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Research at the Biological Station Zingst

Abstract

The Biological Station Zingst was founded in September 1977. Research in the Darß-Zingst Bodden Chain started in the late 1960ies in cooperation with the Maritime Observatory of the Leipzig University. Data recording began with hydrological parameters and meteorology. Nutrients in the water column were added in the early 1980ies. The (at least) monthly cruises along the salinity and trophy gradient are one central component of the monitoring in this lagoon system. The other major activity is the daily sampling of the Zingster Strom as a site of moderate conditions in this lagoon system. Nutrients and abiotic parameters were monitored from 1980 in an equidistant series. Phytoplankton biomass (chlorophyll a) and seston were added in the late 1990ies. Total nitrogen and phosphorus, bacterio-, phyto- and zooplankton are monitored weekly in summer and biweekly in winter at least since the 1990ies. Microbial activities and food web interactions were investigated experimentally – mostly in enclosure experiments. This article summarises the scientific objectives and main results of research based or supported by the Biological Station.

Keywords: inner coastal waters, Southern Baltic, long term ecological research (LTER), mesocosm experiments, eutrophication

1 Introduction

The collectivisation of agricultural production was finished in 1960 in the German Democratic Republic (GDR). The objective of this process was to guarantee the populace' provision with foodstuff in a good quality (EWALD 1968). However, the taken measures involved an intensive industrialisation of agricultural production, i.e. the formation and cultivation of large fields as well as the routine application of mineral fertilisers and crop pesticides (KUHRT et al. 1999). Very late, these measures were re-evaluated and partly cancelled or revoked (HEINZ 2011).

As in all other countries, the intensive use of natural resources led to many problems, which were addressed also in the GDR by the Landeskulturgesetz (1970). Even before that, there was a resolution by the ministerial council to set up a network of measuring stations along the Baltic coast. The objectives were to collect data on primarily hydrological data (ice cover, navigability, water levels), but also on eutrophication indicators (CORRENS & ZÄNGER 1967). Measuring programs by state's agencies as well as research institutions incl. universities were established.

The idea of a field station for teaching came up already in the 1950ies (SCHUMANN et al. 2019). In the early 1970ies, it was decided to build a research and teaching station in Zingst (SCHUMANN 2018). The Darß-Zingst Bodden Chain has a connection to the open Baltic. Zingst is situated in “the middle” of a salinity and eutrophication gradient of this bodden chain (Fig. 1). The station was opened in 1977 and is staffed by 3 persons. Thus, a daily monitoring program could be established. The monthly ship cruises started in the late 1960ies in cooperation with the Maritime Observatory of the University of Leipzig. Measuring campaigns in the field and mesocosm experiments included many more scientists from the institute as well as students.

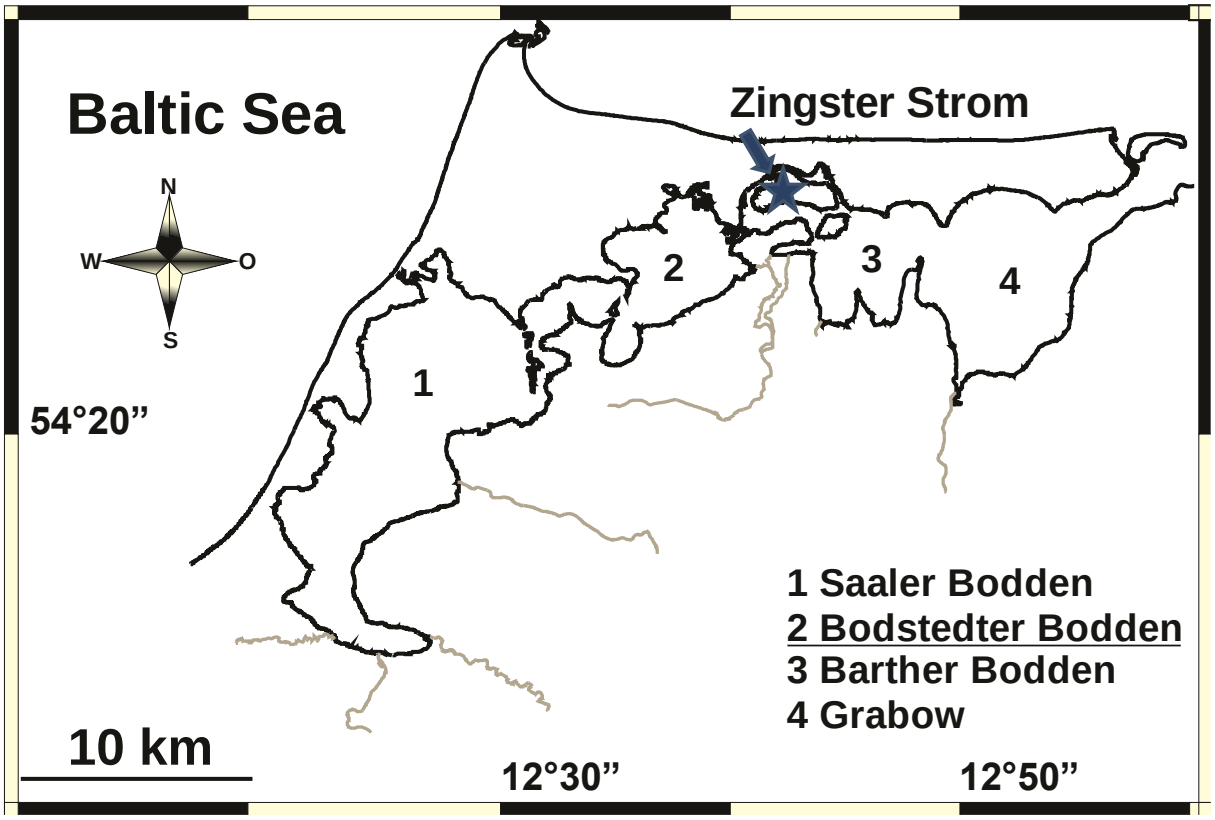

Fig. 1 Map of the Lagoon system: Darß-Zingst Bodden Chain with the site Zingster Strom near the Biological Station Zingst (arrow). Many experiments were conducted in the Kirr Bight formed by the island Kirr (Star).

