



Universidade do Algarve

Population dynamics of benthic foraminifera in the
intertidal mudflat of Northern Germany

Simon Masche

Tese para obtenção do Grau de Mestre em Biologia Marinha

Trabalho efetuado sob a orientação de:

(Alfred Wegener Institute):

Prof. Dr. Jelle Bijma

Dr. Markus Raitzsch

(Universidade do Algarve):

Dr. Isabel Mendes



Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

Population dynamics of benthic foraminifera in the intertidal mudflat of Northern Germany

Simon Masche

Tese para obtenção do Grau de Mestre em Biologia Marinha

Trabalho efetuado sob a orientação de:

(Alfred Wegener Institute):

Prof. Dr. Jelle Bijma

Dr. Markus Raitzsch

(Universidade do Algarve):

Dr. Isabel Mendes

2012

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

Population dynamics of benthic foraminifera in the intertidal mudflat of Northern Germany

Declaration of authorship of work

I hereby declare, as the author of this work, that it is original and unpublished. Authors and works consulted are properly cited in the text and included in the list of references.

Declaro ser o autor deste trabalho, que é original e inédito. Autores e trabalhos consultados estão devidamente citados no texto e constam da listagem de referências incluída.

Copyright

The University of Algarve has the right, perpetual and without geographical boundaries, to file and publicize this work through printed copies reproduced on paper or digital form, or by any other means known or hereafter invented. It is allowed to distribute your work for promotion through scientific repositories and for educational purposes or research, not commercial, as long as credit is given to the author and publisher.

A Universidade do Algarve tem o direito, perpétuo e sem limites geográficos, de arquivar e publicitar este trabalho através de exemplares impressos reproduzidos em papel ou de forma digital, ou por qualquer outro meio conhecido ou que venha a ser inventado, de o divulgar através de repositórios científicos e de admitir a sua cópia e distribuição com objetivos educacionais ou de investigação, não comerciais, desde que seja dado crédito ao autor e editor.

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

ABSTRACT

The population dynamics of benthic foraminifera from the intertidal mudflat near Dorum-Neufeld in Northern Germany was examined. The study covered the period from September 2011 – July 2012. Biweekly, sediment samples were taken from four spatially distributed sites covering an area of approximately 100,000 m² in the mudflat. Three benthic species are known to dominate the foraminifer population in the study area: *Ammonia aomoriensis* (Asano, 1951), *Haynesina germanica* (Ehrenberg, 1840) and *Elphidium williamsoni* (Haynes, 1973). The aim of this study is to obtain a long-term overview of the population dynamics of the three species and to gain information on the reproduction period for each species, thus providing constraints for optimizing sampling strategies for laboratory cultures. Coexistence and competition for resources among the three dominant foraminifer species in the benthic realm is analyzed.

The very high abundance of living foraminifers in the mudflat in May and June with a maximum in May for both *A. aomoriensis* and *H. germanica* is observed. The fact that the higher abundance, starting in March and declining in June, is observed at all four sampling locations substantiates this finding. The population dynamics in the intertidal mud flats of Dorum-Neufeld has not been systematically analyzed before and now confirms assumptions previously derived from observations in laboratory stock cultures.

In contrast, *E. williamsoni* has a completely different lifecycle than *A. aomoriensis* and *H. germanica* with higher reproduction in colder months between September and March. It is present throughout the year and distributed patchier in all stations.

The most appropriate time for sampling foraminifers for culture experiments is between May and June for *A. aomoriensis* and *H. germanica* and from September until March for *E. williamsoni*.

The abundance of *E. williamsoni* does not show a peak during May and June like *A. aomoriensis* and *H. germanica*, but exhibits the highest abundance during winter

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

months. This means that either *E. williamsoni* competes with *A. aomoriensis* and *H. germanica* or that a colder climate favors the reproduction of *E. williamsoni*. In contrast, the similar abundance peak of *A. aomoriensis* and *H. germanica* suggests that these species coexist without competing with each other, maybe due to the use of different food sources.

Haynesina germanica and *E. williamsoni* are both cleptoplasts, they are able to use diatom chloroplasts for photosynthesis. This adaptation might grant these two species an ecological niche alongside *A. aomoriensis* in the intertidal mudflat ecosystem.

The sediments from Dorum that exclusively consist out of muddy, non-cohesive silt to fine sand plays a role in the relatively high Foraminifer densities, but very low species richness.

In this study, regarding to temperature reconstruction with the help of fossil Foraminifera, the calculated average temperature is $\sim 10^{\circ}$ C higher, than the measured average temperature which shows that population dynamics have a significant influence on possible temperature reconstructions with proxy signals (e. g. Mg/Ca).

Keywords: benthic foraminifera, *Ammonia aomoriensis*, *Haynesina germanica*, *Elphidium williamsoni*, population dynamics

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

RESUMO

A presente tese de Mestrado examinará a dinâmica populacional de foraminíferos bentônicos, numa zona intertidal lodosa, próxima de Dorum-Neufeld, no norte da Alemanha.

Os foraminíferos bentônicos são Protistas comuns, que habitam quase todos os ambientes bentônicos. Apesar da sua distribuição ubíqua são biologicamente versáteis. A sua distribuição e abundância são influenciadas por parâmetros físicos, químicos e biológicos, o que os transforma em excelentes ferramentas para interpretações ecológicas e ambientais. Possuem ainda um potencial de preservação excelente no registo fóssil, podendo fornecer informações credíveis para compreender as alterações em ambientes marinhos, ocorridos no passado histórico e geológico.

O estudo da dinâmica populacional preenche a lacuna entre as características individuais de um organismo na população e a dinâmica da população como um todo. Esta ciência tem a função investigar as alterações ocorridas nas populações em termos de tamanho e composição etária, a curto e longo prazo, fornecendo deste modo bases para futuros estudos.

O objetivo desta investigação é a obtenção a médio-termo, da dinâmica populacional de três espécies de foraminíferos bentônicos. Pretende-se ainda obter informações sobre o período reprodutivo de cada espécie, no sentido de restringir os períodos ideais de amostragem, de modo a proceder à colheita de espécimes para cultura em laboratório. Serão ainda analisadas, a coexistência e competição entre as três espécies de foraminíferos bentônicos dominantes neste ambiente.

A amostragem para a realização deste estudo decorreu entre Setembro de 2011 e Julho de 2012. Bimensalmente, amostras de sedimento superficiais foram colhidas em quatro locais, espacialmente distribuídos na planície lodosa próxima de Dorum-Neufeld, cobrindo uma área aproximada de 100.000 m². Serão analisadas três espécies de

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

foraminíferos bentônicos, que são já conhecidas por dominar a população na área de estudo, nomeadamente: *Ammonia aomoriensis*, *Haynesina germanica* e *Elphidium williamsoni*.

Os valores de abundância mais significativos de foraminíferos vivos, na planície lodosa, ocorreram entre Maio e Junho, para as espécies *A. aomoriensis* e *H. germanica*. Este resultado mostra sem ambiguidade, que estas espécies apresentam o seu período de maior reprodução durante estes dois meses. Este resultado é ainda reforçado pelo aumento de abundância destas espécies, que se inicia em Março e diminui em Junho, em todos os locais de amostragem.

