Abriß der Naturgeschichte des Meeres" (OTTO 1794; p. 165-172). In the extended and supplemented edition "System einer allgemeinen Hydrographie des Erdbodens, erster Theil" (OTTO 1800), he specified on the temperature and salinity conditions of the Baltic Sea:

> „Man hat wahrgenommen, daß es (das Wasser), selbst in den heißesten Sommern, kühler sey, als in anderen Meeren unter der nemlichen Breite. Auch ist es weniger salzig, wovon der Grund in den vielen Flüssen liegt, welche ihr Wasser mit dem ihrigen vermischen."
> [„It was noticed that, compared to other seas at the same latitude, it (the water) is cooler even in the hottest summers. Also it is lower salty, the reason of that is the lot of rivers which mixed the water with that of the Baltic Sea."] (OTTO 1800, p. 622).

In the 19th century, ERNST BOLL (1847), ANTON von ETZEL (1859) and CARL ACKERMANN (1883) published natural history descriptions on the Baltic Sea.

The naturalist and historian ERNST BOLL (1817 – 1868) – founder of the „Naturforschende Gesellschaft in Mecklenburg" [Natural Science Society in Mecklenburg] – described salinity, specific gravity and temperature of the Baltic Sea water (BOLL 1847) and copied a table of salinity analyses in the Baltic Sea (see Section 2.2) first published by GOEBEL (1845).

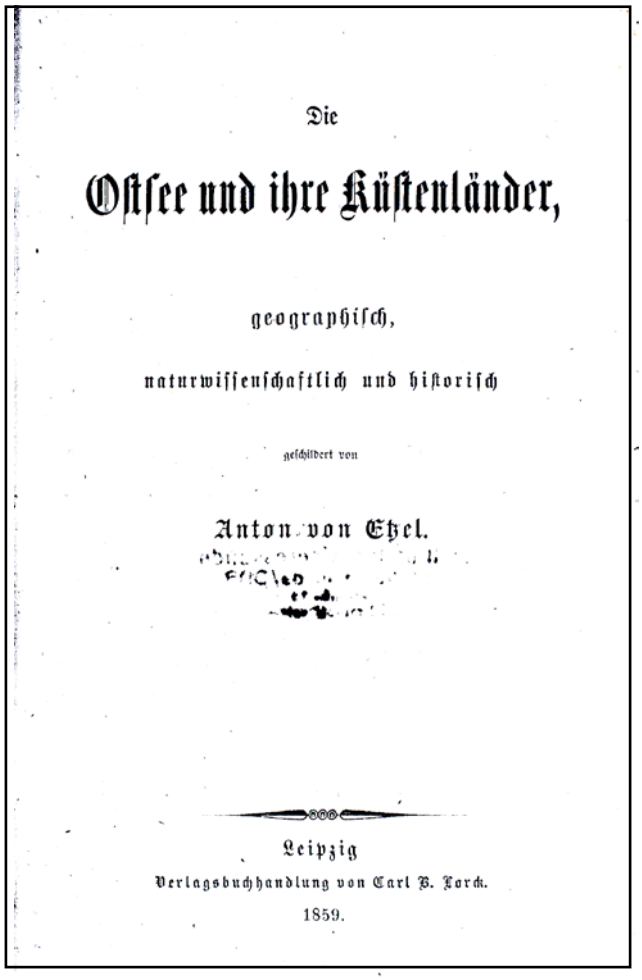
In 1859, the traveller ANTON von ETZEL (1821 – 1870) compiled the knowledge of his time on geography, natural science and history of the Baltic Sea in the book "Die Ostsee und ihre Küstenländer" (Fig. 30) (ETZEL 1859). He wrote in the Section "Chemical conditions of sea water":

> "Das baltische Meer ist … in Folge zahlreicher Regen, des geschmolzenen Schnees, und der großen Menge Flußwassers, das ihm unaufhörlich zugeht, viel weniger reich an Salzgehalt als die anderen Meere."
> [„As a result of a large number of rains, of melting snow, and of the great amount of river water which discharges continuously, the Baltic Sea has a lower salinity compared with other seas."] (ETZEL 1859, p. 214).

Moreover, the salinity varies regionally:

> „In der Ostsee..." there are "...große Verschiedenheiten in verschiedenen, sich naheliegenden Gegenden und Tiefen, die abhängig von den Jahreszeiten und Winden sind. Im Süden ward der Salzgehalt stärker gefunden als im Norden, im hohen Meer bedeutender als in den Buchten und Meerengen,..."

[„In the Baltic, (there are) great differences in various, close together located regions and deeps which are dependent from season and winds. Salinity is greater in the south than in the north, higher in the open sea than in bights and straits,…“] (ETZEL 1859, p. 214/215).



Die

Oſtſee und ihre Küſtenländer,

geographiſch,

naturwiſſenſchaftlich und hiſtoriſch

geſchildert von

Anton von Etzel.

Leipzig

Verlagsbuchhandlung von Carl B. Lorck.

1859.

Fig. 30
Title page of ANTON von ETZEL's book „Die Ostsee und ihre Küstenländer“ published in 1859 (from ETZEL 1859).

Abb. 30
Titelblatt des Buches von ANTON VON ETZEL „Die Ostsee und ihre Küstenländer“ aus dem Jahre 1859 (aus ETZEL 1859).

For the first time, ETZEL coined the German term „Einbrüche des Oceans“ [episodic invasion of the ocean] in connection with the inflow of water into the Baltic Sea (ETZEL 1859, p. 201). One hundred years later, this term was specified and changed into “Salzeinbruch” [episodic salt influx] (WYRTKI 1953, 1954) or “Salzwassereinbruch” [episodic salt water inflow] (FRANCKE & NEHRING 1971). This term describes a basic phenomenon that strongly influences the Baltic

Sea hydrography, in particular the deep-water conditions in the central Baltic (see MATTHÄUS 2006b). ETZEL wrote on this phenomenon in the Section „Currents“:

> “Wenn die Nordsee z.B. durch Südsüdwest-Winde bewegt ist, wälzen sich ihre Wogen nach Ost und treten in das Kattegat hinein, dessen ihr entgegenkommende Ausströmungen zurückgestoßen werden, und ihrerseits wieder die des baltischen Meeres zurückstoßen. Dieses Phänomen wird noch auffallender, wenn der Wind aus Nordwesten längere Zeit hindurch im Oceane herrscht; dann werden die Gewässer ... längs der Küsten Jütlands und des westlichen Schwedens gehen. Diese rückgängige Bewegung macht sich sogar mitunter bis in die Buchten von Bothnien und Finnland bemerkbar,...“
> [„If the North Sea is moved e.g. by south-southwesterly winds then they push the water into easterly direction into the Kattegat, stop the outflow and push back the Baltic water. This phenomenon is more conspicuous if north westerly winds prevail in the ocean for a longer period; then the water ... is transported along the coasts of Jutland and western Sweden. This backward movement sometimes becomes apparent up to the Gulfs of Bothnia and Finland...“] (ETZEL 1859, p. 201).

Results on Baltic Sea research are also reflected in textbooks on geology of that time, for instance by BISCHOF (1863).

The schoolmaster and naturalist CARL ACKERMANN (1841 – 1903) published a book on the Baltic Sea and described beside morphology, geology and biology also the physical conditions covering 150 pages (ACKERMANN 1883). He has given tables of salinity and temperature of both surface and deep water and their seasonal variations. As far as the hydrographic conditions are concerned his description is mainly based on the results obtained by MEYER (1871) and the Kiel Commission (MEYER et al. 1873a; JACOBSEN 1873a; MEYER 1875; KARSTEN 1878a). This part was outdated already in 1896 (SCHOTT 1896).

In the second half of the 19th century, a larger number of German books on the geography of the oceans appeared (e.g. JILEK 1857; KAYSER 1873; ATTLMAYR 1883). In general, the Baltic Sea can cover only a small part in such books. Nevertheless, the Austrian ship’s doctor AUGUST JILEK wrote as early as 1857 in his textbook on oceanography:

> “Die Ostsee und das schwarze Meer, in welche sich viele wasserreiche Ströme münden, und auf welchen wegen der daselbst herrschenden niederen Temperatur die Verdunstung sehr gering ist, haben auch einen geringeren Salzgehalt. Das Wasser der Ostsee hat von allen Meeren das geringste specifische Gewicht,...”
> [„The Baltic Sea and the Black Sea, in which drain a lot of rivers, and where the evaporation is very low due to the low temperature, have a lower salinity, too. The Baltic Sea has the lowest specific gravity among all seas,...“] (JILEK 1857, p. 180).

He already explained that, despite the steady runoff of fresh river water, the salinity of the Baltic Sea is maintained by the under currents transporting salt water into the Baltic.

In the late 19th and the beginning of the 20th centuries, several specific oceanographic textbooks were published in Germany. In 1884, the first German textbook on physical

oceanography was written by GEORG von BOGUSLAWSKI (1827 – 1884), since 1874 head of a department in the "Hydrographisches Amt der Kaiserlichen Admiralität" [Hydrographic Agency of the Imperial Admiralty] in Berlin (v. BOGUSLAWSKI 1884). He described the hydrographic conditions of the North Sea, the Baltic and the transition area based on the observations of the *Pommerania* Expeditions in 1871 (MEYER et al. 1873a) and 1872 (MEYER 1875) and the measurements of the Kiel Commission's coastal stations. He also referred to the investigations of salinity by STRUVE (1864), v. SASS (1866b) and GLASENAPP (SCHWEDER 1884).

KRÜMMEL has given a general introduction to oceanography in his popular book „Der Ozean" published in two editions (KRÜMMEL 1886, 1902). He reported on the temperature minimum in the intermediate layer of the central Baltic in summer measured by the Swedish expedition in 1877 (EKMAN & PETTERSSON 1893) but stated that the Kiel Commission did not observe such conditions (KRÜMMEL 1886, p. 140).

KRÜMMEL's oceanographic textbooks (v. BOGUSLAWSKI & KRÜMMEL 1887; KRÜMMEL 1907, 1911) summarized the scientific knowledge of that time on the oceans (and also on the Baltic Sea) and marked the transition from physical geography to a physics-based ocean dynamics. Compared to the first edition KRÜMMEL reported in the second, completely revised edition (KRÜMMEL 1907, 1911) on annual cycles in salinity and temperature of the Baltic, on periodic and non-periodic temperature fluctuations, on stratification and renewal of the Baltic deep water based, among others, on the results obtained during the regular seasonal cruises carried out in the framework of ICES.

KRÜMMEL's famous two-volume „Handbuch der Ozeanographie" was the best German textbook in the first half of the last century and was frequently mentioned, e.g. in the famous books of SVERDRUP et al. (1942), DIETRICH & KALLE (1957) or DEFANT (1961). His textbooks made him the most recognized German oceanographer of that time.

11. Concluding remarks and outlook into the 20th century

In the 19th and early 20th century, Germany played an important role in Baltic Sea research. Starting point was the formation of a circle of German scientists interested in marine research in the 1850s and 1860s in Kiel culminating in the foundation of the Prussian "Commission for the Scientific Investigation of the German Seas" in 1870. H. A. MEYER installed and maintained the first observation network for measurements of hydrographic parameters in the western Baltic between 1868 and 1870. As far as the Baltic is concerned, highlights in Baltic hydrography of the Commission's activities were the first important expedition for investigating oceanographic conditions of the Baltic Sea on board of the *Pommerania* in summer 1871 and the installation and maintaining of the permanent station network at the Prussian coast since 1872.

Further highlights were the activities of the geographer OTTO KRÜMMEL for Baltic oceanography as well as his initiative for international cooperation in marine research in the 1890s. He pushed forward the international cooperation in the Baltic Sea from the German side. WALTHER HERWIG and OTTO KRÜMMEL played a prominent role in foundation and the work of the International Council for the Exploration of the Sea (ICES) in the late 19th and early 20th century.

In the beginning of the 20th century, a new German maritime centre arose in Berlin. Germany's oceanography was transformed from a branch of physical geography into a marine science based on mathematical physics (see also MILLS 1997). The increasing importance of marine research for both military and economic objectives of the imperial Germany led to the foundation of the first German marine research institute, the "Institut für Meereskunde" in Berlin in 1900 (ANON. 1906; ENGELMANN 1997). However, the institute dealt mainly with basic research of the oceans. The hydrography of the Baltic Sea was only of marginal interest.