The general research topics and measures will be described and listed here accompanied by the resulting publications. There will be another publication in a later issue laying out the mesocosm experiments, especially those having taken place after 1990. The technical setup of the latest mesocosm series (ZOOM) is also published in this issue (BERTHOLD 2018).

2 Research topics

Already in the early 1970ies, research topics of coastal lagoon ecology were agreed upon in a structured fashion. All partners were lined up to produce data on biota, element budgets and control factors as well as to quantify matter flows, growth functions, regulation loops etc. The collaborating institutions were the Water

management directorate Coast-Warnow-Peene (WWD, today part of the State Agencies for Environment, Nature Conservation and Geology – LUNG – as well as State Agency for Environment and Agriculture – StALU in Mecklenburg-Western Pomerania), the Maritime Observatory Zingst of the University Leipzig, several working groups of the University of Rostock and the Institute for Marine Research (today Institute of Baltic Sea Research). The overarching goal was to establish a biocybernetic model of the Darß-Zingst Bodden Chain (SCHNESE et al. 1973). Biocybernetics describe the controlling and regulating mechanisms in organisms and ecosystems. Some smaller models were developed, as a biochemical ecosystem model, matter flows and balances, hydrodynamic model and organism's functions (VIETINGHOFF et al. 1979, VIETINGHOFF et al. 1981, VIETINGHOFF et al. 1982 a and b, BRINCKMANN et al. 1981, BRINCKMANN 1982). Later, some balances of matter flows were calculated without modelling (e.g. SCHUMANN 1993, SCHIEWER et al. 1991, SCHIEWER 1994). However, this great goal inspired many experiments and the long-term monitoring. The Biological Station Zingst with its team of 5 permanent co-workers (back then) formed the basis for the complex investigations of the ecology and matter cycles in the Darß-Zingst Bodden Chain (SCHLUNGBAUM 1988 a).

First plans may have been to build a more or less automatically working measuring platform, as it was planned for the WWD (Landesarchiv Greifswald 1966). Data cables and water pipes were laid below the dike between the Zingster Strom (Fig. 1) and the station. For more than 10 years, physical parameters were measured online in the pumped water flow. In the late 1980ies, this so-called "automat-lab" was disassembled. The daily measurements of meteorological, physical and chemical parameters resulted already in a 40 years long equidistant data series (365 days per year, e.g. SCHUMANN et al. 2006, SELIG et al. 2006, Fig. 2A, Fig. 5). A decade later in 2002, *in situ* probes were installed in the Zingster Strom to obtain again physical online data (see above). They were funded by the LUNG and so meteorological and hydrophysical data are available every 10-15 min. Additionally, there are also weekly to biweekly long-term data on plankton organisms available. Zooplankton observations began in 1969. Phytoplankton biomass and composition was investigated from the 1970 with regular monitoring starting in the early 1980ies. In the 1990ies, weekly measurements of total phosphorus and nitrogen began as well as daily chlorophyll *a* and seston determinations.

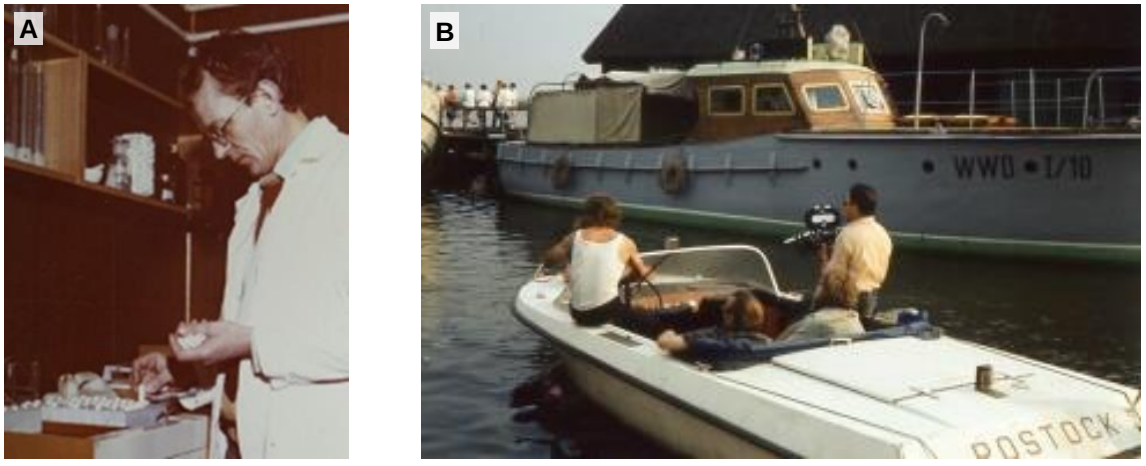

Fig. 2 **A:** Henning Baudler is busy at the first nutrient autoanalyser (Foto: DEWAG). **B:** A film team records the research vessels, which assisted one of the SYNOPTA field campaigns (Foto: provided by H. Baudler).