As maiores abundâncias de foraminíferos observadas em Maio e Junho podem estar relacionadas com o aumento de alimento disponível, nomeadamente forte aumento de fitoplâncton durante a primavera ou aumento das descargas de água-doce. Deve notar-se, contudo, que a classe de tamanho inferior, entre 90-125 μm (considerada a fração juvenil dos foraminíferos), possui o seu pico reprodutivo em Maio em todas as estações, e após este período a sua abundância decresce, ao passo que na classe de tamanho seguinte (125-250 μm) o maior pico de abundância se prolonga por mais tempo. Em alguns casos, o pico de abundância da classe de tamanho 125-250 μm começa logo após o pico de abundância dos juvenis. Estes dois eventos estão possivelmente relacionados com o crescimento dos juvenis, que são posteriormente adicionados à fração de tamanho maior (125-250 μm). Em culturas de laboratório das espécies de *A. aomoriensis* e *H. germanica* realizadas no Instituto Alfred Wegener (Alemanha), o conhecimento prático demonstrou que os foraminíferos juvenis conseguem num dia construir uma nova câmara da sua carapaça. Esta informação pode permitir determinar o momento exato de maior reprodução, através do cálculo do número de câmaras existentes num foraminífero juvenil, por exemplo, um foraminífero com 10 câmaras era um juvenil à 10-20 dias atrás.

Elphidium williamsoni possui um ciclo de vida completamente diferente das espécies *A. aomoriensis* e da *H. germanica*. Esta espécie apresentou as maiores abundâncias nos

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

meses mais frios, entre Setembro e Março, no entanto, ocorreu durante todo o ano, apresentando variações de abundância em todas as estações analisadas.

O melhor período do ano para amostragem de foraminíferos para cultura em laboratório é entre Maio e Junho para as espécies *A. aomoriensis* e *H. germanica*, e entre Setembro e Março para a espécie *E. williamsoni*.

Em termos de competição e coexistência, *E. williamsoni* não apresenta aumento significativo de abundância durante os meses de Maio e Junho, como se verificou para as espécies *A. aomoriensis* e *H. germanica*. Isto poderá indicar que *E. williamsoni* compete diretamente com *A. aomoriensis* e *H. germanica* ou que o clima mais frio favorece a sua reprodução. Por outro lado, os picos de abundância similares apresentados por *A. aomoriensis* e *H. germanica* sugerem que estas espécies coexistem no mesmo ambiente não havendo competição entre elas, talvez devido ao uso de diferentes tipos de alimento.

A influência do tamanho dos grãos de sedimento na densidade e na diversidade das associações de foraminíferos continua a ser controverso. Tipicamente, num ambiente com correntes fortes os sedimentos são mais grosseiros, enquanto correntes mais fracas permitem a sedimentação de material mais fino. Uma grande amplitude da maré em zonas de planície lodosa pode também ser considerada um importante fator limitante, devido à energia variável que controla a sedimentação, resultando na deposição de sedimentos finos em cima de sedimentos mais grosseiros. O que está de acordo com os sedimentos superficiais da planície lodosa de Dorum, que é composta por sedimentos lodosos não coesivos a areia fina. Baseado nas observações de densidade e diversidade das associações de foraminíferos bentônicos, pode ser assumido que substratos grosseiros (silte + argila <12-13%) favorecem o estabelecimento dos foraminíferos epifaunais. Outros estudos, no entanto, revelam que quer a densidade quer a riqueza específica estão claramente relacionados com o tamanho dos grãos de sedimento: quanto maior for o grão, menor a densidade e a riqueza específica e vice-versa. Os resultados obtidos neste estudo revelaram ser diferentes. A densidade de foraminíferos

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

bentônicos é relativamente elevada, mas a riqueza específica é muito baixa. Apenas três espécies de foraminíferos bentônicos ocorrem na planície lodosa de Dorum. Isto poderá estar relacionado com as severas condições físicas de hidrodinâmica que apenas permitem a sobrevivência e desenvolvimento de espécies muito tolerantes.

Isto poderá explicar a existência de *H. germanica* num ambiente fisicamente controlado como a planície lodosa de Dorum, onde existe uma elevada turbulência hidrodinâmica. Outra explicação poderá estar relacionada com o facto de a *H. germanica* e o *E. williamsoni* serem cleptoplásticos, isto é, são capazes de usar cloroplastos de diatomáceas para fazer fotossíntese. Esta adaptação poderá conceder a estas duas espécies um nicho ecológico em paralelo com a *A. aomoriensis* no ecossistema da planície lodosa.

Quando são efetuadas reconstruções de temperatura com base em foraminíferos fósseis (ex. Mg/Ca), a dinâmica de populações poderá ter uma influência significativa nos valores obtidos. O sinal do registo geoquímico é obtido, normalmente, a partir do registo químico total, que representa a média de crescimento de numerosos indivíduos durante diferentes períodos, isto sob a influência de diferentes condições ambientais. No entanto, o registo obtido é um sinal médio que não tem em conta as variações sazonais de abundância. Quando são investigados foraminíferos fósseis, para a maior parte das espécies, não é conhecido o seu pico de abundância durante o ano.

Neste estudo, o cálculo da temperatura média (23.4°C) é aproximadamente 10°C superior ao valor de temperatura média registado para esta área, que é de 13.4°C. O que vem demonstrar que é importante conhecer as variações populacionais dos foraminíferos, de modo a melhorar e compreender os indicadores (*proxies*) geoquímicos, assim como a sua fiabilidade e limitação.

A dinâmica populacional na planície lodosa de Dorum-Neufeld nunca tinha sido analisada de uma forma sistemática, confirmando com este estudo os pressupostos anteriormente assumidos com base em observações realizadas em cultura de laboratório.

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

Palavras-chave: Foraminíferos bentônicos, *Ammonia aomoriensis*, *Haynesina germanica*, *Elphidium williamsoni*, dinâmica de populações

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

Acknowledgments

I would like to express my gratitude to my supervisors Prof. Dr. Jelle Bijma and Dr. Markus Raitzsch for the useful comments, remarks and engagement through the learning process of this master thesis. This master thesis would not have been possible without the guidance and the outstanding help of my Portuguese supervisor Dr. Isabel Mendes. I also want to thank my family and my girlfriend for their loving and devoted support.

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

Table of Contents

ABSTRACT	4
RESUMO	6
Acknowledgments	11
List of Figures	14
GENERAL INTRODUCTION	16
<u>Goals:</u>	18
<u>Ocean Acidification</u>	19
<u>Study area</u>	22
MATERIALS AND METHODS	24
<u>Sampling sites and sample collection</u>	24
<u>Sample preparation</u>	28
<u>Speciation</u>	31
<u>Classification and Phylogeny</u>	34
<u>Reproduction</u>	36
<u>Residual calculations</u>	38
<u>Mg/Ca temperature calculation</u>	39
RESULTS	41
<u>Total abundance of foraminifers</u>	41
<u>Size fractions</u>	43
<u>Temporal variation of foraminifers</u>	44
<u>Residuals</u>	54

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

DISCUSSION	59
GLOSSARY.....	66
REFERENCES.....	68
SUPPLEMENTAL MATERIAL	75
<u>Excel table with original data:</u>	75
<u>Excel table with Residual data:</u>	86

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

List of Figures

Figure 1: A. Bjerrum plot for inorganic carbon species (Zeebe and Wolf-Gladrow, 2001). B. Carbonate chemistry (Bijma and Burhop, 2010)..... 20