The Baltic Sea research remained at the Kiel University. However, despite the active part in marine research in Kiel in the second half of the 19th century, done within the university institutes of geography, geology, botany and zoology, the first German centre for Baltic Sea research was instituted as late as in 1937 as "Institut für Meereskunde" of the University (WÜST et al. 1956; KRAUSS 1990; GERLACH & KORTUM 2000). In the 1940s, hydrographic investigations of the Baltic Sea were focussed on stratification, circulation and water balance (see e.g. WATTENBERG 1941, 1949; DIETRICH 1950; WÜST et al. 1956). From the 1950s to the 1970s, the Kiel Institute was active, among others, in investigating physical problems of the Baltic Sea (see e.g. DIETRICH 1951; KÄNDLER 1951; WYRTKI 1953, 1954; KRAUSS 1960; SIEDLER 1961; KRAUSS & MAGAARD 1961, 1962; MAGAARD & RHEINHEIMER 1974). Later, the hydrographic work of the institute was also focussed on modelling activities (e.g. KIELMANN 1981; LEHMANN 1992, 1995; MEIER 1996; LEHMANN & HINRICHSEN 2002).

As a result of the political development after World War II a further centre for investigation of the Baltic Sea was instituted in Eastern Germany in the 1950s – the "Institut für Meereskunde" in Warnemünde, today "Leibniz-Institut für Ostseeforschung Warnemünde (IOW)" (BROSIN 1996). The Warnemünde Institute played a prominent role in the investigation of the Baltic Sea in the second half of the 20th century until today (see e.g. IOW 1997; FEISTEL et al. 2008). It worked in numerous national projects on the water exchange between the North Sea and the Baltic (see e.g. MATTHÄUS et al. 1982; FENNEL et al. 1987; MATTHÄUS & FRANCK 1992; LASS et al. 2005). Also before the German re-unification, the Warnemünde Institute participated in international Baltic projects like IBY 1969/1970 (see NEHRING & FRANCKE 1973), BOSEX-77 (see Kullenberg 1984) or PEX-86 (see Schulz et al. 1989) and even initiated the first international Baltic investigations after World War II in 1964 (MATTHÄUS 2008). In recent decades, the institute is engaged in all international Baltic research programmes (e.g. BASYS: see v. BODUNGEN 1997, Anon. 1999; BALTEX: LASS et al.

2003) and dealt with modelling not only of the physical conditions but also of the Baltic ecosystem (e.g. FENNEL & NEUMANN 2004; SCHMIDT et al. 2008).

Summary

A summarizing appreciation of Germany's contribution to the investigation of the hydrography of the Baltic Sea in the 19th and early 20th century is lacking so far. This paper tries to close this gap.

In the 19th century, there took place a change in investigation of the seas. The oceanography separated from geography and instituted as an independent science. That was also the time from individual to common investigations of several countries in marine research, in particular in the North Sea and the Baltic. Although Germany is not a maritime nation, Germany along with Sweden was the pioneers in marine research of the Baltic Sea. Additionally, marine research in Germany was promoted by the foundation of the German „Reich" in 1871, which led to an increased German interest in the seas and formed the basis for a favourable development of marine activities.

In the first Section, the oldest individual measurements of temperature and analyses of the chemical composition of sea water are summarized recorded in scientific literature of the late 18th and the 19th century and done by German travellers and naturalists as well as scientists of German origin. Table 1 gives an overview of the chemical analyses of sea water composition and measurements of salinity by means of areometers carried out during that time in the Baltic Sea coastal areas.

The German Baltic Sea research is very closely connected with the Royal Prussian „Commission for the Scientific Investigation of the German Seas" in Kiel instituted in summer 1870. This Commission represents the oldest institution of that kind in Europe and has done an important work for hydrographic research in the Baltic Sea. The contributions of the merchant and factory owner HEINRICH ADOLPH MEYER (1822 – 1889) to Baltic hydrography are summarized in Section 3. In Kiel, he formed a circle of marine scientists in the 1850s and 1860s and he was one of the first who started systematic investigations in the western Baltic in the late 1850s. Moreover, MEYER installed and maintained the first observation network in the Belt Sea between 1868 and 1870 and developed measuring instruments.

In a further Section, the preparatory work, the realization and the results of the first important expedition for investigation of the oceanographic conditions of the Baltic Sea on board of the German steamer *Pommerania* in summer 1871 are described in detail. The Baltic Sea cruises of the German steamer *Holsatia* in 1887 and 1901/1902 and its contributions to Baltic hydrography are shortly summarized in Section 6.

For the first time, the work of the physicist among the leading German marine scientists of the 19th century, GUSTAV KARSTEN (1820 – 1900), for Baltic hydrography is appreciated in Section 5. His way to oceanography, his activities in the Kiel Commission and his work for the permanent observation network at the German Baltic coast are described.

Section 7 is devoted to the contributions of the geographer OTTO KRÜMMEL (1854 – 1912) for Baltic oceanography as well as KRÜMMEL's initiative for international cooperation in marine research in the 1890s. International cooperation in the Baltic Sea started in the Scandinavian countries. KRÜMMEL was the first German marine scientist who contacted the colleagues in Scandinavia and tried to push forward cooperation from the German side.

Section 8 is concerned with Germany's role in the foundation of the International Council for the Exploration of the Sea (ICES). WALTHER HERWIG (1838 – 1912) and also OTTO KRÜMMEL played a prominent role in foundation and work of ICES in the late 19th and early 20th century.

A further Section describes Germany's part in establishing a permanent coastal station network and the use of light vessel observations in the Baltic Sea. Finally, German investigations in Baltic Sea hydrography reflected in natural history descriptions and oceanographic textbooks of the 19th century are summarized in Section 10. This contribution is completed with a short outlook for the German Baltic Sea research during the 20th century.

Zusammenfassung

Eine zusammenfassende Würdigung des deutschen Beitrages zur Erforschung der Hydrographie der Ostsee im 19. und frühen 20. Jahrhundert fehlte bisher. Diese Arbeit versucht diese Lücke zu schließen.

Im 19. Jahrhundert vollzog sich eine Veränderung bei der Erforschung der Meere. Die Ozeanographie trennte sich von der Geographie und entwickelte sich zur eigenständigen Wissenschaft. Das war auch die Zeit des Übergangs von Einzelforschungen zu länderübergreifenden gemeinsamen Untersuchungen in der Meeresforschung, insbesondere in der Nord- und Ostsee. Obwohl Deutschland keine Meeresnation war, war Deutschland zusammen mit Schweden Wegbereiter bei der Erforschung der Ostsee. Die Gründung des Deutschen Reiches im Jahre 1871 förderte die Meeresforschung in Deutschland, was zu einem verstärkten Interesse am Meer führte und die Grundlage für eine günstige Entwicklung der marinen Aktivitäten bildete.

Im ersten Abschnitt werden die ältesten Einzelmessungen der Wassertemperatur und Analysen der chemischen Zusammensetzung des Meerwassers zusammenfassend dargestellt, die in der wissenschaftlichen Literatur des späten 18. und des 19. Jahrhunderts

veröffentlicht wurden und von deutschen Reisenden und Naturforschern sowie Wissenschaftlern deutscher Herkunft vorgenommen wurden. Tabelle 1 gibt einen Überblick über die zu der Zeit durchgeführten chemischen Analysen der Zusammensetzung des Meerwassers und der Messungen des Salzgehaltes mit Hilfe von Aräometern in den Küstengebieten der Ostsee.

Die deutsche Ostseeforschung ist eng verknüpft mit der Königlich Preußischen "Kommission zur wissenschaftlichen Untersuchung der deutschen Meere" in Kiel, die im Sommer 1870 eingesetzt wurde. Diese Kommission ist die älteste ihrer Art in Europa und hat Bedeutendes zur Erforschung der Ostsee geleistet. Die Beiträge des Kaufmanns und Fabrikbesitzers HEINRICH ADOLPH MEYER (1822 – 1889) zur Hydrographie der Ostsee sind in Abschnitt 3 zusammengefasst. In den 1850er und 1860er Jahren sammelte er in Kiel einen Kreis von engagierten Meeresforschern um sich, die die deutsche Ostseeforschung entscheidend vorangetrieben haben. Er war einer der ersten, der bereits in den späten 1850er Jahren mit systematischen Untersuchungen in der westlichen Ostsee begann. Darüber hinaus errichtete und unterhielt er zwischen 1868 und 1870 das erste Beobachtungsnetz in der Beltsee und entwickelte Messinstrumente.

In einem weiteren Abschnitt werden Vorbereitung, Durchführung sowie die Ergebnisse der ersten bedeutenden Expedition zur Erforschung der ozeanographischen Bedingungen der Ostsee auf dem deutschen Dampfer *Pommerania* im Sommer 1871 detailliert beschrieben. Die Ostseefahrten des deutschen Dampfers *Holsatia* in den Jahren 1887 und 1901/1902 und deren Beiträge zur Ostseehydrographie werden kurz in Abschnitt 6 dargestellt.

Zum ersten Mal wird die Arbeit von GUSTAV KARSTEN (1820 – 1900), dem Physiker unter den führenden deutschen Meereswissenschaftlern des 19. Jahrhunderts, für die Hydrographie der Ostsee in Abschnitt 5 gewürdigt. Sein Weg zur Ozeanographie sowie sein Wirken in der Kieler Kommission und seine Arbeit für den Aufbau eines permanenten Netzes von Beobachtungsstationen an der deutschen Ostseeküste werden beschrieben.

Abschnitt 7 ist den Beiträgen des Geographen OTTO KRÜMMEL (1854 – 1912) zur Hydrographie der Ostsee sowie seiner Initiative für die internationale Zusammenarbeit in der Meeresforschung in den 1890er Jahren gewidmet. Die internationale Kooperation in der Ostsee ging von den skandinavischen Ländern aus. KRÜMMEL war der erste deutsche Meereswissenschaftler, der auf die skandinavischen Kollegen zuging und versuchte, die Zusammenarbeit von deutscher Seite voranzubringen.

Abschnitt 8 befasst sich mit Deutschlands Rolle bei der Gründung und der Arbeit des Internationalen Rates für Meeresforschung (ICES). Dabei hatten WALTHER HERWIG (1838 – 1912) und auch OTTO KRÜMMEL im ausgehenden 19. und frühen 20. Jahrhundert bedeutenden Anteil.

Ein weiterer Abschnitt beschreibt Deutschlands Anteil bei der Errichtung eines ständigen Netzes von Beobachtungsstationen an der Küste der Ostsee und an der Nutzung von Beobachtungen auf den Feuerschiffen. Schließlich werden in Abschnitt 10 die Deutschen Forschungen zur Ostsee-Hydrographie im Spiegel naturhistorischer Beschreibungen und ozeanographischer Handbücher des 19. Jahrhunderts dargestellt. Der Beitrag wird komplettiert mit einem kurzen Ausblick auf die deutsche Ostseeforschung im 20. Jahrhundert.

Acknowledgements

The author is very much appreciated to WALTER LENZ for the very careful and critical looking over the manuscript as well as for comments and suggestions. The author also thanks very much REINHARD HOHEISEL-HUXMANN, Deutsches Schifffahrtsmuseum Bremerhaven, for information on the paddle wheel steamer *Pommerania* extracted from the Bundesarchiv-Militärarchiv in Freiburg. Moreover, the author is thankful to him and to GERD WEGNER, Johann Heinrich von Thünen-Institut (vTI), Institut für Seefischerei Hamburg, for making available photos of German research vessels. He is also thankful to GERHARD KORTUM and ILONA OELRICHS, IfM-Geomar Kiel, who placed at disposal photos of OTTO KRÜMMEL, GUSTAV KARSTEN, VICTOR HENSEN, KARL MÖBIUS and SAMUEL REYHER. The Archive of the Rostock University made available photos of SAMUEL GOTTLIEB VOGEL and OSCAR JACOBSEN. GERD WEGNER, Institut für Seefischerei Hamburg, and DETLEV MACHOCZEK, Bundesamt für Seeschifffahrt und Hydrographie Hamburg, supported me with information on German research vessels and light ships, respectively. The author also would like to thank very much the librarians of the Leibniz-Institut für Ostseeforschung Warnemünde, OLIVIA DIEHR and BRIGITTE SCHILLER, for the friendly assistance in finding historical sources and for making available papers and books of the 18th and 19th century. In addition, the author is indebted to the libraries of the Leibniz-Institut für Meereswissenschaften IfM-Geomar in Kiel, of the Berlin-Brandenburgische Akademie der Wissenschaften in Berlin and of the Fischerei Informationszentrum of the J. H. v. Thünen-Institut in Hamburg for making available a lot of relevant books and papers.