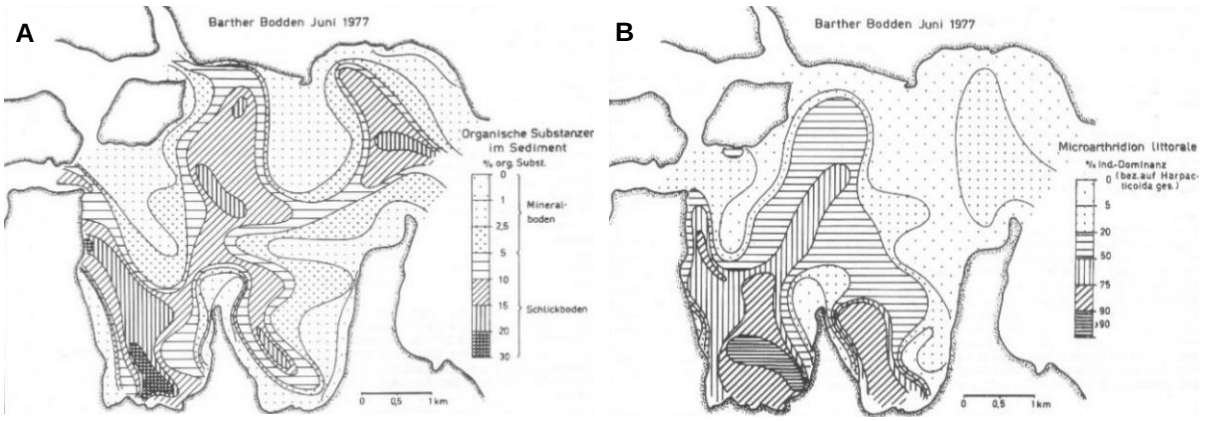

Fig. 3 **A:** Map of the organic contents in sediments of the Barther Bodden (SCHLUNGBAUM et al. 1979). **B:** Map of the benthic harpacticoid copepod *Microarthridion littorale* (same area as in Fig. 3A, ARLT & SCHLUNGBAUM 1979)

1972 and 1979, two extraordinary field campaigns took place: SYNOPTA, which were synoptic sampling events in all bodden basins for water and sediment parameters (e.g. JOST & NAUSCH 1980, Fig. 3A). Many ships of the Maritime Obersvatory and from the WWD supported these campaigns (Atair, Ikarus, Adler, WWD I/10 and 4, Fig. 2B, BAUDLER & HUPFER 2011). The results of these campaigns as well as further sampling events were maps of sediment properties and benthos organisms, which were compiled to sediment atlases (e.g. Figs. 3A and 3B). Many working groups were involved: marine biology, ecology, applied ecology, botany and zoology. The WWD funded also in the following years research on matter and nutrient cycles in respect to eutrophication effects (see below). The related questions were primarily investigated by so called mesocosm or enclosure experiments (e.g. SCHIEWER & JOST 1986, SCHIEWER 1997). From these results, a concept for a coastal waters TGL (Technische Normen, Gütevorschriften und Lieferbedingungen der DDR = technical standards, quality regulations and delivery conditions of the GDR) was compiled, which corresponded to the Western German DIN (SCHLUNGBAUM 1988 b). Both anticipated many aspects of the European Water Framework Directive, which was set in force in 2000.

In the 1990ies, several projects, all initiated by Hendrik Schubert (Ecology), investigated (also) the Darß-Zingst Bodden Chain. The impact of UV radiation on plankton organisms was addressed by UV-MAOR. Main results were data on the underwater light climate and its dynamics and light adaptation of phytoplankton (e.g. SCHUBERT et al. 2003, FORSTER & SCHUBERT 2001). The mechanism of state transition (quick and short term adaptation of the photosynthesis apparatus to changing light) was proven for the first time under natural conditions with phytoplankton of the Darß-Zingst Bodden Chain (SCHUBERT et al. 1997). In the EU-project CHARM, phytoplankton biomass and composition was evaluated as an eutrophication indicator (e.g. SAGERT et al. 2008, RIELING et al. 2003). A whole project series (e.g. ELBO and MAKMO) developed comprehensive bioindication systems for coastal waters (e.g. SCHUBERT et al. 2007, SCHORIES et al. 2005).