Figure 2: Sampling locations (sites 1-9) in the intertidal mudflat near Dorum-Neufeld, Northern Germany (N 53° 44', E 08° 30'). Stations 1, 6, 8 and 9 (yellow mark) were continuously sampled. Stations 2, 3, 4, 5, 7 only during September - December 2011..... 24

Figure 3: Sampling at Site 1 during low tide, close to a tidal flat channel. 25

Figure 4: Surface sediment collection (~0.5 to 1 cm)..... 26

Figure 5: Total number per cm³ of living and dead *A. aomoriensis*, *H. germanica* and *E. williamsoni*. 27

Figure 6: Removing macrofauna, silt, clay and excess Rose Bengal. 28

Figure 7: Sediment samples mixed with Sodium Polytungstate..... 29

Figure 8: Stained foraminifers floating on top of the Sodium Polytungstate solution. 30

Figure 9: Electron micrographs of: *E. williamsoni* (left) (in Hayward et al., 1997), *H. germanica* (2nd from left) (in Banner and Culver, 1978), and *A. aomoriensis* T6 (umbilical view, 2nd from right and spiral view, right) (in Hayward et al., 2004). Scale bar is 100 μm..... 31

Figure 10: Live shots of: *E. williamsoni* (left) (in Austin, 2001), *H. germanica* (middle) (in Goldstein, 2006), and *A. aomoriensis* T6 (right) (in Dissard et al., 2010). Scale bar is 100 μm if not labeled. 31

Figure 11: Elphidiids rDNA phylogeny and content of kleptochloroplasts per individual per species (Pillet et al., 2010). Each pie represents a single individual; they are shown by morphospecies horizontally and by sampling location vertically, Chezzetcook Inlet (Ch In), Trebeurden (Trb), Roscoff (Rosc) and others..... 33

Figure 12: Foraminiferal suborders and phylogeny. Redrawn from Tappan and Loeblich (1988). 35

Figure 13: Generalized foraminifera life cycle. Redrawn from Goldstein (1999). 37

Figure 14: Total numbers of individual foraminifers per cm³ for each species from September to July at Station 1. Living and dead foraminifers are shown in red and black, respectively. 46

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

Figure 15: Total numbers of individual foraminifers per cm ³ for each species from September to July at Station 6. Living and dead foraminifers are shown in red and black, respectively.	47
Figure 16: Total numbers of individual foraminifers per cm ³ for each species from September to July at Station 8. Living and dead foraminifers are shown in red and black, respectively.	48
Figure 17: Total numbers of individual foraminifers per cm ³ for each species from September to July at Station 9. Living and dead foraminifers are shown in red and black, respectively.	49
Figure 18: Foraminifer abundance in four different size classes from station 1. Only living individuals are shown.....	50
Figure 19: Foraminifer abundance in four different size classes from station 6. Only living individuals are shown.....	51
Figure 20: Foraminifer abundance in four different size classes from station 8. Only living individuals are shown.....	52
Figure 21: Foraminifer abundance in four different size classes from station 9. Only living individuals are shown.....	53
Figure 22: Residuals of <i>A. aomoriensis</i> . Left side shows all sampling dates and sampling day. Right side bar shows percentage deviation from the mean relative abundance.	56
Figure 23: Residuals of <i>H. germanica</i> . Left side shows all sampling dates and sampling day. Right side bar shows percentage deviation from the mean relative abundance.	57
Figure 24: Residuals of <i>E. williamsoni</i> . Left side shows all sampling dates and sampling day. Right side bar shows percentage deviation from the mean relative abundance.	58
Figure 25: Measured temperature and salinity over the sampling period.....	62

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

GENERAL INTRODUCTION

Benthic foraminifera are common marine protozoa inhabiting almost all benthic environments. Formerly, benthic foraminifera were considered to occupy only the sediment surface and the top centimeters of the sediment, but later they were found also to inhabit deeper sediment layers (Jorissen, 1999). Benthic foraminifera are capable of vertical migration (Severin and Erskian, 1981; Moodly et al., 1998). The upper layers of sediment are usually well oxygenated, thus vertical migration is an excellent adaptation to escape temporary environmental changes such as severe anoxia, since the sediment surface is the last microhabitat to turn chemically hostile and the first to be re-oxygenated (Duijnsteet et al., 2003). Under conditions of experimental bottom-water anoxia, typical shallow living foraminiferal taxa reside almost exclusively in the top 5 mm of the sediment, whereas they live deeper in the sediment (and reach a density maximum between 5 and 10mm) when the bottom-water is oxygenated (Duijnsteet et al., 2003).

Despite their ubiquity in the marine realm (e.g. Murray, 1991), their biological versatility (e.g. Lipps, 1983), and their importance in the carbon cycle (e.g. Gooday et al., 1992; Graf, 1992; Moodley et al., 1998), modern benthic foraminifera have been seriously neglected by biologists. This lack of attention is compensated for by their popularity among paleontologists. The calcareous and agglutinated tests that foraminifera produce have a high potential to fossilize such that they are very abundant in old marine sediments. Some are found in deposits dating back to Cambrian times (e.g. Culver, 1991).

The calcareous tests of foraminifera are susceptible to dissolution in calcite undersaturated waters due to decreasing water pH (ocean acidification), which makes them an important group to study the effects of ocean acidification. During the Paleocene-Eocene, $\sim 2000 \times 10^9$ metric tons of carbon were rapidly released in form of methane, which lowered the ocean pH and led to an increase in ocean temperature.

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

During the Paleocene-Eocene thermal maximum (PETM), sea surface temperature rose by 5°C in the tropics and as much as 9°C at high latitudes (Zachos et al., 2005), which contributed to the mass extinction of benthic foraminifera at the P-E boundary.

Because of their excellent preservation potential, fossil foraminiferal shells are used for paleoenvironmental reconstructions in the marine realm (e.g. Duijnsteet et al., 2003). For instance, paleoecological transfer functions are empirically derived equations for quantitatively estimating past atmospheric or oceanic conditions. The relationships represented in these functions are based on the spatial correlations between modern climate data and Foraminifera (assemblages and shape diversity), which are used as calibration sets (Sachs et al., 1977). Paleoenvironmental reconstructions also use geochemical composition of tests and include, among others, the Mg/Ca ratio as a recorder of bottom-water temperature (e.g. Martin et al., 2002), B/Ca as a proxy for the calcite saturation state (e.g. Yu and Elderfield, 2007), the boron isotopic composition as a pH proxy (e.g. Hönisch et al., 2008), and the stable isotopes of oxygen and carbon that are used to reconstruct past changes in sea level, temperature, carbon cycle and marine productivity (e.g. Zachos et al., 2001).

However the exact calcification mechanisms and secondary factors influencing the minor and trace metal incorporation into shell calcite are largely unknown. Another source of uncertainty when developing or applying proxies using shells from sediments is the lack of knowledge about foraminiferal population dynamics. The recorded geochemical signal is usually derived from bulk chemistry, which displays an average of numerous individuals grown at different times and thus under different environmental conditions. Consequently, the record is an averaged signal that obliterates seasonal changes in abundance. For this reason, it is important to gain knowledge about foraminiferal population variations to improve our understanding of geochemical proxies as well as their reliability and limitation.