References

ACKERMANN, C., 1883: Beiträge zur physischen Geographie der Ostsee. Hamburg: O. Meissner, 399 pp. (2. Ausg., Hamburg: O. Meissner, 1891).

ANONYMOUS, 1874: Ergebnisse der Beobachtungsstationen an den deutschen Küsten über die physikalischen Eigenschaften der Ostsee und Nordsee und die Fischerei. – Veröff. Ministerial-Komm. Unters. Dt. Meere Kiel, Berlin: Wiegandt, Hempel & Parey, Jg. 1873, H. I - XII. (Monthly booklets are published for the years 1873 to 1893).

ANONYMOUS, 1878a: Die Beobachtungen über die physikalischen Eigenschaften des Wassers der Ostsee und Nordsee. – Ann. Hydrogr. Marit. Meteorol., **6**, 118-124.

ANONYMOUS, 1878b: Nautisk-meteorologisk Konference i Kjøbenhavn mellem delegerede fra Norge, Sverige og Danmark. Oktober 1878. – Report from Kongelige danske Søkortarkiv. Copenhagen: J. H. Schultz, 1-16.

ANONYMOUS, 1878c: Ergebnisse der Beobachtungsstationen an den deutschen Küsten über die physikalischen Eigenschaften der Ostsee und Nordsee und die Fischerei. – Veröff. Ministerial-Komm. Unters. Dt. Meere Kiel, Berlin: Wiegandt, Hempel & Parey, Jg. 1877.

ANONYMOUS, 1888: Oceanographische Beobachtungen in der Ost- und Nordsee. – Ann. Hydrogr. Marit. Meteorol., **16**, 67-69.

ANONYMOUS, 1889: Indienststellung und Ausrüstung S.M.S. „Gazelle“. In: Die Forschungsreise S.M.S. „Gazelle“ in den Jahren 1874 bis 1876. Herausgegeben vom Hydrographischen Amt des Reichs-Marine-Amts. Berlin: Mittler & Sohn, I. Theil, Der Reisebericht, Kap. II, 10-30.

ANONYMOUS, 1890: Erinnerungen an Dr. H. A. Meyer. Nach seinen eigenen Aufzeichnungen. Hamburg, 108 pp.

ANONYMOUS, 1902: Die Ostsee-Expedition 1901 des Deutschen Seefischerei-Vereins. – Abh. Dt. Seefischerei-Vereins, **7**, 284 pp.

ANONYMOUS, 1906: Das Institut und Museum für Meereskunde an der Universität Berlin. – Z. Ges. Erdkunde Berlin, **41**, 347-355.

ANONYMOUS, 1913 : Procès-verbaux de la douzième réunion du Conseil et des réunions des sections, Copenhague, Septembre 1913. – Rapp. P.-v. Réun., Cons. Int. Explor. Mer., **19**, Part B, 142 pp.

ANONYMOUS, 1999. BASYS – Baltic Sea System Study. – URL : http.//www2008.io-warnemuende.de/Projects/Basys/publications/pub_all.htm

ATTLMAYR, F. (Ed.), 1883: Handbuch der Oceanographie und maritimen Meteorologie. Kaiserl.-Königl. Hof- und Staatsdruckerei, Wien; I. Band, 1-598; II. Band, 601-990.

BAER, K. von, 1862: Über ein neues Project, Austern-Bänke an der russischen Ostsee-Küste anzulegen und über den Salz-Gehalt der Ostsee in verschiedenen Gegenden. – Bulletin de l'Acad. Impér. des Sciences de St.-Pétersbourg, **IV**, 17-47,119-149.

BAHR, K., 1962: Rückblick auf die Entwicklung der Deutschen Wissenschaftlichen Kommission für Meeresforschung (DWK) in sechs Jahrzehnten. – Ber. Dt. Wiss. Komm. Meeresforsch., N.F., **17**, 34-44.

BENEKE, K., 2010: Samuel Reyher (19. 04. 1635 Schleusingen – 22. 11. 1714 Kiel). In: Zur Geschichte der Christian-Albrechts-Universität zu Kiel, deren Hochschullehrer der

Chemie, und dessen Chemisches Institut von der Gründung an (1665) bis heute (2010), (in Vorbereitung).

BENNEKOM, A. J. van, DE GROOT, S. J., OTTO, L., 2002: Dutch involvement in fisheries research prior to and in early ICES. ICES Marine Science Symposia, **215**, 56-63.

BIERMANN, K.-R. (Ed.), 1979: Letter of A. v. Humboldt to H. C. Schumacher, dated 25 July 1838. In: Briefwechsel zwischen Alexander von Humboldt und Heinrich Christian Schumacher. – Beitr. zur A. v. Humboldt-Forschung, Berlin, **6**, 83-85.

BISCHOF, G., 1863: Lehrbuch der chemischen und physikalischen Geologie. 2. Aufl., 1. Bd., Bonn: A. Marcus, 865 pp.

BLADH, P. J., 1776: Om vattnens varme och specifica tyngd uti Ålandshaf och Botniska Viken. – Kungl. Svenska Vetensk. Akad. Handlingar, Bd. **37**, 324 - 326.

BODUNGEN, B. v., 1997. BASYS – ein europäisches Forschungsprojekt unter Koordination des IOW. – Dt. Ges. Meeresforsch., Mitt. 1-2/1997: 8-11.

BOGUSLAWSKI, G. von, 1884: Handbuch der Ozeanographie. Band I: Räumliche, physikalische und chemische Beschaffenheit der Ozeane. Stuttgart: J. Engelhorn, 400 pp.

BOGUSLAWSKI, G. von, KRÜMMEL, O., 1887: Handbuch der Ozeanographie. Band II: Die Bewegungsformen des Meeres. Stuttgart: J. Engelhorn, 528 pp.

BOLL, E., 1847: Die Ostsee. Eine naturgeschichtliche Schilderung. – Archiv des Vereins der Freunde der Naturgeschichte in Meklenburg, H. **1**, 31-120.

BOYLE, R., 1670: Relations about the bottom of the sea. In: HUNTER, M., DAVIS, E. B., The works of Robert Boyle. Vol. 6, Publications of 1668 – 71, p. 363. London: Pickering & Chatto, 1999, 558 pp.

BRANDT, K., 1928: Die beiden Meereslaboratorien in Kiel. Rapp. – P.-v. Réun., Cons. Int. Explor. Mer. (Rapport Jubilaire), **47**, Part III, 3-16.

BRAUN, M., 1884: Physikalische und biologische Untersuchungen im westlichen Theile des finnischen Meerbusens. – Arch. Naturkunde Liv-, Ehst- u. Kurlands, Ser. II, **10 (1)**, 132 pp.

BRENNECKE, W., 1909: Ozeanographie. In: Forschungsreise S.M.S. "Planet". Reichs-Marine-Amt, Berlin: K. Siegismund, Bd. 3, 154 pp.

BREWSTER, D., 1821: On the submarine current at the Strait of Gibraltar, and at the Sound near Elsinore. – Edinburgh Philosophical J., **4**, 243 – 245.

BROSIN, H.-J., 1996: Zur Geschichte der Meeresforschung in der DDR. – Meereswiss. Ber. Warnemünde, **17**, 212 pp.

BUCHANAN, J. Y., 1878: Laboratory experiences on board the „Challenger". – J. Chem. Soc., Trans., **33**, 445-469.

DAU, J. H. L., 1831: Einjährige Beobachtungen über die Temperatur des Meeres bei Kopenhagen. – Berghaus' Ann. Erd-, Völker- u. Staatenkunde, Berlin, **4**, 142-172.

DEFANT, A., 1961: Physical oceanography. Oxfort, London, New York, Paris: Pergamon Press, Vol. I, 729 pp; Vol. II, 598 pp.

DFV, 1870a: Dt. Fischerei-Verein, Circular Nr. 1 vom 7. März 1870, 1-3.

DFV, 1870b: Verzeichnis der Mitglieder des Deutschen Fischerei-Vereins. – Dt. Fischerei-Verein, Circular Nr. 4 vom 12. Juni 1870, Correspondenzblatt, 25-28.

DFV, 1870c: Schreiben des Professor Dr. Moebius zu Kiel vom 4 April d. Js. – Dt. Fischerei-Verein, Circular Nr. 2 vom 22. April 1870, Correspondenzblatt, 7-9.

DFV, 1870d: Auszug aus dem Schreiben des Dr. H. A. Meyer in Kiel vom 6 April d. Js. – Dt. Fischerei-Verein, Circular Nr. 2 vom 22. April 1870, Correspondenzblatt, 9-10.

DFV, 1870e: Dt. Fischerei-Verein, Circular Nr. 2 vom 22. April 1870, 1-3.

DIETRICH, G., 1950: Die natürlichen Regionen von Nord- und Ostsee auf hydrographischer Grundlage. – Kieler Meeresforsch., **7**, 35-69.

DIETRICH, G., 1951: Oberflächenströmungen im Kattegat, im Sund und in der Beltsee. – Dt. Hydrogr. Z., **4**, 129-150.

DIETRICH, G., KALLE, K., 1957: Allgemeine Meereskunde. Berlin: Borntraeger, 492 pp.

DITTMAR, W., 1884: Report on researches into the composition of ocean-water collected by H.M.S. Challenger during the years 1873-76. In: Report of the scientific results of the voyage of HMS „Challenger" during the years 1873 – 76. Physics and chemistry, Vol. 1, Part I, 247 pp.

DOVE, H. W., 1858a: Ueber die Temperatur der Ostsee verglichen mit der des atlantischen Oceans. Z. allg. Erdkunde, N.F., **4**, 60-62.

DOVE, H. W., 1858b: Ueber die Wärme des Meerwassers im finnischen Meerbusen. – Z. allg. Erdkunde, N.F., **4**, 503-506.

DOVE, H. W., 1859: Ueber die Veränderungen der Temperatur des Meerwassers in der jährlichen Periode. – Z. allg. Erdkunde, N.F., **6**, 1-12.

DSV, 1904: Über internationale Untersuchungen der nordeuropäischen Meere im Interesse der Seefischerei (Gutachten [1899], dem Reichsamt des Innern erstattet). – Mitt. Dt. Seefischereivereins, **20**, 112-122.

EKMAN, F. L. , PETTERSSON, O., 1893: Den svenska hydrografiska expeditionen år 1877 under ledning af F. L. Ekman. – Kungl. Svenska Vetensk. Akad. Handlingar, Bd. 25, No. 1, Stockholm, 163 pp.

ENGELHARDT, R., 1899: Untersuchungen über die Strömungen der Ostsee. Die Dichtigkeitsfläche. – Aus dem Archiv der Dt. Seewarte, **22 (6)**, 1-27.

ENGELMANN, G., 1997: Die Gründungsgeschichte des Instituts und Museums für Meereskunde in Berlin 1899 – 1906. – Historisch-meereskundl. Jahrbuch, **4**, 105-122.

ETZEL, A. von, 1859: Die Ostsee und ihre Küstenländer, geographisch, naturwissenschaftlich und historisch. Zweites Buch: Hydrographisch-naturhistorische Darstellung der Ostsee. Leipzig: Verlagsbuchhandl. von Carl B. Lorck, 154-241.

FEISTEL, R., NAUSCH, G., WASMUND, N. (Eds.), 2008: State and evolution of the Baltic Sea, 1952 – 2005. A detailed 50-year survey of meteorology and climate, physics, chemistry, biology and marine environment. Hoboken: John Wiley & Sons, 703 pp.

FENNEL, W., NEUMANN, T., 2004: Introduction to the modelling of marine ecosystems. Elsevier Oceangr. Ser., **72**, 297 pp.