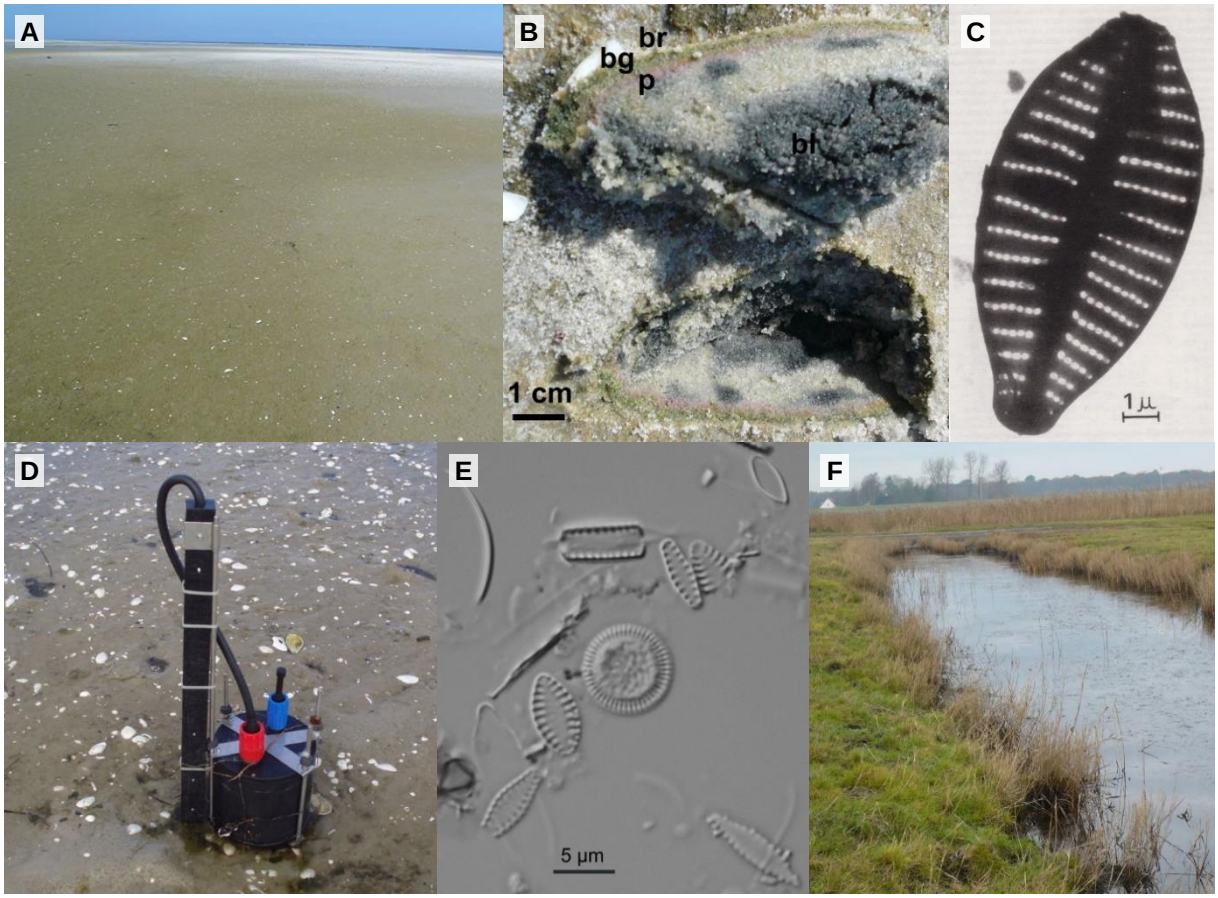

Fig. 4 **A:** Wind flat at the tip of the Zingst peninsula. The darker sediment areas are infested by diatoms as microphytobenthos and most likely by cyanobacteria beneath as well. **B:** Microbial mats forming a vertically structured sediment in the wind flat. br (brown) = diatoms, bg (blue green) = cyanobacteria, p (pink) = purple sulphur bacteria, bl (black) = sulphate reducing bacteria. **C:** *Gomphonema parvulum* (Kütz.) Grun. Diatom from microphytobenthic communities described early in the 1970ies (PODELLECK 1980). **D:** Autonomous water level probe constructed by the working group of "Technical electronics and sensorics". Foto: H. Baudler modified from KARSTEN et al. 2012. **E:** Diatoms inhabiting sand grains are rather small. Foto: K. Kuriyama. **F:** Polder in the Sundische Wiese at the Eastern part of the Zingst peninsula, which will be restructured from 2019 on.

One major joint project with the University of Greifswald investigating matter cycling was ÖKOBOD (funded by the Federal Ministry for Education and Research, 1996-1998). Objectives were to quantify carbon turnover in the water column and sediments, to balance matter exchange between water and sediment and to evaluate the role of the top fluffy sediment layer in this context. Several analytical methods were established in the ecology working groups and at the Biological Station: dissolved and particulate carbon and nitrogen, total protein and free amino acids, total carbohydrates, particle sizes and composition (e.g. SCHUMANN et al. 1998 and 2001, GÖRS et al. 2007). Other more applied projects were: Efficiency of sediment traps, assessment of the Barth harbour modification, several lagoon studies. A more recent study was KEI (short term variability of eutrophication indicators, 2000-2010). The Darß-Zingst Bodden Chain is, moreover, an official study site of the LTER community (Long term ecological research) and the Biological Station serves as its management and provides data for projects and publications. The good data basis of the station made another joint project possible – BACOSA (Baltic Coastal Sea System Analysis), which joins the Universities

of Rostock (and here the Institute of Biosciences and the Agricultural Faculty), Greifswald and Kiel. Main objectives are the estimation of processes in the phosphorus cycle, the impact of submerse macrophytes and reed belts on phosphorus availability to phytoplankton, the structure of food webs and the quantification of ecosystem services.

Since 2000, the wind flat “Bock” at the end of the Zingst Peninsula is also intensively investigated (Fig. 4A). Several diploma and dissertation theses were written about cyanobacterial mats and diatom microphytobenthos (e.g. WITTE 2005, HEYL 2015, Fig. 4B) as well as the hydrological situation of the flat (KARSTEN et al. 2012, Fig. 4D). Investigations on microphytobenthos there and older results (Fig. 4C) are expanded / re-evaluated for the whole Bodden Chain (Fig. 4E). The cooperation with the national park’s authority was intensified, so that new research topics were agreed upon. One project is the observation of nutrient releases after renaturation measures of former grasslands, which is very interesting in the case of the East Zingst area (Sundische Wiese, Fig. 4F), because data from the status before restauration can be recorded.