The study of population dynamics bridges the gap between the characteristics of individual organisms in a population and the dynamics of the total population as a

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

whole. Individuals in biological populations differ with regard to their physical and behavioral characteristics and therefore in the way they interact with their environment (Cushing, 1998). The science of population dynamics has the task to investigate the short and long term changes in size and age composition of populations, thus providing a baseline for future studies such as to investigate the impact of Ocean Acidification on foraminiferal population structure.

Three benthic species, which will be examined in this study, have been identified to be the only calcareous foraminifers that populate in the intertidal mudflat of Dorum-Neufeld: *Elphidium williamsoni* (Haynes, 1973), *Ammonia aomoriensis* (Asano, 1951) and *Haynesina germanica* (Ehrenberg, 1840). The foraminifer sampling is carried out approximately biweekly, and the obtained time series data cover the period from September 2011 to July 2012. The present study is limited to this period, but the study will be extended beyond the deadline of this Master thesis to finally span approximately 1 ½ years (November 2011 – July 2013).

Shallow-water species such as *A. aomoriensis* are also often used for culturing studies because most deep-sea foraminifers are unable to survive under laboratory conditions, which is probably due to the pressure differences between natural habitat and laboratory. At the Alfred Wegener Institute for Polar and Marine Research (AWI) these shallow-water species are taken from the intertidal mudflat near Dorum-Neufeld in northern Germany. However, to date it has never been systematically investigated when the highest population densities occur in this area, and foraminifera for culturing were more or less randomly sampled.

Goals:

- Provide information on the population structure of each of the benthic species and investigate the potential influence on the mean geochemical proxy-signal (e.g. Mg/Ca)

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

- Provide information on the timing of reproduction of foraminifera in the intertidal mudflat. The number of juveniles is expected to give an idea of the optimum time for reproduction.
- The factors that influence foraminiferal abundance changes are still unknown and need to be explored; this study will provide some ideas concerning this matter. In addition, coexistence and competition among the three dominant foraminifer species in the benthic realm will be analyzed.
- Baseline for future studies to investigate the impact of ocean acidification on foraminiferal population structure.

Ocean Acidification

Over the last century, human activities have significantly influenced the biogeochemical cycles of carbon and nutrient elements with profound environmental impacts on local to global scales (IPCC, 2007). Since the industrial revolution surface ocean pH decreased by 0.1 units and model projections show that this decrease can reach 0.3 to 0.4 units in 2100 (IPCC scenario B2, 2007).

Carbon is the fourth most abundant element in the Universe. Most of it is stored in rocks, about 65,500 billion metric tons. The rest resides in the ocean, atmosphere, plants, soil, and fossil fuels. The carbon cycle represents the flows between each reservoir, which is divided into slow and fast components. A carbon increase puts carbon gases into the atmosphere resulting in warmer temperatures on Earth. The carbon cycle maintains a balance that prevents all of Earth's carbon from entering the atmosphere or from being stored entirely in rocks, thus it acts as a planet's thermostat. Human disturbances such as burning fossils and deforestation change the global carbon cycle. By clearing forests, the ability of the plants to store carbon, as they grow, vanishes and in agriculture, woods are often replaced by plants which store less carbon.

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

With deforestation soil is exposed that vents carbon into the atmosphere. Since the beginning of the Industrial Revolution, when humans first started burning fossil fuels, carbon dioxide concentrations in the atmosphere have risen from about 280 parts per million to 387 parts per million, a 39 percent increase. As for now, land plants and the ocean have taken up about 55 percent of the extra carbon that humans have put into the atmosphere while about 45 percent has stayed in the atmosphere (Riebeek, 2011). The main reason of this surface ocean pH decrease is the increase of anthropogenic carbon dioxide (CO_2) in the atmosphere. The carbon dioxide data from Mauna Loa (volcano on Hawaii in the Pacific Ocean), which constitute the longest record of direct measurements of atmospheric CO_2 , show a steady increase of atmospheric CO_2 from 1960 to 2010 (Tans, NOAA/ESRL). Since the partial pressure of CO_2 in the surface ocean tends to equilibrate with the atmosphere, the carbon uptake by the oceans increases with increasing atmospheric CO_2 . In seawater, carbon is present in three forms (CO_2 , HCO_3^- and CO_3^{2-}) (Fig. 1B), the relative proportions of which determine the pH (Zeebe and Wolf-Gladrow, 2001) (Fig. 1A). Hence, the more CO_2 is released by human beings, the more is absorbed by the ocean, which leads to a reduced surface ocean pH, also known as ocean acidification, yet the ocean remains alkaline.

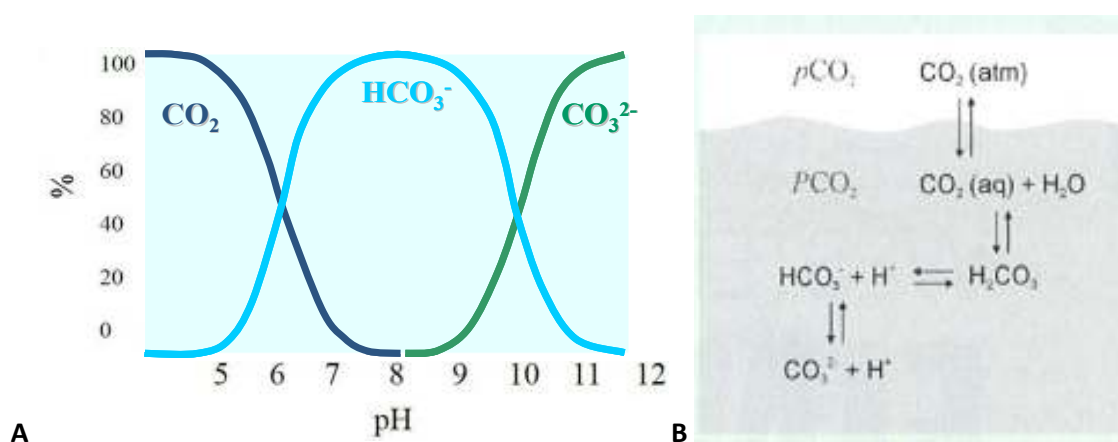


Figure 1: A. Bjerrum plot for inorganic carbon species (Zeebe and Wolf-Gladrow, 2001). B. Carbonate chemistry (Bijma and Burhop, 2010).

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

The increase of CO₂ due to human activity has contributed to growing concerns about climate change consequences (Gruber and Sarmiento, 2002) and perturbation of ocean chemistry (Doney, 2006).

Population dynamic studies serve as a baseline study for the effects of ocean acidification. Ocean acidification is a major threat for marine organisms, although the response is highly species-specific. Some organisms show no response or even higher growth rates (some marine algae) while others, especially corals and pteropods, which are carbonate producers, whose skeletons and shells are made up of the more soluble form of calcium carbonate – aragonite, are highly sensitive to ocean acidification. As a result, the shells end up being thinner and more fragile. For example, sea grass shows increased photosynthetic rates and higher reproduction rates in acidified water (Fabry et al., 2008). On the other hand, corals are more sensitive in a way that calcification rates may vary substantially in response to changes in pH and aragonite saturation state (McNeil et al., 2004). The effect of elevated atmospheric CO₂ on marine calcification is more diverse than previously thought. That is why further species-specific and multispecies studies with multiple stress factors have to be carried out.