FENNEL, W., STURM, M., HELM, R., 1987: Response patterns of the western Baltic. – Beitr. Meereskunde, Berlin, **57**, 3-10.

FONSELIUS, S. H., 2002: Hydrographical investigations in the Baltic Sea area before the founding of ICES. – ICES Marine Science Symposia, **215**, 138-147.

FORCHHAMMER, G., 1865: On the composition of sea-water in the different parts of the ocean. – Phil. Trans. Roy. Soc. London, **155**, 203-262.

FRANCKE, E., NEHRING, D., 1971: Erste Beobachtungen über einen erneuten Salzwassereinbruch in die Ostsee im Februar 1969. – Beitr. Meereskunde, Berlin, **28**, 33-47.

GERLACH, S. A., 2000: Heinrich Adolph Meyer (1822 – 1889) und die „Marie", der erste Kieler Forschungskutter (1862). – Mitt. Dt. Ges. Meeresforsch., 1/2000, 6-8.

GERLACH, S. A., KORTUM, G., 2000: Zur Gründung des Instituts für Meereskunde der Universität Kiel 1933 bis 1945. Historisch-meereskundl. Jahrbuch, **7**, 7-48.

GILBERT, L. W., 1820: Noch einige Nachträge zu dem Aufsatze der Dr. Marcet über das Meerwasser. – Ann. Phys., **66**, 161-167.

GOEBEL, C. C. T. F., 1845: Das Seebad bei Pernau an der Ostsee in physikalisch-chemischer und topographisch-statistischer Beziehung, nebst einer vergleichenden chemischen Untersuchung des Ostsee-Wassers bei Reval, Hapsal und Pernau. Dorpat und Leipzig: Verlag O. Model, 77 pp.

GRASSHOFF, K., 1974: Die Geschichte der internationalen Meeresforschung im Ostseeraum. In: MAGAARD, L., RHEINHEIMER, G. (Eds.), Meereskunde der Ostsee, Berlin, Heidelberg, New York: Springer, 261-263.

HAHLBECK, W. H., 1998: Die Seefischerei-Forschung der DDR. In: BOYSEN, H.-O. (Ed.), (1998). 50 Jahre Fischerei in Deutschland 1948-1998. – Verb. Dt. Fischereiverwaltungsbeamter und Fischereiwissenschaftler, **12**, 358-365.

HEINCKE, F., HENKING, H., 1913: Dr. Walther Herwig. Präsident des Deutschen Seefischerei-Vereins. Ein Gedenkblatt. – Mitt. Dt. Seefischerei-Vereins, **29**, 92-136.

HENSEN, V., 1893: Das Plankton der östlichen Ostsee und des Stettiner Haffs. In: Die Expedition der Sektion für Küsten- und Hochseefischerei in der östlichen Ostsee. – Sechster Ber. Komm. Wiss. Unters. Dt. Meere Kiel. für die Jahre 1887 bis 1891, Berlin, Jg. 17 – 21, H. II, 103 – 137.

HERWIG. W., 1905: Die Beteiligung Deutschlands an der internationalen Meeresforschung. I. Bericht (1902), 1-6; II. Bericht (1903), 39-42.

HERWIG. W., 1906: Die Beteiligung Deutschlands an der internationalen Meeresforschung. III. Jahresbericht (1904/05), 1-10.

HERWIG. W., 1908: Die Beteiligung Deutschlands an der internationalen Meeresforschung. IV/V. Jahresbericht (1905-1907), 1-6.

HILDEBRAND, H. H., RÖHR, A., STEINMETZ, H.-O., 1979: Die deutschen Kriegsschiffe: Biographien – ein Spiegel der Marinegeschichte von 1865 bis zur Gegenwart. Abschnitt: Aviso Pommerania. Hamburg: Koehlers Verlagsgesellschaft mbH, Lizenzausgabe Mundus-Verlag, Bd. 6, 234-236.

HIMLY, C., 1868: V. Chronik der Universität zu Kiel. 19) Das chemische Laboratorium, No. 36 und 38. Schriften der Universität zu Kiel aus dem Jahre 1867, C. F. Mohr, Kiel, **14**, 48-50.

HUMBOLDT, A. von, 1834: Bemerkungen über die Temperatur der Ostsee. – Poggendorff's Ann. Phys. Chem., **23**, 223-227.

HUPFER, P., 2010: Ostseeforschung. In: HUPFER, P., Die Ostsee – kleines Meer mit großen Problemen. 5. Aufl., Stuttgart: Borntraeger, 244-255.

IOW, 1997: Aufbaubericht 1992 – 1996. Institut für Ostseeforschung Warnemünde, 1-122, A1 - A51.

JACOBSEN, O., 1872: Die physikalisch-chemischen Untersuchungen. In: MEYER, H. A., KARSTEN, G., MÖBIUS, K., HENSEN, V., General-Bericht der Commission zur Untersuchung der deutschen Meere in Kiel über ihre Thätigkeit im Jahre 1871, insbesondere über die Expedition S.M.S. Pommerania. Kiel, 21. October 1871. Anlage 3; Die physikalisch-chemischen Untersuchungen. – Dt. Fischerei-Verein, Circular Nr. 1 vom 29. Januar 1872, Correspondenzblatt, 21-25.

JACOBSEN, O., 1873a: Die Beobachtungen auf der Expedition 1871. In: MEYER, H. A., MÖBIUS, K., KARSTEN, G., HENSEN, V. (Eds.), Die Expedition zur physikalisch-chemischen und biologischen Untersuchung der Ostsee im Sommer 1871 auf S. M. Avisodampfer Pommerania. – Jahresber. Comm. Wiss. Unters. Dt. Meere Kiel für das Jahr 1871, Berlin, Jg. **1**, 37-56.

JACOBSEN. O., 1873b: Ueber die Luft des Meerwassers. – Ann. Chem. Pharm., **167**,1-38.

JACOBSEN, O., 1875: Über die Luft des Meerwassers. In: MEYER, H. A., MÖBIUS, K., KARSTEN, G., HENSEN, V., KUPFFER, C. (Eds.), Die Expedition zur physikalisch-chemischen und biologischen Untersuchung der Nordsee im Sommer 1872. – Jahresber. Comm. Wiss. Unters. Dt. Meere Kiel für die Jahre 1872, 1873, Jg. **2** und **3**, Teil II, 43-58.

JACOBSEN, O., 1888: Chemische Untersuchung der von S.M.S. „Gazelle“ geschöpften Meerwasserproben. In: Die Forschungsreise S.M.S. „Gazelle“ in den Jahren 1874 bis 1876. Herausgegeben vom Hydrographischen Amt der Admiralität, II. Theil: Physik und Chemie. Berlin: Mittler & Sohn, 61-68.

JILEK, A., 1857: Lehrbuch der Oceanographie zum Gebrauche der k. k. Marine-Akademie. Kaiserl.-Königl. Hof- und Staatsdruckerei, Wien, 298 pp.

KÄNDLER, R., 1951: Der Einfluß der Wetterlage auf die Salzgehaltsschichtung im Übergangsgebiet zwischen Nord- und Ostsee. – Dt. Hydrogr. Z., **4**, 150 – 160.

KÄNDLER, R., 1962: Die Ostsee als Versuchsbecken der Fischereiforschung. – Ber. Dt. Wiss. Komm. Meeresforsch., N. F., **17**, 27-33.

KARSTEN, C. J. B., 1846/1847: Lehrbuch der Salinenkunde. Erster Theil (1846). Berlin: G. Reimer, 884 pp. Contains a chapter „Das Meer“ (pp. 827-862) on salinity of sea water; Zweiter Theil (1847), Berlin: G. Reimer, 700 pp.

KARSTEN, G., 1846: Untersuchungen über das Verhalten der Auflösungen des reinen Kochsalzes in Wasser. Berlin: G. Reimer, 256 pp.

KARSTEN, G., 1865. Denkschrift über den grossen Norddeutschen Kanal zwischen Brunsbüttler Koog an der Elbe und dem Kieler Hafen. Herausgegeben von dem Kieler Committee für den Kanalbau. Kiel: Schwers’sche Buchhandl., 112 pp.

KARSTEN, G., 1873a: Frühere Untersuchungen. Das angenommene Beobachtungssystem und die Instrumente. In: MEYER, H. A., MÖBIUS, K., KARSTEN, G., HENSEN, V. (Eds.), Die Expedition zur physikalisch-chemischen und biologischen Untersuchung der Ostsee im Sommer 1871 auf S. M. Avisodampfer Pommerania. – Jahresber. Comm. Wiss. Unters. Dt. Meere Kiel für das Jahr 1871, Berlin, Jg. **1**, 1-8.

KARSTEN, G., 1873b: Die Beobachtungen an den Ostseestationen. In: MEYER, H. A., MÖBIUS, K., KARSTEN, G., HENSEN, V. (Eds.), Die Expedition zur physikalisch-chemischen und

biologischen Untersuchung der Ostsee im Sommer 1871 auf S. M. Avisodampfer Pommerania. – Jahresber. Comm. Wiss. Unters. Dt. Meere Kiel für das Jahr 1871, Berlin, Jg. **1**, 9-36.

KARSTEN, G., 1874a: Ueber die wissenschaftliche Untersuchung der Ostsee und Nordsee. – Ann. Phys. Chem., Poggendorff's Ann., Jubelband, 506-532.

KARSTEN, G., 1874b: Tafeln zur Berechnung der Beobachtungen an den Küsten-Stationen und zur Verwandlung der angewendeten Maasse in metrisches Maass. Im Auftr. Komm. Unters. Dt. Meere Kiel zusammengest. Kiel: Univ.-Buchhandl., 25 pp.

KARSTEN, G., 1874c: Introductory remarks, dated 10 February 1874. In: Ergebnisse der Beobachtungsstationen an den deutschen Küsten über die physikalischen Eigenschaften der Ostsee und Nordsee und die Fischerei. – Veröff. Ministerial-Komm. Unters. Dt. Meere Kiel, Berlin: Wiegandt, Hempel & Parey, Jg. 1873, Heft I, Januar.

KARSTEN, G., 1875: Die physikalischen Beobachtungen an den Stationen der deutschen Ostsee- und Nordsee-Küsten und Beobachtungen über Wassertemperaturen bei der Expedition im Jahre 1871. – Jahresber. Comm. Wiss. Unters. Dt. Meere Kiel für die Jahre 1872, 1873, Berlin, Jg. **2** und **3**, 317-339.

KARSTEN, G., 1877: V. Chronik der Universität zu Kiel. 27) Das physikalische Institut. Schriften der Universität zu Kiel aus dem Jahre 1876, C. F. Mohr, Kiel, **23**, 80-81.

KARSTEN, G., 1878a: Die Beobachtungen über die physikalischen Eigenschaften des Wassers der Ostsee und Nordsee. – Jahresber. Comm. Wiss. Unters. Dt. Meere Kiel für die Jahre 1874, 1875, 1876, Berlin, Jg. **4-6**, 253-285.

KARSTEN, G., 1878b: Die Ergebnisse der Expeditionen und Beobachtungsstationen der Kieler Commission zur wissenschaftlichen Untersuchung der deutschen Meere. – Verh. Ges. Erdkunde Berlin, **5**, 83-86.

KARSTEN, G., 1878c: Ueber das Problem der Meeresströmungen. – Verh. Ges. Erdkunde Berlin, **5**, 161-164.

KARSTEN, G., 1880: Etwas von den physikalischen Eigenschaften der Ostsee und Nordsee. In: MEYER, H. A., MÖBIUS, K., KARSTEN, G., HENSEN, V., Gemeinfassliche Mittheilungen aus den Untersuchungen der Kommission zur wissenschaftlichen Untersuchung der deutschen Meere. Kiel: Schmidt & Klaunig, 5-17.

KARSTEN, G., 1884: Die Beobachtungen an den Küstenstationen und Schiffsbeobachtungen. – Vierter Ber. Comm. Wiss. Unters. Dt. Meere Kiel für die Jahre 1877 bis 1881, Berlin, Jg. **7-11**, III. Abt. (Schluss), 13-60.