3 Important Results

Meteorology, hydrography and hydrology: The Darß Zingst Bodden Chain is characterised by a strong and stable gradient of salinity and trophy, which allows studying eutrophication impacts on matter cycles within the same climate zone and even under the same weather conditions. In addition to our own data, we can use meteorological data as well as data on air pollution of the atmosphere measuring station Müggenburg (Federal Environmental Agency) and water balance (inflow, water exchange with the Baltic) by the Federal Maritime and Hydrographic Agency. These data can be combined with our own current data and may serve as the basis for a hydrological model.

Eutrophication: The long term data series and the monthly samplings along the trophy gradient describe the eutrophication until the late years of the 1980ies. Signs of remesotrophication were expected and searched for after certain management measures, like manure storage, treatment and controlled application as well as a general waste water treatment. Changes in the management of liquid manure from the mid 1980ies on (VOIGT 1988) improved at least the phosphate concentrations in the water column strongly (Fig. 5). Nitrogen import into the lagoon system seems to depend more on hydrological parameters (water runoff as river input and as diffuse sources). Further measures since the 1990ies (waste water treatment plants, decreased agricultural land use, national park) did not decrease phytoplankton biomass yet. This very high biomass causes the very low Secchi depth of 30 cm on average (SCHUMANN et al. 2012) and is the most obvious sign of the ecosystem degradation.

Element cycles: The ecosystem understanding was improved and partly changed by various mesocosm experiments and caused an extension of the monitoring program. The flux of phosphates from sediments or the amounts of phosphate as readily available from the sediments seems to be lower than thought before. The before assumed high diffusive release rates from the sediment (e.g. SCHLUNGBAUM 1982, BERGHOFF et al. 2000) may be not as high as thought before (BITSCHOFSKY 2016). However, resuspended sediment particles may even adsorb more phosphate than was released due to their high adsorption capacity

(SCHLUNGBAUM 1982, KARSTENS et al. 2015) also in the oxic water (SELIG et al. 2005). Moreover, an oxic sediment surface layer may hinder phosphate release from the sediments at calm conditions. The water column is almost permanently oxic in this water body and other along the southern Baltic Sea coast (LUNG 2013). The high phytoplankton biomass still has a high nutrient demand (BERTHOLD & SCHUMANN in revision). We base that opinion on the seasonal different phosphate uptake behavior of phytoplankton, i.e. changing supply. Furthermore, apparent growth rates and primary production were low without additional fertilization, at simultaneously high phosphatase activities, low growth rates and primary production without phosphate fertilisation as well as a high phosphatase activity (SCHUMANN et al. 2009). Additionally, zooplankton seems unable to control phytoplankton standing stocks most of the year. If this is caused by the food web structure (top down control) or if potent filter feeders cannot develop due to the brackish conditions (FEIKE & HEERKLOß 2008), is subject of the recent project BACOSA (see above). All in all, the food webs and element cycles seem to be in such a stable state that the ecosystem cannot be easily manipulated to a reduce phytoplankton.