Relating to the timing of reproduction of benthic foraminifers, biological consequences of ocean acidification suggest that calcification and metabolic processes are compromised in acidified seawater. Calcifying organisms can increase the rates of many of their biological processes, such as their metabolism and the ability to calcify to compensate for increased seawater acidity (Wood et al., 2008).

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

Study area

The Wadden Sea stretches along the European continental coastline from Den Helder in the Netherlands to Esbjerg in Denmark with a length of 450 km and 20 km in width. In Germany it covers an area of 500.000 ha. The term “Wadden Sea” stands for the area from the dike towards the sea within a 10 meter depth contour line.

The Wadden Sea at the North Sea coast is the largest continuous Wadden Sea on Earth and a world heritage site, where millions of migratory birds take refuge. The Wadden Sea National Park in Schleswig-Holstein is with an area of 285.000 ha, the largest National Park in middle Europe. My study area is located in the intertidal mudflat near Dorum-Neufeld, Northern Germany (N 53° 44', E 08° 30').

The Wadden Sea is an open system where water exchange with the North Sea occurs through tidal inlets. The quality of water, sediment and marine habitats is to a large degree influenced by processes occurring in the North Sea and vice versa.

Especially the intertidal estuarine mudflat with its organic substances offers a splendid amphibian biotope. The upper centimeters of the sediment habitats many algae, bivalves, snails, worms and crustaceans. At 30 cm depth, no oxygen is present and forms blackish colored sediment due to composition processes.

Organisms living in tidal flat ecosystems have to tolerate extreme environmental gradients in salinity, incident light, oxygen availability and temperature. Nevertheless, this type of landscape exhibits high rates of primary production (Loebl et al., 2007).

These high rates are not only supported by the presence of well-adapted phytoplankton and microorganism consortia, but also by enhanced nutrient availability due to rapid organic matter (OM) remineralization. In intertidal areas, aerobic and anaerobic OM degradation processes are fuelled by filtration of suspended particles and dissolved OM from the water column within permeable sediments (Beck and Brumsack, 2012).

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

Continuous supply of organic substrate supports enhanced microbial activity, and ultimately the release of metabolic products such as nutrients and methane (CH₄) to the pore waters. Tidal pumping induces advective flushing of permeable sediments and the transport of remineralization products to the open water column, where they can once again support primary production (Beck and Brumsack, 2012).

Intertidal mudflats are favored habitats for benthic foraminifera. They are, non-vegetated, soft sediment habitats, found between mean high-water and mean low-water spring tide datums (Dyer et al. 2000) and are generally located in estuaries and other low energy marine environments. Intertidal mudflats underlie drastic changes in soil composition due to seasonal and tidal changes. Although tidal flats comprise only about 7% of total coastal shelf areas (Stutz and Pilkey 2002), they are highly productive components of shelf ecosystems responsible for recycling organic matter and nutrients from both terrestrial and marine sources and are areas of high primary and secondary productivity (Black et al., 1998). Large amounts of sediment and organic matter are transported and deposited in intertidal mudflats, thus resulting in a high food supply for microorganisms, finfish, shellfish and migrating birds.

MATERIALS AND METHODS

Sampling sites and sample collection

Nine spatially distant sampling sites were selected in the intertidal mudflat near Dorum-Neufeld. They were arranged in three rows. Within each row, three sampling sites are located approximately 100 meters away from each other, ranging from close to the shore towards 300 m off shore (Fig. 2). The sampling sites 1-3 and 8-9 are located close to tidal flat channels, while site 7 is located in a salt grass patch. Sites 4-6 are in the midst of the sampling area.

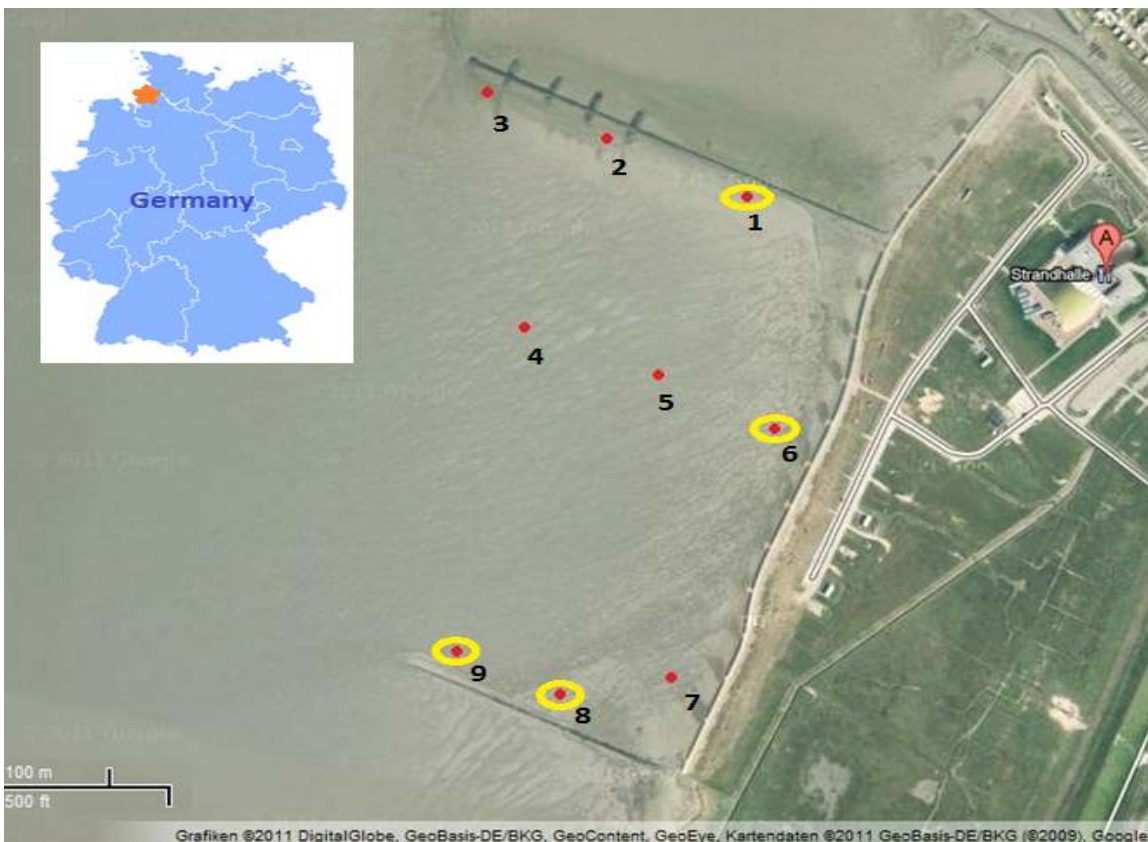


Figure 2: Sampling locations (sites 1-9) in the intertidal mudflat near Dorum-Neufeld, Northern Germany (N 53° 44', E 08° 30'). Stations 1, 6, 8 and 9 (yellow mark) were continuously sampled. Stations 2, 3, 4, 5, 7 only during September - December 2011.