KARSTEN, G., 1887: Die Beobachtungen an den Küstenstationen. – Fünfter Ber. Komm. Wiss. Unters. Dt. Meere Kiel für die Jahre 1882 – 1886, Berlin, Jg. **12-16**, 135-157.

KARSTEN, G., 1888: Specifisches Gewicht und Salzgehalt des Meerwassers nach den auf der Expedition S.M.S. „Gazelle" entnommenen Wasserproben. In: Die Forschungsreise S.M.S. „Gazelle" in den Jahren 1874 bis 1876. II. Theil: Physik und Chemie. Berlin: Mittler & Sohn, 47-60.

KARSTEN, G., 1890: Kurzer Abriss der wissenschaftlichen Thätigkeit Heinrich Adolph Meyer's. In: Erinnerungen an Dr. H. A. Meyer. Nach seinen eigenen Aufzeichnungen. Hamburg, 109-118.

KARSTEN, G., 1893a: Die Beobachtungen an den Ostseestationen 1887 - 1890. – Sechster Ber. Komm. Wiss. Unters. Dt. Meere Kiel für die Jahre 1887 bis 1891, Berlin, Jg. **17-21**, 207-226.

KARSTEN, G., 1893b: Dr. Heinrich Adolph Meyer. – Sechster Ber. Komm. Wiss. Unters. Dt. Meere Kiel für die Jahre 1887 bis 1891, Berlin, Jg. **17-21**, H. II, 253-256.

KARSTEN, G., 1896a: II. Ueber die bisherigen Ergebnisse und über fernere Aufgaben zur Physik der deutschen Meere. – Wiss. Meeresunters., N. F., **1 (2)**, 167-180.

KARSTEN, G., 1896b: Die physikalischen Beobachtungen an den Stationen. – Wiss. Meeresunters., N. F., **1 (2)**, 145-166.

KAYSER, J., 1873: Physik des Meeres. Paderborn: F. Schöningh, 359 pp.

KIELMANN, J., 1981: Grundlagen und Anwendung eines numerischen Modells der geschichteten Ostsee. Ber. – Inst. Meereskunde Kiel, Teil 1, **87a**, 158 pp; Teil 2, **87b**, 116 pp.

KNUDSEN, M., 1903: Ueber den Gebrauch von Stickstoff-Bestimmungen in der Hydrographie. – Publ. de Circonst., Cons. Perm. Int. Explor. Mer, **4**, 1-9.

KOHLMANN, R., 1905: Beiträge zur Kenntnis der Strömungen der westlichen Ostsee. – Wiss. Meeresunters., N. F., Abt. Kiel, **8**, 189-238.

KÖLMEL, R., 1990: The Prussian „Kommission zur wissenschaftlichen Untersuchung der deutschen Meere in Kiel“ and the origin of modern concepts in marine biology in Germany. In: LENZ, W., DEACON, M. (Eds.), Ocean sciences – their history and relation to man. – Dt. Hydrogr. Z., Erg.-H. B, **22**, 399-407.

KORTUM, G., 1993: Otto Krümmel an der Deutschen Seewarte in Hamburg. – Dt. Hydrogr. Z., Erg.-H. B, **25**, 63-76.

KORTUM, G., 1994: Samuel Reyher (1635 – 1714) und sein “Experimentum Novum“. – Ber. Inst. Meereskunde Kiel, **246**, 3-12.

KORTUM, G., 1996: Geschichte der Ostseeforschung. In: RHEINHEIMER, G. (Ed.), Meereskunde der Ostsee. Springer, 2. Aufl., 5-9.

KORTUM, G., LEHMANN, A., 1997: A. v. Humboldts Forschungsfahrt auf der Ostsee im Sommer 1834. – Schr. Naturwiss. Ver. Schleswig-Holstein, **67**, 45-58.

KORTUM, G., PAFFEN, K., 1979: Das Geographische Institut und die Meeres- und Küstenforschung in Kiel. – Kieler Geogr. Schr., **50**, 71-131.

KRAUSS, W., 1960: Hydrographische Messungen mit einem Beobachtungsmast in der Ostsee. – Kieler Meeresforsch., **16**, 13-27.

KRAUSS, W., 1990: The Institute of Marine Research in Kiel. In: Lenz, W., Deacon, M. (Eds.), Ocean sciences – their history and relation to man. Dt. Hydrogr. Z., Erg.-H. B, **22**, 131-140.

KRAUSS, W., MAGAARD, L., 1961: Zum Spektrum der internen Wellen der Ostsee. – Kieler Meeresforsch., **17**, 137-147.

KRAUSS, W., MAGAARD, L., 1962: Zum System der Eigenschwingungen der Ostsee. – Kieler Meeresforsch., **18**, 184-186.

KRÜMMEL, O., 1877: Die aequatorialen Meeresströmungen des Atlantischen Oceans und das allgemeine System der Meerescirculation. Leipzig (Thesis: Göttingen 1876), 52 pp.

KRÜMMEL, O., 1886: Der Ozean. Eine Einführung in die allgemeine Meereskunde. In: Das Wissen der Gegenwart, Bd. 52, Leipzig, Prag: Freytag & Tempsky, 242 pp.

KRÜMMEL, O., 1890: Ueber die Bestimmung des specifischen Gewichts des Seewassers an Bord. – Ann. Hydrogr. Marit. Meteorol., **18**, 381-395.

KRÜMMEL, O., 1892: Reisebeschreibung der Plankton-Expedition. In: Hensen, V., Ergebnisse der Plankton-Expedition der Humboldt-Stiftung, Bd. 1, Abt. A, Kiel, Leipzig: Lipsius & Tischer, 370 pp.

KRÜMMEL, O., 1893: Geophysikalische Beobachtungen. In: Hensen, V., Ergebnisse der Plankton-Expedition der Humboldt-Stiftung, Bd. 1, Abt. C, Kiel, Leipzig: Lipsius & Tischer, 118 pp.

KRÜMMEL, O., 1894a: Ueber einige neuere Beobachtungen an Aräometern. – Ann. Hydrogr. Marit. Meteorol., **22**, 415-427.

KRÜMMEL, O., 1894b: Neue physikalische Untersuchungen aus der Ostsee. – Mitt. Dt. Seefischerei-Vereins, **10**, 133-142.

KRÜMMEL, O., 1895: Zur Physik der Ostsee. – Petermanns Geogr. Mitt., **41**, 81-86, 111-118.

KRÜMMEL, O., 1896a: Ueber die Abhängigkeit der großen nordischen Seefischereien von den physikalischen Zuständen des Meeres. – Mitt. Dt. Seefischerei-Vereins, **12 (7)**, 122-127.

KRÜMMEL, O., 1896b: Professor Dr. Friedrich Dahls Aräometerbeobachtungen auf der Fahrt von Neapel nach Matupi. – Ann. Hydrogr. Marit. Meteorol., **24**, 539-546.

KRÜMMEL, O., 1901: Neue Beiträge zur Kenntnis des Aräometers. – Wiss. Meeresunters., N. F., Abt. Kiel, **5**, 8-36.

KRÜMMEL, O., 1902: Der Ozean. Eine Einführung in die allgemeine Meereskunde. In: Das Wissen der Gegenwart, Bd. 52, 2. Aufl. Wien, Leipzig, Prag: Tempsky & Freytag, 285 pp.

KRÜMMEL, O., 1904: Die Deutschen Meere im Rahmen der internationalen Meeresforschung. – Veröff. Inst. Meereskunde Berlin, **6**, 36 pp.

KRÜMMEL, O., 1905a: Bericht über die hydrographischen Untersuchungen. In: Herwig. W. (Ed.), Die Beteiligung Deutschlands an der internationalen Meeresforschung. I. Bericht (1902), 19-28.

KRÜMMEL, O., 1905b: Bericht über die Terminfahrt in der Nordsee an Bord des Dampfers „Poseidon“ vom 3. bis 12. August 1903. In: Herwig. W. (Ed.), Die Beteiligung Deutschlands an der internationalen Meeresforschung. II. Bericht (1903), 44-50.

KRÜMMEL, O., 1905c.: Bericht über die hydrographischen Untersuchungen. In: Herwig. W. (Ed.), Die Beteiligung Deutschlands an der internationalen Meeresforschung. II. Bericht (1903), 61-67.

KRÜMMEL, O., 1907: Handbuch der Ozeanographie, Band I: Die räumlichen, chemischen und physikalischen Verhältnisse des Meeres. 2. Aufl., Stuttgart: J. Engelhorn, 526 pp.

KRÜMMEL, O., 1908: Bericht über die hydrographischen Untersuchungen. In: Herwig. W. (Ed.), Die Beteiligung Deutschlands an der internationalen Meeresforschung. IV/V. Jahresbericht (1905-1907), 7-16.

KRÜMMEL, O., 1911: Handbuch der Ozeanographie, Band II: Die Bewegungsformen des Meeres (Wellen, Gezeiten, Strömungen). 2. Aufl., Stuttgart: J. Engelhorn Nachf., 766 pp.

KULLENBERG, G. (Ed.), 1984: Overall report on the Baltic open sea experiment 1977 (BOSEX). – ICES Coop. Res. Rep., **127**, 82 pp.

LASS, H.U., MOHRHOLZ, V., SEIFERT, T., 2005: On pathways and residence time of saltwater plumes in the Arkona Sea. – J. Geophys. Res., **110**, C11019, doi: 10.1029/2004JC002848.

LASS, H. U., PRANDKE, H., LILJEBLADH, B., 2003. Dissipation in the Baltic proper during winter stratification. – J. Geophys. Res., 108, C6, 3187, doi: 10.1029/2002JC0011401.

LEHMANN, A., 1992: Ein dreidimensionales wirbelauflösendes Modell der Ostsee. – Ber. Inst. Meereskunde Kiel, **231**, 104 pp.

LEHMANN, A., 1995: A three-dimensional baroclinic eddy-resolving model of the Baltic Sea. – Tellus, **47A**, 1013–1031.

LEHMANN, A., HINRICHSEN, H. H., 2002: Water, heat and salt exchange between the deep basins of the Baltic Sea. – Boreal Environm. Res., **7 (4)**, 405-415.

LEPPÄRANTA, M., MYRBERG, K., 2009: Research history. In: Physical Oceanography of the Baltic Sea, Chapter 2. Chichester: Springer Praxis Books, 16-25.

LICHTENBERG, F. D., 1811: Chemische Untersuchung des Ostsee-Wassers. – Schweigger's J. Chem. Phys., **2**, 252-257.

MAGAARD, L., RHEINHEIMER, G. (Eds.), 1974: Meereskunde der Ostsee. Berlin, Heidelberg, New York: Springer, 269 pp.

MAKAROFF, S. O., 1894: Le „Vitiaz" et l'Océan Pacifique. St.-Pétersbourg, Vol. 1: 337 pp., Vol. 2: 510 pp.

MATTHÄUS, W., 1966: Die historische Entwicklung der meereskundlichen Temperaturmeßgeräte für größere Tiefen. – Schriftenr. Gesch. Naturwiss., Techn., Med. (NTM), **3 (8)**, 58-73.

MATTHÄUS, W., 1967a: Die Berufung des Ozeanographen Otto Krümmel zum Ordinarius für Geographie an der Universität Kiel. – Monatsber. Dt. Akad. Wiss. Berlin, **9**, 535-537.

MATTHÄUS, W., 1967b: Der Ozeanograph Johann Gottfried Otto Krümmel (1854 – 1912). – Wiss. Z. Univ. Rostock, Math.-Naturwiss. R., **16**, 1219-1224.

MATTHÄUS, W., 2006a: The history of investigation of salt water inflows into the Baltic Sea – from the early beginning to recent results. – Meereswiss. Ber. Warnemünde, **65**, 73 pp.

MATTHÄUS, W., 2006b: The investigation of salt water inflows and their effects on the Baltic ecosystem – a historical survey. – Historisch-meereskundl. Jahrbuch, **12**, 7-44.

MATTHÄUS, W., 2008: The first joint research programme in the Baltic Sea after World War II – the Cooperative Synoptic Investigation in August 1964. – Historisch-meereskundl. Jahrbuch, **14**, 57-88.

MATTHÄUS, W., 2010: Oscar Jacobsen (1840 – 1889) – der erste deutsche Meereschemiker. – Historisch-meereskundl. Jahrbuch, **16,** 7-48.