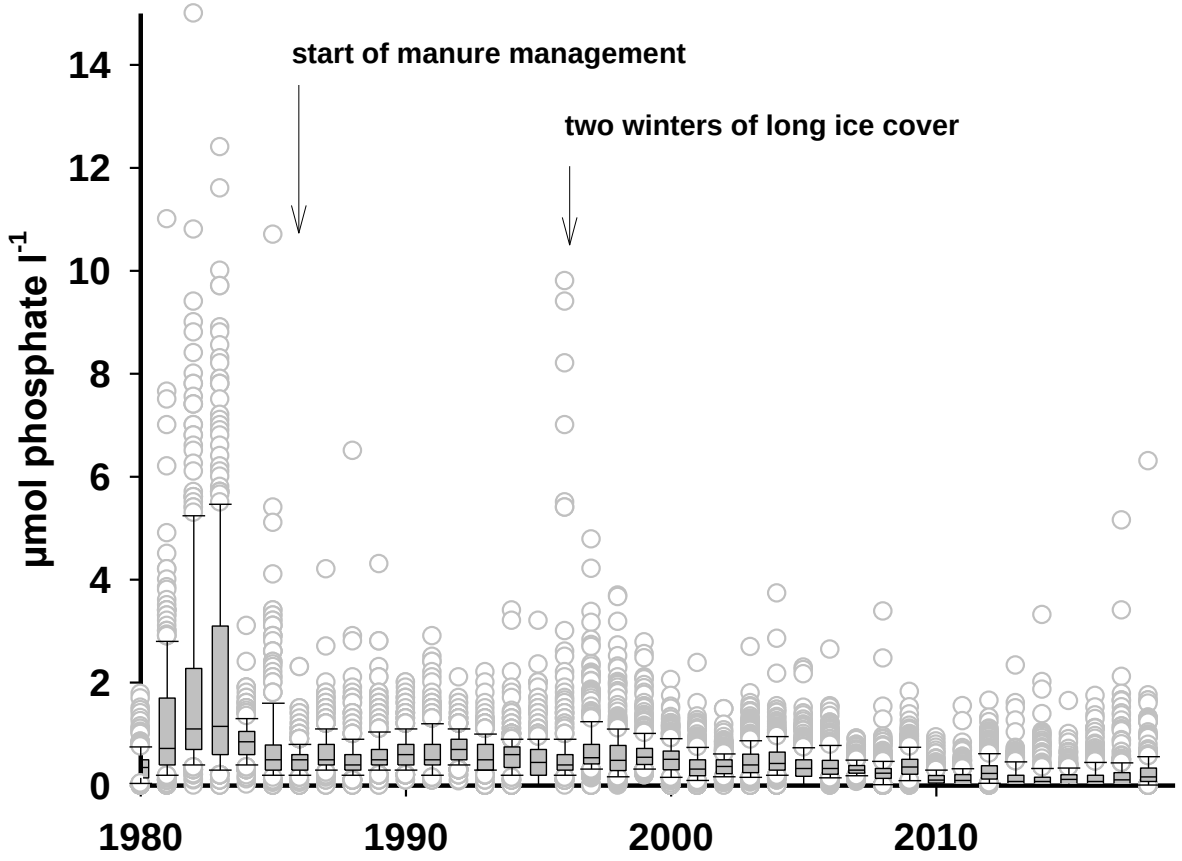

Fig. 5 Box whisker plots of phosphate concentrations (µmol phosphate-P l^{-1}) in the Zingster Strom since 1980 based on daily measurements. Line in box: annual median, box: interquartile distance, whisker: 10 and 90 % percentile. n_{total} = 13890

4 Future plans

In the next future, we plan to provide online retrieved hydrological parameters (water temperature, oxygen saturation, conductivity and pH in the internet. This helps other researchers to plan samplings on an event basis.

Other aims are to unravel matter fluxes from land to sea as well as matter cycling within this eutrohicated lagoon. Additionally, more key players of matter cycling shall be identified: bacteria, protists and larger consumers.

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Projects and initiatives

BACOSA (2013-2019) Baltic Coastal System Analysis and Status Evaluation. Funded by the Federal Ministry of Education and Research

CHARM (2002-2005) Characterisation of the Baltic Sea Ecosystem: Dynamics and Function of Coastal Types. Workpackage 2 and 3: Key indicators and response in relation to typology for phytoplankton and macrophytes, Workpackage 7: Dissemination. European Community

ELBO (2000-2003) Entwicklung von leitbildorientierten Bewertungsgrundlagen für die Übergangsgewässer nach der EU-Wasserrahmenrichtlinie – Übergangsgewässer der deutschen Ostseeküste. Funded by the Federal Ministry of Education and Research

KEI (2000-2010) Untersuchungen zur Kurzzeitvariabilität ausgewählter Eutrophierungsindikatoren im Zingster Strom. Funded by the State Agency for Environment, Nature Conservation and Geology Mecklenburg-Western Pomerania

LTER (ongoing membership in this society) Long-term Ecological Research

MAKMO (2003-2004) Entwicklung eines Monitoringschemas für die Außenbereiche der deutschen Ostseeküste – Makrophytobenthos. Funded by the respective State Agencies of Mecklenburg-Western Pomerania and Schleswig-Holstein.

ÖKOBOD (1996-1998) Ökosystem Boddengewässer - Organismen und Stoffhaushalt. Teilprojekt: Charakterisierung und Klassifizierung von Aggregaten Funded by the Federal Ministry of Education and Research

SYNOPTA (1972 and 1979) Synoptische Aufnahmen von Ökosystemparametern. University of Rostock.

UV-MAOR (1993-1998) UV-Wirkung auf Marine Organismen. Teilprojekt: UV-Wirkung auf Planktonmikroorganismen in eutrophen Flachwassergebieten. Funded by the Federal Ministry of Education and Research

References

Arlt, G. & G. Schlungbaum, 1979. Zur Verbreitung der Meiofauna im Barther Bodden. Meer Beitr Sekt Biol Univ Rostock 7: 507-514

Bachor, A., Carstens, M., Prange, S. & M. von Weber, 2013. Zur Entwicklung und zum Stand der Nährstoffbelastung der Küstengewässer Mecklenburg-Vorpommerns. Berichte zur Gewässergüte, Landesamt für Umwelt, Naturschutz und Geologie Mecklenburg-Vorpommern (LUNG), Güstrow

Baudler, H. & P. Hupfer, 2011. Forschungsschiffe auf dem Bodden. Zingster Strandbote. 20(05): 1-3

Berghoff, S., Schlungbaum, G. & U. Selig, 2000. Phosphorus in sediments from coastal waters of Mecklenburg-Vorpommern (Southern Baltic Sea). In: Flemming B. W., Delafontaine M. T. & G. Liebezeit (eds.) Muddy coast dynamics and resource management. Elsevier Amsterdam: 161-172

Berthold, M., 2018. Take a ZOOM into eutrophication of coastal water bodies – The Zingster Outdoor Benthocosms. Rostock Meerebiol Beitr 28: xx-yy

Berthold, M. & R. Schumann, in revision. Phosphorus dynamics in a eutrophic lagoon: Uptake and utilisation of nutrient pulses by phytoplankton. Front Mar Sci

Bitschofsky, F., 2016. Phosphorus dynamics in sediments of Darß-Zingst Bodden Chain, a eutrophic estuary in the southern Baltic Sea. PhD Thesis University of Rostock

Brinckmann, M., 1982. Weitere Ergebnisse des hydrodynamischen Teilmodells. Meer Beitr Sekt Biol Univ Rostock 10: 89-97

Brinckmann, M., Vietinghoff, U. & W. Schnese, 1981. Ergebnisse der Modellierung der Hydrodynamik des Barther Boddens. Meer Beitr Sekt Biol Univ Rostock 9: 73-78

Correns, M. & Zänger, G.,1967. Hydrologische Verhältnisse und Belastung mit Abwässern der Boddenkette südlich des Darßes und Zingstes. Bericht der Wasserwirtschaftsdirektion Küste – Warnow – Peene

Ewald, G., 1968. Die weitere Durchführung der Beschlüsse des VII. Parteitages der SED zur Steigerung der Produktion und für den schrittweisen Übergang zu industriemäßigen Formen der Leitung und Organisation in der Landwirtschaft und Nahrungsgüterwirtschaft. In: X. Deutscher Bauernkongreß vom 13.-15.06.1968. Protokoll. Staatsverlag Leipzig