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

Starting in September 2011 until July 2012, sediment was collected biweekly from the sediment surface of the intertidal mudflat near Dorum-Neufeld at low tide (Fig. 3). Stations 1, 6, 8 and 9 were continuously sampled. Stations 2, 3, 4, 5, 7 only during September - December 2011. From each sampling site, the upper ~0.5 to 1 cm of the sediment was collected from a 30 cm x 30 cm frame, filled into plastic jars, and subsequently covered with sea water to avoid desiccation (Fig. 3 and 4). Temperature and salinity were measured in a tidal flat channel along with sample collection. In the laboratory, the sediment was resuspended for homogenization and subsamples (20 ml, ± 1 ml) were put into centrifuge tubes containing 70% ethanol and Rose Bengal (1g/l) (for further details see Diz, et al., 2009), and stored at 4°C until further processing. Rose Bengal was used to distinguish between (recently) living and dead individuals as it adheres to proteins and produces a red coloration (Murray and Bowser, 2000) when the organism are alive. To obtain the exact number of foraminifers, which were counted from the varying amounts of sediment, the data was normalized by dividing the number of counted foraminifers through the respective sediment amount.



Figure 3: Sampling at Site 1 during low tide, close to a tidal flat channel.

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany



Figure 4: Surface sediment collection (~0.5 to 1 cm).

After the first three months of sampling (September through December 2011), I excluded some of the nine sampling sites (Fig. 5) to focus on the most productive sampling sites.

Station 1, 6, 8 and 9 showed the highest abundance of species throughout the first three sampling month, which was the criterion for sorting out the sampling sites. The second main criterion is to keep sampling sites with a high abundance of *A. aomoriensis*, because this species is the primary target species used in culture experiments at the AWI and is therefore of special importance for further investigation.

Sampling station 1 shows a high abundance of *A. aomoriensis* in all three sampling months and has also a high abundance of the other two species. Station 6 is another sampling station with relatively high number of *A. aomoriensis*, especially in the months of November and December. Station 8 has a relatively high occurrence of *A. aomoriensis* compared to stations 3, 4, 5 and 7.

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

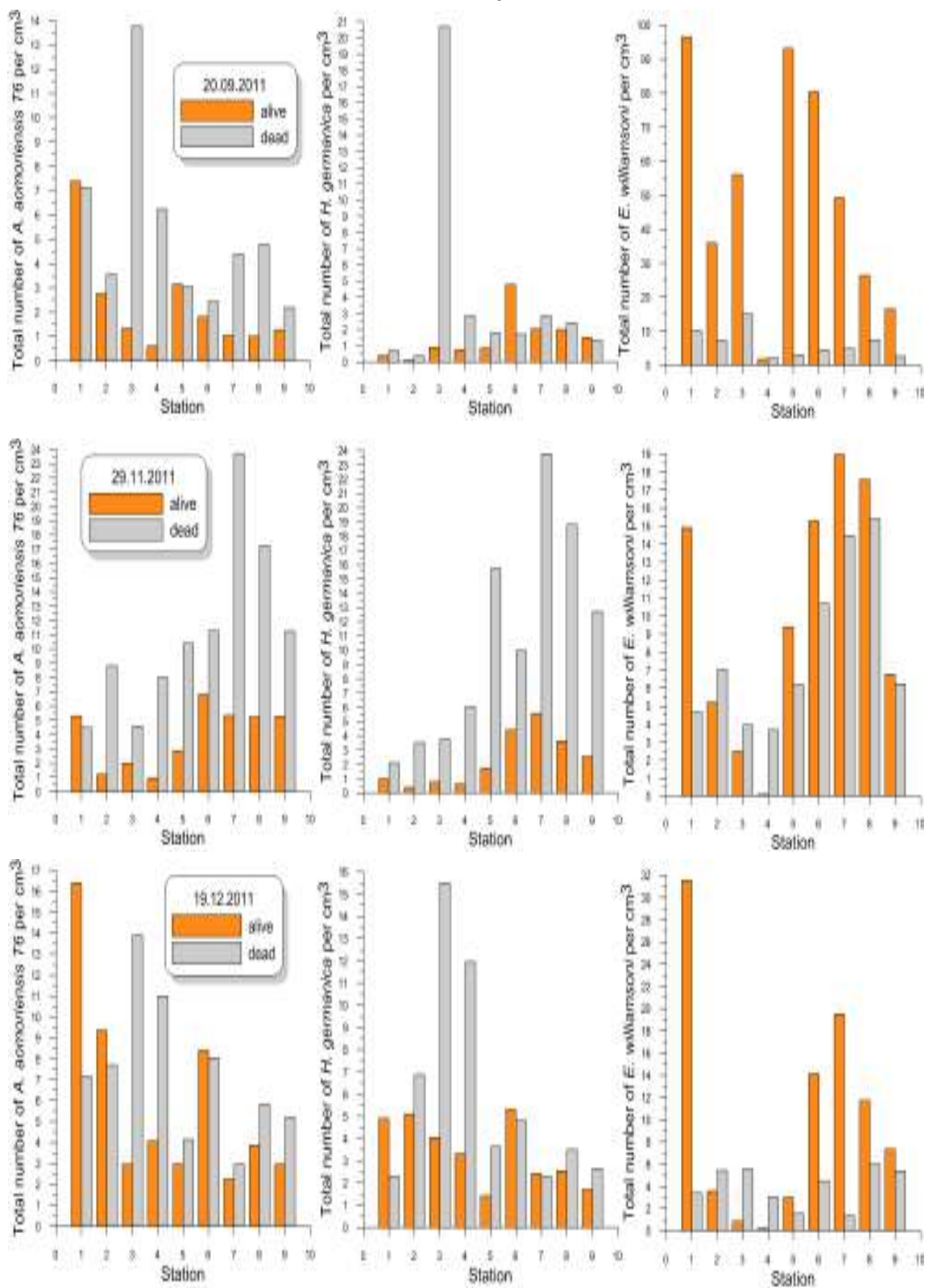


Figure 5: Total number per cm³ of living and dead *A. aomoriensis*, *H. germanica* and *E. williamsoni*.

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

Stations 2, 3, 4, 5, and 7 were excluded because they had the lowest abundance of foraminifers and are therefore less attractive for further investigation. The number of dead individuals was not considered for site selection.

From January 2012 samples were only taken from stations 1, 6, 8 and 9 and these were taken into account in the results.

Sample preparation

In the laboratory, the subsamples were fixed in Alcohol and Rose Bengal stained. After 24 hours, they were washed and wet-sieved over 63 μm and 1.6 mm sieves to remove macrofauna and sediment smaller than 63 μm (silt and clay < 63 μm) and excess Rose Bengal and ethanol (Fig. 6). The washed sediment samples are then oven dried (60°C) and filled in glass jars for subsequent heavy liquid separation with Sodium Polytungstate.



Figure 6: Removing macrofauna, silt, clay and excess Rose Bengal.

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

In order to separate the foraminifera (stained and unstained) in the samples from the remaining sediment we use a heavy liquid separation technique with Sodium Polytungstate (Munstermann and Kersthold, 1996). Sodium Polytungstate [$\text{Na}_6(\text{H}_2\text{W}_{12}\text{O}_{40})$] is a high-density agent, which is non-toxic, ecologically safe and recoverable, so that it can be re-used. To obtain the best results in separating foraminifers, we adjusted to a density of 2.45 g/ml, by adding distilled water to the solution. The exact density of 2.45 g/ml, which worked best for separating foraminifers, was eventually obtained by trial and error.

We verified the efficiency of the separation. After density centrifugation no foraminifera were found in the remaining sand fraction and all foraminifera were kept in the supernatant.