MATTHÄUS, W., FRANCK, H. 1992: Characteristics of major Baltic inflows - a statistical analysis. – Cont. Shelf Res., **12**, 1375-1400.

MATTHÄUS, W., FRANCKE, E., LASS, H. U., SCHWABE, R., 1982: Untersuchungen der Wasseraustauschprozesse im Bereich der Darßer Schwelle. – Beitr. Meereskunde, Berlin, **47**, 31-50.

MAYER, E., 1883: Die oceanographischen Instrumente und der Vorgang bei deren Anwendung. In: ATTLMAYR, F. (Ed.), Handbuch der Oceanographie und maritimen Meteorologie. Kaiserl.-Königl. Hof- und Staatsdruckerei, Wien; I. Band, 61-124.

MEIER, H. E. M., 1996: Ein regionales Modell der westlichen Ostsee mit offenen Randbedingungen und Datenassimilation. – Ber. Inst. Meereskunde Kiel, **284**, 118 pp.

MEYER, H. A., 1871: Untersuchungen über physikalische Verhältnisse des westlichen Theiles der Ostsee. Ein Beitrag zur Physik des Meeres. Kiel: – Schwers'sche Buchhandl., 1-85 und 82 Tabellen.

MEYER, H. A., 1875: Zur Physik des Meeres. Beobachtungen über Meeresströmungen, Temperatur und specifisches Gewicht des Meerwassers während der Nordseefahrt vom 21. Juli bis 9. September 1872. In: MEYER, H. A., MÖBIUS, K., KARSTEN, G., HENSEN, V., KUPFFER, C. (Eds.), Die Expedition zur physikalisch-chemischen und biologischen Untersuchung der Nordsee im Sommer 1872. – Jahresber. Comm. Wiss. Unters. Dt. Meere Kiel für die Jahre 1872, 1873, Berlin, Jg. **2** und **3**, Teil I, 1-41.

MEYER, H. A., 1884: Periodische Schwankungen des Salzgehaltes im Oberflächenwasser in der Ostsee und Nordsee. – Vierter Ber. Comm. Wiss. Unters. Dt. Meere Kiel für die Jahre 1877 bis 1881, Berlin, Jg. **7-11**, III. Abt. (Schluss), 1-10.

MEYER, H. A., MÖBIUS, K., 1865: Fauna der Kieler Bucht. 1. Band: Die Hinterkiemer oder Opisthobranchia. Leipzig: Wilhelm Engelmann, 88 pp.

MEYER, H. A., MÖBIUS, K., 1872: Fauna der Kieler Bucht. 2. Band: Die Prosobranchia und Lamellibranchia. Leipzig: Wilhelm Engelmann, 139 pp.

MEYER, H. A., KARSTEN, G., HENSEN , V., MÖBIUS, K., 1871: II. Untersuchung der Deutschen Meere. Denkschrift der wissenschaftlichen Commission zur Untersuchung der deutschen Meere in Kiel in Betreff der im Jahre 1871 auszuführenden Arbeiten. – Dt. Fischerei-Verein, Circular Nr. 3 vom 19. April 1871, Correspondenzblatt, 13-16.

MEYER, H. A., KARSTEN, G., MÖBIUS, K., HENSEN, V., 1872: General-Bericht der Commission zur Untersuchung der deutschen Meere in Kiel über ihre Thätigkeit im Jahre 1871, insbesondere über die Expedition S.M.S. Pommerania. Kiel, 21. October 1871. – Dt. Fischerei-Verein, Circular Nr. 1 vom 29. Januar 1872, Correspondenzblatt, 5-28 einschl. 4 Anlagen.

MEYER, H. A., MÖBIUS, K., KARSTEN, G., HENSEN, V. (Eds.), 1873a: Die Expedition zur physikalisch-chemischen und biologischen Untersuchung der Ostsee im Sommer 1871 auf S. M. Avisodampfer Pommerania. – Jahresber. Comm. Wiss. Unters. Dt. Meere Kiel für das Jahr 1871, Berlin, Jg. **1**, 1-178.

MEYER, H. A., MÖBIUS, K., KARSTEN, G., HENSEN, V. (Eds.), 1873b: Vorbericht der Commission vom 16. Juli 1872. In: Die Expedition zur physikalisch-chemischen und biologischen Untersuchung der Ostsee im Sommer 1871 auf S. M. Avisodampfer Pommerania. – Jahresber. Comm. Wiss. Unters. Dt. Meere Kiel für das Jahr 1871, Berlin, Jg. **1**, V-XI.

MEYER-WAARDEN, P. F., 1970: Aus der Deutschen Fischerei: Geschichte einer Fischereiorganisation. Berlin: H. Heenemann, 359 pp.

MILL, H. R., 1900: The Pettersson-Nansen insulating water-bottle. – Geogr. J., **16**, 469-471.

MILLS, E. L., 1997: „Physische Meereskunde": from geography to physical oceanography in the Institut für Meereskunde, Berlin, 1900-1935. – Historisch-meereskundl. Jahrbuch, **4**, 45-70.

MODEL, F., 1966: Geophysikalische Bibliographie von Nord- und Ostsee. Teil I und II. – Dt. Hydrogr. Z., Erg.-H. **8**, Teil I: 878 pp; Teil II: 600 pp.

NATTERER, K., 1892: Aus den Berichten der Commission für Erforschung des östlichen Mittelmeeres. Chemische Untersuchungen im östlichen Mittelmeer. I. Reise S.M. Schiffes „Pola“ im Jahre 1890. – Monatsh. Chem., Österr. Akad. Wiss. Wien, **13**, 873-890.

NEGRETTI, H., ZAMBRA, J. W., 1874: On a new deep-sea thermometer. – Proc. Roy. Soc., **22**, 238-241.

NEHRING, D., FRANCKE, E., 1973: Zusammenfassende Darstellung der hydrographisch-chemischen Veränderungen in der Ostsee 1969/70. – Fischerei-Forsch., Rostock, **11 (1)**, 31-43.

NILSSON, H., SVANSSON, A., 1974: Long term variations of oceanographic parameters in the Baltic and adjacent waters. – Medd. Havsfiskelab. Lysekil, **174**, 1-11.

OTTO, J. F. W., 1794: Abriß einer Naturgeschichte des Meeres. Ein Beytrag zur physischen Erdbeschreibung. Zweytes Bändchen, Berlin: F. Franke, 220 pp.

OTTO, J. F. W., 1800: Versuch einer physischen Erdbeschreibung. Nach den neuesten Beobachtungen und Entdeckungen. In: System einer allgemeinen Hydrographie des Erdbodens, Erster Theil, Berlin: G. C. Nauck, 662 pp.

PETERMANN, A., 1870: Der Golfstrom und Standpunkt der thermometrischen Kenntnis des Nord-Atlantischen Oceans und Landgebiets im Jahre 1870. – Petermanns Mitt., **16**, 201-244.

PETTERSSON, O., 1894a: A review of Swedish hydrographic research in the Baltic and the North Seas. I. Introductory remarks, apparatus and methods of investigation. – Scottish Geogr. Mag., **10**, 281-302.

PETTERSSON, O., 1894b: Redogörelse för de Svenska hydrografiska undersökningarne åren 1893 – 1894 under ledning af G. Ekman, O. Pettersson och A. Wijkander. I. Östersjön. – Bihang till Kongl. Svenska Vetensk. Akad. Handlingar, N. F., Bd. **19 (II)**, No. 4, Stockholm, 1-14.

PETTERSSON, O., 1894c: A review of Swedish hydrographic research in the Baltic and the North Seas. – Scottish Geogr. Mag., **10**, 281-302, 352-359, 413-427, 449-462, 525-539, 617-631.

PETTERSSON, O., EKMAN, G., 1891: Grunddragen af Skageracks och Kattegats hydrographi. – Kongl. Svenska Vetensk. Akad. Handlingar, N. F., Bd. **24**, No. 11, Stockholm, 1-162.

PETTERSSON, O., EKMAN, G., 1897: De hydrografiska förändringarne inom Nordsjöns och Östersjöns område under tiden 1893 – 1897. – Kongl. Svenska Vetensk. Akad. Handlingar, N. F., Bd. **29**, No. 5, Stockholm, 1-125.

PFAFF, C. H., 1814: Ueber die Mischung des Ostseewassers im Hafen von Kiel, und die Coexistenz von Salzen, die sich wechselseitig zersetzen in Mineralwasser. – Schweigger’s J. Chem. Phys., **11**, 8-15.

PFAFF, C. H., 1818: Nachtrag zu meiner Analyse des Ostseewassers. – Schweigger’s J. Chem. Phys., **22**, 271-273.

PFAFF, C. H., 1822: Das Kieler Seebad, dargestellt und verglichen mit andern Seebädern an der Ostsee und Nordsee, nebst einer bey der Eröffnung gehaltenen Rede. Kiel: Mohr, 102 pp.

PFLAUM, H., 1896: Salzgehalt des Rigaschen Meerbusens. – Correspondenzblatt des Naturforscher-Vereins zu Riga, **39**, 108-109.

PICCARD, E. F., 1904: Beiträge zur physischen Geographie des Finnischen Meerbusens. Short report in: Geographischer Literatur-Bericht für 1904, Beilage zu Petermanns Mitt., **50**, 157-158.

REDNAK, D., 1994: Heinrich Adolph Meyer. In: Neue Deutsche Biographie, **17**, 294-295.

REIBISCH, J., 1902: Hydrographische Beobachtungen. In: Die Ostsee-Expedition 1901 des Deutschen Seefischerei-Vereins. – Abh. Dt. Seefischerei-Vereins, **7**, 85- 100.

REINKE-KUNZE, C., 1986: Den Meeren auf der Spur. Geschichte und Aufgaben der deutschen Forschungsschiffe. Herford: Koehlers Verlagsges., 169 pp.

REYHER, S., 1697: Experimentum novum, quo aquae marinae dulcedo, die VI. Febr. Ann. 1697 examinata, descibitur. Kiel: 1-16 (cited after Wenk, 1966). The only copy still existing has the Royal Library in Copenhagen.

ROZWADOWSKI, H. M., 1999: Marine science in the age of internationalism. – Historisch-meereskundl. Jahrbuch, **6**, 83-104.

ROZWADOWSKI, H. M., 2002: The sea knows no boundaries: A century of marine science under ICES. ICES: Copenhagen and Univ. Washington Press: Seattle & London, 410 pp.

RØRDAM, K., 1896: De hydrografiske Forhold i de danske Farvande inden for Skagen i 1891 – 93. – Beretning fra Kommissionen for videnskabelig Undersøgelse af de danske Farvande, **1 (1)**, 1-197, and **1 (2)**, Tavler I-XXXXVII.

RUPPIN, E., 1905: Bestimmung und Verwertung des Gasgehaltes des Meerwassers. – Wissensch. Meeresuntersuchungen N. F., Bd. **8**, Abt. Kiel, Kiel und Leipzig, 127-134.

SAHRHAGE, D., 1982: 80 Jahre Deutsche Wissenschaftliche Kommission für Meeresforschung. – Meeresforsch., **29**, 197-207.

SASS, A. F. von, 1866a: Analyse des Ostseewassers aus dem grossen Sunde zwischen den Inseln Oesel und Moon. – J. prakt. Chem., **98**, 251.

SASS, A. F. von, 1866b: Ueber die chemische Constitution des Ostseewassers in verschiedenen Gegenden. – Ann. Phys. Chem., **205**, 412-429.

SASS, A. F. von, 1866c: Beobachtungen über die Variationen im specifischen Gewicht des Ostseewassers. – Bulletin de l'Acad. Impér. des Sciences de St.-Pétersbourg, **X**, 507-513.

SASS, A. F. von, 1867: Resultate aus meinen Untersuchungen über die Variationen im Salzgehalte des Ostseewassers. – Z. Ges. Erdkunde Berlin, **2**, 481-498.

SCHMIDT, M., FENNEL, W., NEUMANN, T., SEIFERT, T., 2008: Description of the Baltic Sea with numerical models. In: FEISTEL, R., NAUSCH, G., WASMUND, N. (Eds.), State and evolution of the Baltic Sea, 1952 – 2005. A detailed 50-year survey of meteorology and climate, physics, chemistry, biology and marine environment. Hoboken: John Wiley & Sons, 583-624.