Feike, M. & R. Heerkloß, 2008. Long-term stability of the seasonal succession of different zooplankton species in a brackish water lagoon (southern Baltic Sea). Hydrobiologia 611: 17-28

Forster, R. M. & H. Schubert, 2001. The effects of ultraviolet radiation on the planktonic community of a shallow, eutrophic estuary: results of mesocosm experiments. Helgoland Mar Res 55: 23-34

Görs, S., Rentsch, D., Schiewer, U., Karsten, U. & R. Schumann, 2007. Dissolved organic matter along the eutrophication of Darß-Zingst Bodden Chain, Southern Baltic Sea: I. Chemical characterisation and composition. Mar Chem 104: 125-142

Heinz, M., 2011. Von Mähdreschern und Musterdörfern. Industrialisierung der DDR-Landwirtschaft und die Wandlung des ländlichen Lebens am Beispiel der Nordbezirke. Metropol-Verlag

Heyl, K., 2015. Role and function of hydrolytic enzymes for cycling of organic material within microbial mats. PhD Thesis University of Rostock

Jost, G. & G. Nausch, 1980. Zielsetzung und Realisierung der „SYNOPTA ‘79“. Meer Beitr Sekt Biol Univ Rostock 8: 1-4

Karsten, U., Baudler, H., Himmel, B., Jaskulke, R., Ewald, H. & R. Schumann, 2012. Short-term measurements of exposure and inundation of sediment areas in a tide-less wind flat system at the Southern Baltic Sea coast. J Mar Syst 105: 187-193

Karstens, S., Buczko U. & S. Glatzel, 2015. Phosphorus storage and mobilization in coastal Phragmites wetlands: Influence of local-scale hydrodynamics. Est Coast Shelf Sci 164: 124-133

Kuhrt, E., Buck, H F. & G. Holzweißig (Hrsg.), 1999. Die Endzeit der DDR-Wirtschaft. Analysen zur Wirtschafts-, Sozial- und Umweltpolitik. Springer-Verlag

Landesamt für Kultur und Denkmalpflege, Landesarchiv Greifswald (1966) Amt für Wasserwirtschaft beim Ministerrat der DDR: Konzeption zum Ausbau eines Netzes küstenhydrologischer (ozeanologischer) Stationen.

Landeskulturgesetz, 1970. Gesetz über die planmäßige Gestaltung der sozialistischen Landeskultur in der Deutschen Demokratischen Republik - Landeskulturgesetz -. Gesetzblatt der Deutschen Demokratischen Republik. Berlin. Teil I Nr. 12. 28.05.1970

Podelleck, R., 1980. Saprobiologische Untersuchungen in der Ribnitzer See. Meer Beitr Sekt Biol Univ Rostock 8: 103-105

Rieling, T., Sagert, S., Bahnwart, M., Selig, U. & H. Schubert, 2003. Definition of seasonal phytoplankton events for analysis of long-term data from coastal waters of the Southern Baltic Sea with respect to the requirements of the European Water Framework Directive. Water Pollution 6: 103-113

Sagert, S., Selig, U. & H. Schubert, 2008. Phytoplanktonindikatoren zur ökologischen Klassifizierung der deutschen Küstengewässer der Ostsee. Rostock Meeresbiol Beitr 20: 45–69

Schiewer, U., 1994. Regulationsmechanismen und Wechselwirkungen zwischen Pelagial und Benthal. Rostock Meeresbiol Beitr 2: 179–190

Schiewer, U., 1997. Design, experiences and selected results of meso- and microcosm experiments in shallow coastal waters 1981/95. Rostock Meeresbiol Beitr 5: 37–52

Schiewer, U. & G. Jost, 1986. Ecosystem research during the 1981/85 period in the Darss-Zingst estuary. Meer Beitr Sekt Biol Univ Rostock 14: 28-36

Schiewer, U., Schumann, R., Jost, G. & C. Sievert, 1991. Microbial food web dynamics in tideless eutrophic estuaries of the Baltic Sea. Kieler Meeresforschungen. Sonderheft 8: 20-28

Schlungbaum, G., 1982. Sediment chemical investigations in the coastal waters of the German Democratic Republic. 10. The role of the matter exchange processes at the sediment water contact zone of eutrophic shallow waters and possibilities of investigating by the example of the phosphate cycle - A survey by the example of the Darss-Zingst Bodden Chain. Acta Hydrochim Hydrobiol 10: 119-134

Schlungbaum, G., 1988 a. 10 Jahre Laborstation Zingst der Sektion Biologie der Wilhelm-Pieck-Universität Rostock – ein Überblick zur Entwicklung der Station für Aufgaben in der Forschung, der Lehre und der Weiterbildung sowie für volkswirtschaftliche Entscheidungen. Meer Beitr Sekt Biol Univ Rostock 16: 3-5

Schlungbaum, G., 1988 b. Der Entwurf einer Küstengewässer-TGL – ein Ergebnis komplexer ökologischer Forschung der Sektion Biologie und ihrer Kooperationspartner. Meer Beitr Sekt Biol Univ Rostock 16: 18-24

Schlungbaum, G., Nausch, G. & S. Stolle, 1979. Sedimentchemische Untersuchungen in Küstengewässern der DDR. VIII. Spezielle Untersuchungen zur Verteilung von Phosphaten und Eisenverbindungen in der Sedimentoberflächenschicht des Barther Boddens. Meer Beitr Sekt Biol Univ Rostock 7: 499-505