Figure 7: Sediment samples mixed with Sodium Polytungstate.

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany



Figure 8: Stained foraminifera floating on top of the Sodium Polytungstate solution.

For separation, each sediment sample (20 cm³) was equally divided into four centrifuge tubes containing Sodium Polytungstate (Fig. 7). After mixing and centrifuging for 10 minutes at 2000 rpm, the foraminifera were decanted from the upper layer of the solution (Fig. 8) over a filter to collect the Sodium Polytungstate. The remaining Sodium Polytungstate in the tube and bottom sediment was also filtered for recycling. The filter containing the foraminifera (stained and unstained) and sediment remains was thoroughly washed with MilliQ water to remove any remaining Sodium Polytungstate from the shells. Subsequently, the sample was air-dried and filled into vials for further processing.

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

Speciation

Before counting and classification, the foraminifera were dry-sieved over 90, 125, 250 and 355 μm sieves to separate different size classes and to remove remaining sediment.

The foraminifera of each size class were identified and total numbers of dead or alive specimens were counted. Counting was done using a binocular (Zeiss, steREO, Discovery, V12) and picking trays. We identified three benthic species that are present in the intertidal flat of Dorum, which will be examined in this study: *E. williamsoni*, *A. aomoriensis* and *H. germanica*. No other species, except the three mentioned above, were observed.

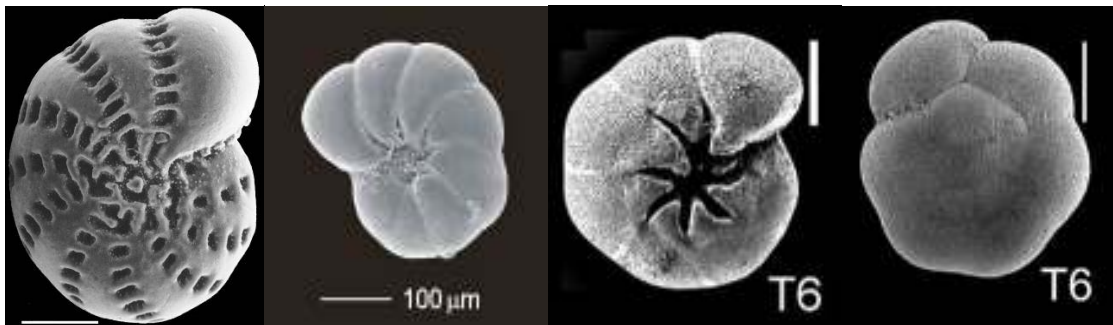


Figure 9: Electron micrographs of: *E. williamsoni* (left) (in Hayward et al., 1997), *H. germanica* (2nd from left) (in Banner and Culver, 1978), and *A. aomoriensis* T6 (umbilical view, 2nd from right and spiral view, right) (in Hayward et al., 2004). Scale bar is 100 μm .



Figure 10: Live shots of: *E. williamsoni* (left) (in Austin, 2001), *H. germanica* (middle) (in Goldstein, 2006), and *A. aomoriensis* T6 (right) (in Dissard et al., 2010). Scale bar is 100 μm if not labeled.

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

In the literature, the *Ammonia* species that is present in Northern Germany's mudflats is often referred to as *Ammonia tepida* (Cushman, 1926). Morphological distinction of molecular types in *Ammonia* revealed though, that the species near Dorum, Neufeld is the molecular subtype (T6) of *A. aomoriensis*. This specific molecular subtype is characterized by a commonly elongate folium, pointed, with weak, imperforate, secondary calcite; often with one or more small umbilical bosses; radial sutures perpendicular to spiral suture on spiral side (Fig. 9 and 10) (Hayward et al., 2004). *Ammonia* species are free epibenthic or endobenthic in fine sediments. "Foraminifera are recorded as feeding primarily upon bacteria, small diatoms, and nannoplankton. Thus their food items are usually below 50 μm and commonly below 25 μm in size" (Lipps, 1970).

Haynesina germanica and *E. williamsoni* are both cleptoplasts, they are able to use diatom chloroplasts for photosynthesis (see Fig 10 for green color of chloroplasts in *H. germanica*). "Kleptoplastidy is the ability of heterotrophic organisms to preserve chloroplasts of algal preys they eat and partially digest. As the sequestered chloroplasts stay functional for months, the "host" becomes photosynthetically active"(Pillet et al., 2010).

Characterizing kleptoplastidy is of major importance for understanding endosymbiosis and the emergence of photosynthesis among eukaryotes. Most of the hypotheses assume that the acquisition of chloroplasts by the host cell was carried through a predator-prey relationship between a heterotrophic eukaryotic cell feeding on algae (Keeling, 2004).

Haynesina germanica mainly bears chloroplasts of pennate diatoms (see Fig 11). The majority of kleptochloroplasts found in *E. williamsoni* belong to diatoms from clades C (*Cymatosirales*) and D (pennate diatoms) with almost the same ratio. In comparison to other foraminifers, chloroplasts sequestered by *Haynesina* and *Elphidium* originated exclusively from diatoms (Pillet et al., 2010).