SCHOTT, G., 1896: Die Hydrographie des Skageracks, Kattegats und der Ostsee. – Geogr. Z., **2**, 142-158.

SCHOTT, G., 1928: Otto Krümmel, * 8. Juli 1854, † 12. Oktober 1912. – Rapp. P.-v. Réun., Cons. Int. Explor. Mer. (Rapport Jubilaire), **47**, Part II, 32-34.

SCHRENK, A. G., 1854-1857: Uebersicht des oberen silurischen Schichtsystems Liv- und Ehstlands, vornämlich ihrer Inselgruppe. – Arch. Naturkunde Liv-, Ehst- u. Kurlands, Ser. I, **1**, 1-112.

SCHULZ, B., 1956: Hydrographische Untersuchungen in der Ostsee 1925 – 1938 mit dem Reichsforschungsdampfer „Poseidon". – Dt. Hydrogr. Z., Erg.-H. B, **1**, 1-87.

SCHULZ, S., BREUEL, G., LASS, U., MATTHÄUS, W., NEHRING, D., POSTEL, L., 1989: The patchy distribution of oceanological parameters during the spring bloom in the Baltic proper. In: RYLAND, J. S., TYLER, P. A. (Eds.), Reproduction, genetics and distribution of marine organisms. Fredensborg: Olsen & Olsen, 451-458.

SCHWEDER, G., 1881: Salzgehalt des Rigaschen Meerbusens I. – Correspondenzblatt des Naturforscher-Vereins zu Riga, **24**, 26-29; Part II (1882), **25**, 41-43; Part III (1883), **26**, 68-69; Part IV (1884), **27**, 46-47; Part V (1885), **28**, p. 33; Part VI (1886), **29**, p. 30; Part VII (1887), **30**, p. 30.

SCHWEDER, G., 1884: Salzgehalt des Rigaschen Meerbusens IV. – Correspondenzblatt des Naturforscher-Vereins zu Riga, **27**, 46-47.

SIEDLER, G., 1961: Über die kurzfristige Veränderlichkeit von Temperatur- und Salzgehaltsschichtung in der östlichen und mittleren Ostsee im Sommer 1960. – Kieler Meeresforsch., **17**, 148-153.

SIVERS, von, 1820: Versuche über die Salzigkeit des Wassers in der Ostsee, im Sunde und im Schwarzen Meere. – Ann. Phys., **66**, p. 226.

SMED, J., 1990a: Hydrographic investigations in the North Sea, the Kattegat and the Baltic before ICES. In: LENZ, W., DEACON, M. (Eds.), Ocean sciences – their history and relation to man. Dt. Hydrogr. Z., Erg.-H. B, **22**, 357-366.

SMED, J., 1990b: Walther Herwig: the first President of the International Council for the Exploration of the Sea (ICES). In: LENZ, W., DEACON, M. (Eds.), Ocean sciences – their history and relation to man. – Dt. Hydrogr. Z., Erg.-H. B, **22**, 323-329.

SMED, J., 1994: Otto Krümmel's participation in the international oceanographic cooperation in the 1890's and his troubles with the Kiel Commission. – Historisch-meereskundl. Jahrbuch, **2**, 59-67.

SMITH, T., 1684: A conjecture about an *under-Current* at the *Streights*-Mouth. – Phil. Trans., **14**, 564-566.

STRUVE, H., 1864: Über den Salzgehalt der Ostsee. – Mémoires de l'Acad. Impér. des Sciences de St.-Pétersbourg, VII Serie, **8**, No. 6, 1-13.

SVERDRUP, H. U., JOHNSON, M. W., FLEMING, R. H., 1942: The oceans, their physics, chemistry, and general biology. New York: Prentice-Hall, 1087 pp.

THOMAS, G., 1863: Meteorologische Beobachtungen in Cranz während der Jahre 1852 bis 1863, jedesmal vom 15. Juni bis 20. September angestellt. – Schriften der königlich physikalisch-ökonomischen Gesellschaft zu Königsberg, **4**, 140-175.

TORNØE, H., 1880: On the amount of salt in the water of the Norwegian Sea. In: The Norwegian North-Atlantic Expedition 1876 – 1878. Chemistry, Part III, Christiania: Grøndahl & Søn, 47-76.

ULRICH, J., KORTUM, G., 1997: Otto Krümmel (1854 – 1912) – Geograph und Wegbereiter der modernen Ozeanographie. – Kieler Geogr. Schr., **93**, 310 pp.

VOGEL, S. G., 1794: Ueber den Nutzen und Gebrauch der Seebaeder. Nebst der Ankuendigung einer oeffentlichen Seebadeanstalt, welche an der Ostsee in Mecklenburg angelegt wird. Stendal: Franzen & Grosse, 150 pp.

VOGEL, S. G., 1819: Handbuch zur richtigen Kenntniß und Benutzung der Seebadeanstalt zu Doberan. Stendal: Franzen & Grosse, 185 pp.

WALLACE, W. J., 1974: The development of the chlorinity/salinity concept in oceanography. Amsterdam: Elsevier, 227 pp.

WANDEL, C. F., 1896: Indledning. – Beretning fra Kommissionen for videnskabelig Undersøgelse af de danske Farvande, **1 (1)**, III-XII.

WATERMANN, B., WRZESINSKI, O. J., 1989: Bibliographie zur Geschichte der deutschen Meeresforschung. Chronologische Titelaufzählung (1557 – 1989). 2. erw. Aufl., Dt. Ges. Meeresforsch., Hamburg, 248 pp.

WATTENBERG, H., 1941: Über die Grenzen zwischen Nord- und Ostseewasser. – Ann. Hydrogr. Marit. Meteorol., **69**, 265-279.

WATTENBERG, H., 1949: Entwurf einer natürlichen Einteilung der Ostsee. – Kieler Meeresforsch., **6**, 10-15.

WEBER, L., 1878: Ueber die Temperatur der Maximaldichtigkeit für destillirtes Wasser und Meerwasser. – Jahresber. Comm. Wiss. Unters. Dt. Meere Kiel für die Jahre 1874, 1875, 1876, Berlin, Jg. **4 – 6**, 1-22.

WEBER, L., 1900: Zum Gedächtnisse Gustav Karsten's. Univ.-Buchhandl., Kiel, 24 pp.

WEGNER, G., 1990. Some remarks about the role of the Deutsche Wissenschaftliche Kommission für Meeresforschung in the promotion of interdisciplinary investigations. In: Lenz, W., Deacon, M. (Eds.), Ocean sciences – their history and relation to man. Dt. Hydrogr. Z., Erg.-H. B, **22**, 408-416.

WEGNER, G., 1995: 125 Jahre Deutsche Fischereiforschung. – Infn. Fischwirtsch., **42 (3)**, 128-133.

WEGNER, G., 1998a: Wissenschaft im Dienste der Seefischerei. In: Boysen, H.-O. (Ed.), (1998). 50 Jahre Fischerei in Deutschland 1948-1998. Verb. Dt. Fischereiverwaltungsbeamter und Fischereiwissenschaftler, **12**, 366-382.

WEGNER, G., 1998b: Die Deutsche Wissenschaftliche Kommission für Meeresforschung. – Dt. Schiffahrtsarchiv, **21**, 219-232.

WEGNER, G., 2000: Deutsche Forschungsschiffe und ihre Namen. – Dt. Schiffahrtsarchiv, **23**, 217-250.

WENK, H. G., 1966: Die Geschichte der Geographie und der geographischen Landesforschung an der Universität Kiel von 1665 bis 1879. – Schr. Geogr. Inst. Univ. Kiel, **24 (1)**, 253 pp.

WENT, A. E. J., 1972: Seventy years agrowing – a history of the International Council for the Exploration of the Sea 1902 – 1972. – Rapp. P.-v. Réun. Cons. Int. Explor. Mer, **165**, 252 pp.

WILCKE, J. C., 1771: Beskrifning på et instrument at uphämta vatten ifrån större djup utur hafvet med rön om hafsvattnets värma och tyngd på olika djup uti Öresund. – Kungl. Svenska Vetensk. Akad. Handlingar, Bd. **32**, 60 - 66.

WÜST, G., HOFFMANN, C., SCHLIEPER, C., KÄNDLER, R., KREY, J., JAEGER, R., 1956: Das Institut für Meereskunde der Universität Kiel nach seinem Wiederaufbau. – Kieler Meeresforsch., **12**, 127-153.

WYRTKI, K., 1953: Die Dynamik der Wasserbewegungen im Fehmarnbelt I. – Kieler Meeresforsch., **9**, 155–170.

WYRTKI, K., 1954: Der große Salzeinbruch in die Ostsee im November und Dezember 1951. – Kieler Meeresforsch., **10**, 19 - 25.

Archive material

Geheimes Staatsarchiv Preußischer Kulturbesitz Berlin (ehem. Deutsches Zentralarchiv in der DDR, Dienststelle Merseburg)

GStA PK 1: Brief von Krümmel an den geheimen Rat Friedrich Althoff vom 13. August 1883: Rep. 76 Va, Sekt. 9, Tit. IV, Nr. 1: Die Anstellung und Besoldung der außerordentlichen und ordentlichen Professoren in der philosophischen Fakultät der Universität Kiel, Bd. V: Jan. 1880 – Nov. 1883, Fol. 278.

GStA PK 2: Rep.76 Vc, Sekt. 1, Tit. XI, Teil V C, Nr. 11: Die wissenschaftliche Untersuchung der Meere, Bd. 1: 1884 – 1900.

Bundesarchiv-Militärarchiv Freiburg

BA-MA 1: RM.1/2616: Pommerania, Band.1: 1871/02-1871/12, Fol. 6.

BA-MA 2: RM.1/2616: Pommerania, Band.1: 1871/02-1871/12, Fol. 3.

BA-MA 3: RM.1/2616: Pommerania, Band.1: 1871/02-1871/12, Fol. 3 and 5.

BA-MA 4: RM. 1/2616 Pommerania, Band 1: 1871/02-1871/12, [Kaiserliche Admiralität:] Plan für die im Jahre 1871 beabsichtigten Vorarbeiten zur Hebung der Norddeutschen Seefischerei. Fol. 9-11.

Abbreviations and translations of names of German authorities and agencies into English

BA-MA	Bundesarchiv-Militärarchiv Freiburg
DFV	Deutscher Fischerei-Verein = German Fishery Association
DSV	Deutscher Seefischerei-Verein = German Sea Fishing Association
DWK	Deutsche Wissenschaftliche Kommission für Meeresforschung = German Scientific Commission for Marine Research
DWKIM	Deutsche Wissenschaftliche Kommission für die Internationale Meeresforschung = German Scientific Commission for the International Marine Research

German Marine Observatory = Deutsche Seewarte

GStA PK	Geheimes Staatsarchiv Preußischer Kulturbesitz Berlin (ehem. Deutsches Zentralarchiv in der DDR, Dienststelle Merseburg)

Hydrographic Agency of the Imperial Admiralty = Hydrographisches Amt der Kaiserlichen Admiralität

ICES	International Council for the Exploration of the Sea = Internationaler Rat für Meeresforschung

Imperial Office of the Interior = Reichsamt des Innern

Imperial research steamer = Reichsforschungsdampfer

Kiel Commission	Kommission zur wissenschaftlichen Untersuchung der deutschen Meere = Commission for the Scientific Investigation of the German Seas
RM	Reichsmarine = Imperial Navy

Section for Coastal and High Seas Fisheries = Sektion für Küsten- und Hochseefischerei

Ships involved in Germany's Baltic Sea research in the 19th and early 20th century

Further ships mentioned

Index of names

Meereswiss. Ber., Warnemünde 83 (2010)

MATTHÄUS, W.:

Publications on the history of the marine research in Warnemünde/Germany

Contents

Matthäus, W.:

Publications on the history of the marine research in Warnemünde/Germany

Abstract

All publications and important typescripts came out so far on the history of marine research in Warnemünde/Germany are compiled. The list contains publications both on the development of the institutions and on the oceanographers deserved well of the development of the research location. Moreover, papers on the history of the Warnemünde research vessels, of exceptional expeditions and research programmes and of the oceanographic measuring technique are summarized.