Schnese, W., Schlungbaum, G. & O. Miehlke, 1973. Zu Aspekten der Küstengewässerforschung der DDR, unter besonderer Berücksichtigung der Aufgaben der Sektion Biologie der Universität Rostock und ihrem Zusammenwirken mit den Kooperationspartnern. Meer Beitr Sekt Biol Univ Rostock 2: 1057-1065

Schories, D., Selig, U., Jegzentis, K. & H. Schubert, 2005. Klassifizierung der äußeren Küstengewässer an der deutschen Ostseeküste nach der Europäischen-Wasserrahmenrichtlinie anhand von Makrophyten – Eine Zwischenbilanz. Rostock Meeresbiol Beitr 14: 135–150

Schubert, H., Matthijs, H. C. P. & R. M. Forster, 1997. Occurrence of complementary chromatic adaptation in a eutrophic estuary. The Phycologist 46: 28

Schubert, H., Schlüter, L. & P. Feuerpfeil, 2003. The underwater light climate of a shallow baltic estuary – ecophysiological consequences. ICES Coop Res Rep 257: 29-37

Schubert, H., Schubert, M. & J. C. Krause, 2007. Reconstruction of XIXth century submerged vegetation of coastal lagoons of the German Baltic Sea. Jura ir Aplinka 14: 16-27

Schumann, R., 1993. Zur Rolle des Pico- und Nanophytoplanktons im mikrobiellen Nahrungsgefüge der Darß-Zingster Boddenkette. PhD Thesis University of Rostock

Schumann, R., Baudler, H., Glass, Ä., Dümcke, K. & U. Karsten, 2006. Hydrography of the inner coastal water Darß Zingster Bodden chain (Southern Baltic Coast). J Mar Syst 60: 330-344

Schumann, R. Krause, I. & H. Baudler, 2019. Biologische Station Zingst und die aquatischen Wissenschaften an der Universität Rostock. 279-317. In: Friedrich, G. & Kosmac U. (Hrsg.) Geschichte der Limnologischen Stationen in Deutschland. Im Auftrag der Deutschen Gesellschaft für Limnologie e.V., E. Schweizerbart Stuttgart

Schumann, R., Rentsch, D., Görs, S. & U. Schiewer, 2001. Seston particles along a eutrophication gradient in coastal waters of the Southern Baltic Sea: significance of detritus and transparent mucoid material. Mar Ecol Progr Ser 218: 17-31

Schumann, R. & D. Rentsch, 1998. Staining particulate organic matter with DTAF- a fluorescence dye for carbohydrates and protein: a new approach and application of a 2D image analysis system. Mar Ecol Progr Ser 163: 77-88

Schumann, R., Schoor, A. & H. Schubert, 2009. Fine resolution of primary production and its limitation in phytoplankton communities of the Darss-Zingst Bodden Chain, a coastal lagoon of the Southern Baltic Sea. Baltic Coastal Zone 13: 97-125

Schumann, R., Wulff, R., Reiff, V., Baudler, H., Feike, M., Marquardt, R. & N. Liebeke, 2012. Untersuchungen zur Kurzzeitvariabilität ausgewählter Eutrophierungsindikatoren im Zingster Strom (KEI). Bericht an das Landesamt für Umwelt, Naturschutz und Geologie MV (LUNG)

Selig, U., Baudler, H., Krech, M. & G. Nausch, 2006. Nutrient accumulation and nutrient retention in coastal waters - 30 years investigation in the Darss-Zingst Bodden chain. Acta Hydrochim Hydrobiol 34: 9-19

Selig, U., Berghoff, S., Schlungbaum, G. & H. Schubert, 2005. Variation in sediment phosphate along an estuarine salinity gradient on the Baltic Sea. In: SERRANO, L. & H. L. GOLTERMAN (eds.) Phosphate in sediments. Backhuys Publishers: 185-194.

Vietinghoff, U., Ballin, G., Jost, G., Hubert, M. L. & W. Schnese, 1981. Ein mathematisches Teilmodell der Rolle der Mikroorganismen im Wasserkörper des Ökosystems Barther Bodden. Meer Beitr Sekt Biol Univ Rostock 9: 53-61

Vietinghoff, U., Hubert, M.-L. & W. Schnese, 1979. Die mathematische Modellierung der Sukzession von Kiesel-, Grün- und Blaualgen in einem flachen, eutrophen Brackwasser-Bodden. Meer Beitr Sekt Biol Univ Rostock 7: 477-485

Vietinghoff, U., Scharf, E.-M., Hubert, M.-L. & W. Schnese, 1982 b. Ein mathematisches Teilmodell des Kompartimentes Prozoa-Ciliata im Benthos des Ökosystems Barther Bodden. Meer Beitr Sekt Biol Univ Rostock 10: 79-87

Vietinghoff, U., Westphal, H., Hubert, M.-L. & W. Schnese, 1982 a. Ein mathematisches Modell für das Kompartiment der benthischen Bakterien des Ökosystems Barther Bodden. Meer Beitr Sekt Biol Univ Rostock 10: 75-78

Voigt, B., 1988. Aspekte der volkswirtschaftlichen Nutzung der Boddenlandschaft und Erfordernisse ihres Schutzes und ihrer Pflege. Natur und Umwelt 13: 13-18

Witte, K., 2005. Untersuchungen zur Entwicklung von Ökotypen in dem Cyanobakterium *Microcoleus chthonoplastes* entlang des Salinitätsgradienten der Ostsee. PhD Thesis University of Rostock