Kurzfassung

Es wird eine Liste der Veröffentlichungen und wesentlichen Manuskripte über die Geschichte des Meeresforschungsstandortes Warnemünde, die bisher erschienen sind, zusammengestellt. Sie enthält sowohl Publikationen über die Entwicklung der meeresforschenden Einrichtungen und Institute als auch über die Meeresforscher, die sich um die Entwicklung des Standortes verdient gemacht haben. Darüber hinaus sind wissenschaftshistorische Arbeiten über die Geschichte der Warnemünder Forschungsschiffe, ausgewählter Expeditionen und Programme sowie der Meeresforschungstechnik enthalten.

List of publications

BENGELSDORFF, E., 1975: DCXW und DHVH. Die ozeanographischen Forschungsschiffe der DDR und ihre Aufgaben. – In: Jahrbuch der Schiffahrt, Berlin, 61-65.

BROSIN, H.-J., 1990: Institut für Meereskunde Rostock-Warnemünde. – Deutsche Gesellschaft für Meeresforschung, Mitteilungen, 1990/H. **4**, 22- 23.

BROSIN, H.-J., 1996: Zur Geschichte der Meeresforschung in der DDR. – Meereswissenschaftliche Berichte, Warnemünde, **17**, 1-212.

BROSIN, H.-J., 2001: Erich Bruns und das Institut für Meereskunde Warnemünde. – Historisch-meereskundliches Jahrbuch, **8**, 71-82.

BROSIN, H.-J., 2003/2004: Das Forschungsschiff „Professor Albrecht Penck“ – über 50 Jahre im Dienste der Meeresforschung. – Historisch-meereskundliches Jahrbuch, **10**, 7-28.

BROSIN, H.-J., 2004/2005: Ein unbekanntes Meeresforschungsinstitut. – Tidingsbringer – ein Warnemünder Bäderjournal, **9**, 40-41.

BROSIN, H.-J., 2005: Von der „Georgius Agricola“ zur „A. v. Humboldt“. – Historisch-meereskundliches Jahrbuch, **11**, 7-38.

BROSIN, H.-J., 2005/2006: Die Dienstgebäude des Instituts für Ostseeforschung und seiner Vorläufereinrichtungen. – Tidingsbringer – ein Warnemünder Bäderjournal, **10**, 41-44.

BROSIN, H.-J., 2006: Klaus Voigt (1934 – 1995) – Ozeanograph und Wissenschaftsorganisator. – Historisch-meereskundliches Jahrbuch, **12**, 81-102.

BROSIN, H.-J., 2007: Warnemünder Beiträge zur Untersuchung des Äquatorialen Unterstroms im Atlantischen Ozean. – Sitzungsberichte der Leibniz-Societät Berlin (in press).

BROSIN, H.-J., SCHEMAINDA, R. , STRIGGOW, K., 1980: 30 Jahre Meeresforschung in der DDR. – Beiträge zur Meereskunde, Berlin, **44/45**, 5-13.

BRUNS, E., 1961: Meereskundliche Expeditionen der DDR auf dem Forschungsschiff „Michail Lomonossov“ im Atlantischen Ozean. – Beiträge zur Meereskunde, Berlin, **1**, 7-18.

BRUNS, E., 1962: Weitere meereskundliche Expeditionen auf dem Forschungsschiff „Michail Lomonossov“ im Atlantischen Ozean. – Beiträge zur Meereskunde, Berlin, **5**, 13-16.

BRUNS, E., 1970: Chronik des Instituts für Meereskunde Warnemünde. – Unpublished Manuscript, Warnemünde, 1-142.

Dugan, J. P., 1992: Institute for Baltic Sea Research. In: Dolezak, H. (Ed.), The East German Research Landscape in Transition, Part B: Non-University Institutes. – Office of Naval Research, European Reports, ONR European Office, London, 37-42.

FEISTEL, R., NAUSCH, G., WASMUND, N. (Eds.), 2008: State and evolution of the Baltic Sea, 1952 – 2005: A detailed 50-year survey of meteorology and climate, physics, chemistry, biology and marine environment. Hoboken: Wiley & Sons, 1-703.

FENNEL, W., HENTZSCH, B. (Eds.), 2003: Festschrift zum 65. Geburtstag von Wolfgang Matthäus. – Meereswissenschaftliche Berichte, Warnemünde, **54**, 1-80.

FRANCK, H., NEHRING, D., SCHULZ, S., 1972: Ozeanologische Untersuchungen der DDR in der nördlichen Nordsee in den Jahren 1965 bis 1969. - Geodätische und geophysikalische Veröffentlichungen. Berlin, Reihe IV, **8**, 1-81.

FRANCKE, E., BENGELSDORFF, E., BROSIN, H.-J., 1978: Forschungsschiff ”Professor Albrecht Penck”. – Seewirtschaft, **10,** 510-513.

Griesseier, H., 1960: Über die Entwicklung und den gegenwärtigen Stand der Küstenforschung in der Deutschen Demokratischen Republik. – Acta Hydrophysica, **6,** 73-96.

HAGEN, E., 2007: Ozeanische Forschungen. In: HUPFER, P. (Ed)., Klimaforschung in der DDR - ein Rückblick. – Geschichte der Meteorologie in Deutschland, Deutscher Wetterdienst, Offenbach, **8**, 41-49.

HAGEN, E., 2009: Atlantic exploration and climate. In: HUPFER, P., DETHLOFF, K. (Eds.), Selected contributions on results of climate research in East Germany (the former GDR). – Berichte zur Polar- und Meeresforschung, **588**, 80-95.

Helm, R., 1990: Erich Bruns zum 90. Geburtstag. – Deutsche Gesellschaft für Meeresforschung, Mitteilungen, 1990/H. **4**, 24- 25.

HUPFER, P. , BROSIN, H.-J., 1995: In memoriam Klaus Voigt. – Meteorologische Zeitschrift, Neue Folge, **4**, 229.

IOW, 1992: Institut für Ostseeforschung Warnemünde, Dokumentation zur Einweihung, Warnemünde, 28. Februar 1992, 1-26.

IOW, 1997: Institut für Ostseeforschung Warnemünde, Historischer Hintergrund. In: IOW, Aufbaubericht 1992 – 1996. Warnemünde, 9-13.

Lange, D., Niedermeyer, R.-O., Brosin, H.-J., 2011: Beiträge zur meeres- und quartärgeologischen Erforschung der Ostsee und ihrer südlichen Küste in der DDR von 1950 - 1990. – Schriftenreihe für Geowissenschaften (in press).

MATTHÄUS, W., 2001/2002: 50 Jahre Meeresforschung in Warnemünde. –Tidingsbringer – ein Warnemünder Bäderjournal, **6**, 76-79.

MATTHÄUS, W., 2003/2004: Zwei Warnemünder und die Wasserstandsvorhersage für unsere Küste. – Tidingsbringer – ein Warnemünder Bäderjournal, **8**, 65-66.

MATTHÄUS, W., 2004/2005: Warnemünder Forscher überwachen seit fünf Jahrzehnten die Meeresumwelt der Ostsee. – Tidingsbringer – ein Warnemünder Bäderjournal, **9**, 61-64.

MATTHÄUS, W., 2005: 50 Jahre Meeresforschung und Meeresumweltüberwachung in Warnemünde. – Beiträge zur Geschichte Warnemündes, **6**, 10-18.

MATTHÄUS, W., 2005/2006: Klaus Voigt und die Meeresforschung in Warnemünde. – Tidingsbringer – ein Warnemünder Bäderjournal, **10**, 63-65.

MATTHÄUS, W., 2006: The history of investigation of salt water inflows into the Baltic Sea – from the early beginning to recent results. – Meereswissenschaftliche Berichte, Warnemünde, **65**, 1-73.

MATTHÄUS, W., 2006: The investigation of salt water inflows and their effects on the Baltic ecosystem – a historical survey. – Historisch-meereskundliches Jahrbuch, 12, 7-44.

MATTHÄUS, W., 2006/2007: Warnemünde und die Gezeiten der Ozeane. – Tidingsbringer – ein Warnemünder Bäderjournal, **11**, 55-56.

MATTHÄUS, W., 2007: Die Atlantikreise des Forschungsschiffes „Professor Albrecht Penck“ im Jahre 1964 – ein Beitrag zur Erforschung des Äquatorialen Unterstroms im östlichen tropischen Atlantik. – Historisch-meereskundliches Jahrbuch, **13**, 63-94.

MATTHÄUS, W., 2007: Meeresklimatische Schwankungen in der Ostsee. In: HUPFER, P. (Ed)., Klimaforschung in der DDR - ein Rückblick. – Geschichte der Meteorologie in Deutschland, Deutscher Wetterdienst, Offenbach, **8**, 97-101.

MATTHÄUS, W., 2008: The first joint research programme in the Baltic Sea after World War II – the Cooperative Synoptic Investigation in August 1964. – Historisch-meereskundliches Jahrbuch, **14**, 69-100.

MATTHÄUS, W., 2009: Zur Geschichte der Entwicklung ozeanographischer Messtechnik in den Warnemünde Meeresforschungseinrichtungen. – Historisch-meereskundliches Jahrbuch, **15**, 7-52.

MATTHÄUS, W., 2009: Marine climatic variations of the Baltic Sea. In: HUPFER, P., DETHLOFF, K. (Eds.), Selected contributions on results of climate research in East Germany (the former GDR). – Berichte zur Polar- und Meeresforschung, **588**, 173-182.

MATTHÄUS, W., 2010/2011: Ein Warnemünder Forschungsschiff geht in den Ruhestand. – Tidingsbringer – ein Warnemünder Bäderjournal, **15**, 49-51.

MATTHÄUS, W., LANGE, D., 1992: In memoriam GÜNTHER SAGER. – Beiträge zur Meereskunde, Berlin, **63**, 137-138.

MATTHÄUS, W., NEHRING, D., BROSIN, H.-J., HAGEN, E., LASS, H. U., 2008: The history of long-term observations in Warnemünde. In: Feistel, R., Nausch, G., Wasmund, N., State and evolution of the Baltic Sea, 1952 – 2005: A detailed 50-year survey of meteorology and climate, physics, chemistry, biology and marine environment. Wiley & Sons: 45-64.

NEHRING, D., 2002: Auf Forschungsfahrt in der Ostsee und im Atlantik- Erinnerungen eines Ozeanographen. Rostock: Klatschmohn Verlag, 1-311.

SCHRÖDER, K., 1987: Forschungsschiff „Professor Albrecht Penck“ über 35 Jahre im Dienste der Meeresforschung. – Seewirtschaft, **19**, 559-563.

SCHRÖDER, K., 1988: Forschungsschiff „Professor Albrecht Penck“ – 35 Jahre im Dienste der Meeresforschung. – Geodätische und geophysikalische Veröffentlichungen. Berlin, Reihe IV, **43**, 1-21 und 4 Anhänge.

STRIGGOW, K., 1983: 25 Jahre Institut für Meereskunde – Die Entwicklung seines wissenschaftlichen Profils. – Beiträge zur Meereskunde, Berlin, **48**, 5-7.

STRIGGOW, K., 1992: Friedrich Möckel – Laudatio. – Deutsche Gesellschaft für Meeresforschung, Mitteilungen, 1992/H. **1**, 21-24.

STRIGGOW, K., 1992: Laudatio für FRIEDRICH MÖCKEL anläßlich des 72. Geburtstages (24. Oktober 1991). – Beiträge zur Meereskunde, Berlin, **63**, 139-140.

TIMM, W., 1977: Chronik des Instituts für Meereskunde 1960 – 1975. – Unpublished Manuscript, Warnemünde, Band 1- 4.

VOIGT, K., 1987: Bericht über ein Kolloquium zum 65. Geburtstag von Dr. Rudolf Schemainda. – Beiträge zur Meereskunde, Berlin, **57**, 105 - 106.

Wissenschaftsrat, 1991: Stellungnahme zu den außeruniversitären Forschungseinrichtungen in der ehemaligen DDR im Bereich Geo- und Kosmoswissenschaften. Köln, Selbstverlag, 103-124.