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

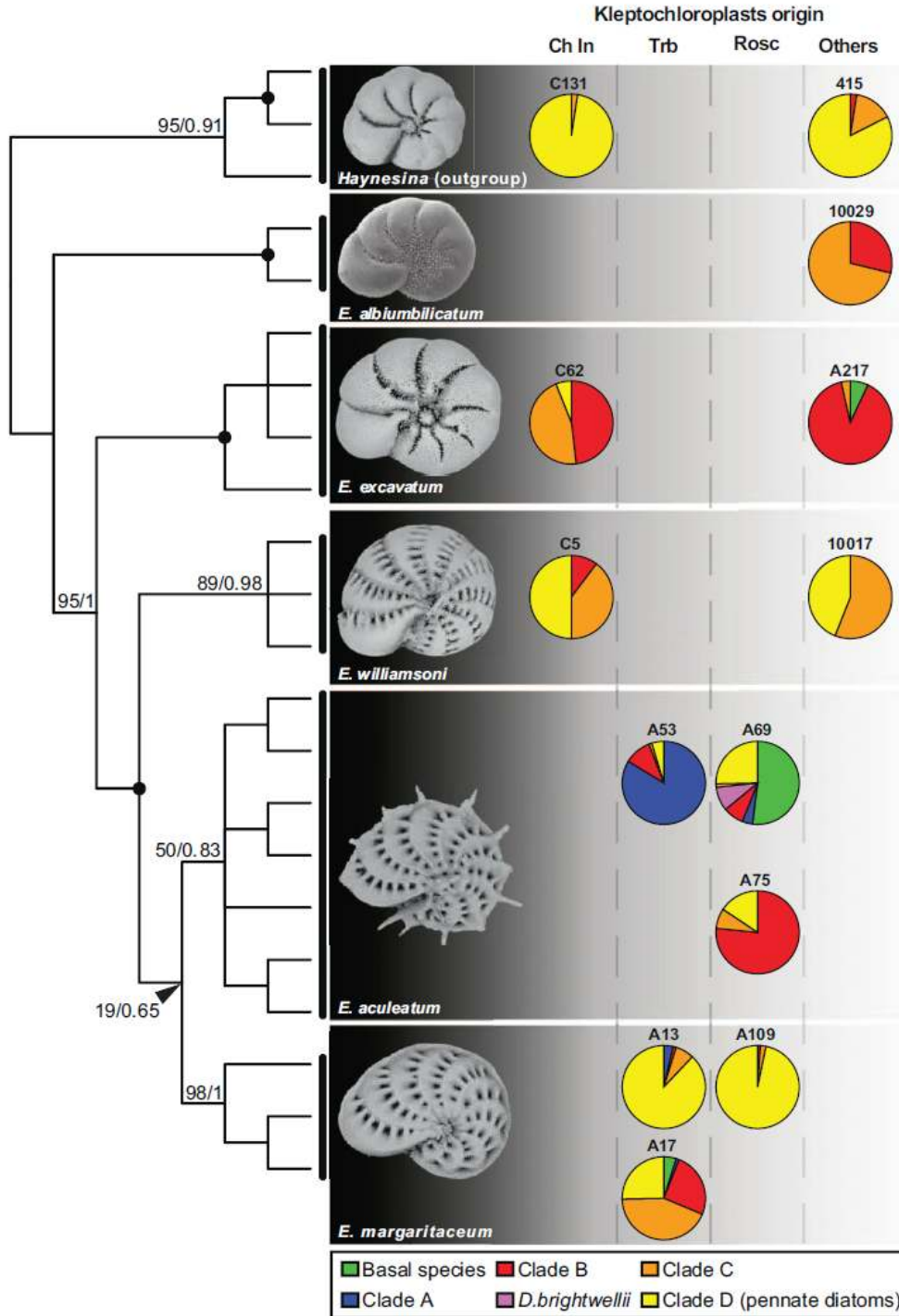


Figure 11: Elphidiids rDNA phylogeny and content of kleptochloroplasts per individual per species (Pillet et al., 2010). Each pie represents a single individual; they are shown by morphospecies horizontally and by sampling location vertically, Chezzetcook Inlet (Ch In), Trebeurden (Trb), Roscoff (Rosc) and others.

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

Haynesina germanica has been widely described as a conspicuous inhabitant of shallow-water settings along European coastlines, the Mediterranean Sea, the Gulf of Mexico and Canada (e.g. Calvo-Marcilese and Langer, 2010, see references therein). It is a mid-latitudinal, temperate and euryhaline species that favors shallow-water muddy and phytal environments of salt-marshes, intertidal habitats with salinities that generally range between 1 and 30, and optimal temperatures between 12 and 22 °C (Banner and Culver, 1978; Hottinger et al., 2001). Arminot du Châtelet et al. (2004) have also shown that *H. germanica* is a successful pioneer species in polluted estuarine environments and in zones that are rich in organic matter (see also Gebhardt, 2009).

Elphidium williamsoni was originally described from beach sands off Dunkerque, France. Tests of *E. williamsoni* exhibit numerous papillae of different sizes in the umbilical area. They are surrounded by thickened extensions of the chamber walls pointing into the umbilicus (Fig. 9). The sutural bridges are generally indistinct. The test of *E. williamsoni* is slightly compressed with a width * 10/diameter ratio of 4–5 (Lutze, 1965).

Classification and Phylogeny

When it comes to foraminiferal classification and phylogenic trees, foraminifera are primarily classified based on the composition and morphology of their test. Three basic wall compositions are known, organic, agglutinated and secreted calcium carbonate.

Agglutinated forms, for example the *Textulariina*, are composed of randomly accumulated grains or grains selected on the basis of specific gravity, form or size; where some forms arrange particular grains in specific parts of the test.

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

Foraminifera that secrete tests are again subdivided into three major groups, microgranular (i.e. *Fusulinina*), porcelaneous (i.e. *Miliolina*) and hyaline (i.e. *Globigerinina*) (Fig 12).

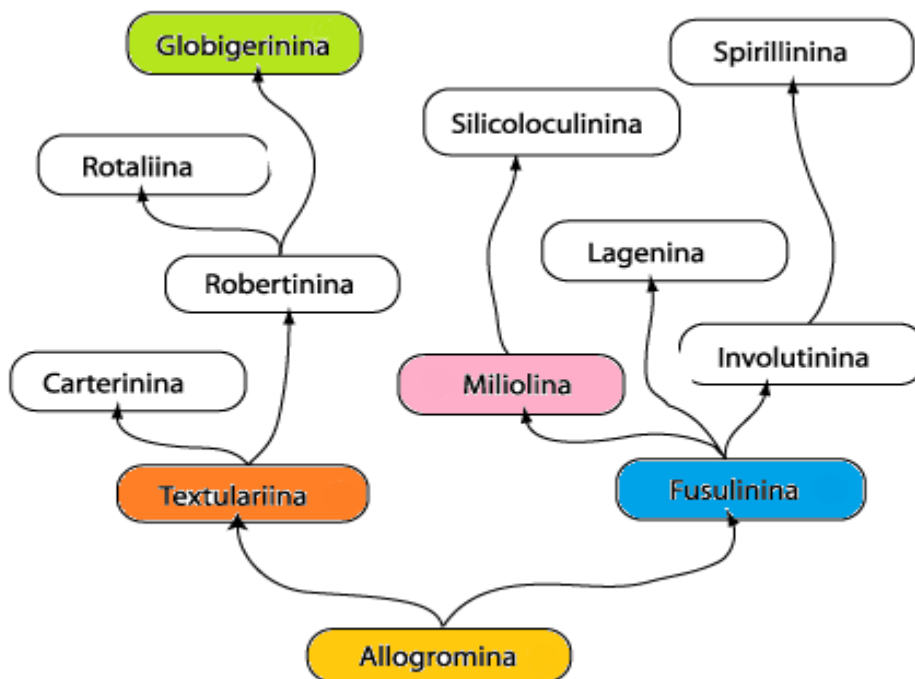


Figure 12: Foraminiferal suborders and phylogeny. Redrawn from Tappan and Loeblich (1988).

Microgranular walled forms are composed of equidimensional subspherical grains of crystalline calcite. Porcelaneous forms have a wall composed of thin inner and outer veneers enclosing a thick middle layer of crystal laths; they are imperforate and made from high magnesium calcite. The hyaline foraminifera add a new lamella to the entire test each time a new chamber is formed (Olney, 2002).

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

The *Spirillinina* have a test constructed of an optically single crystal of calcite, the Suborder *Silicoloculinina* has a test composed of silica. The Suborder *Involutina* have a two chambered test composed of aragonite. The *Robertinina* also have a test composed of aragonite and the Suborder *Carterina* is believed to secrete spicules of calcite which are then weakly cemented together to form the test (Olney, 2002).

Elphidium williamsoni, *A. aomoriensis* and *H. germanica* all belong to the Order *Rotaliida*, whose tests are typically enrolled or may be encrusted with proliferated chambers (Pawłowski et al., 2003).

Reproduction

Of roughly 4000 living species of foraminifera the life cycles of only about 20 are well-known. There is a large variety of reproductive, growth and feeding strategies, yet the alternation of sexual and asexual generations is frequent throughout the group and this characteristic separates the foraminifera from other members of the *Granuloreticulosea*. Asexually produced haploid generations commonly form a large proloculus (initial chamber) and are therefore termed *megalospheric*. Sexually produced diploid generations have a tendency to produce a smaller proloculus and are therefore termed *microspheric*. Importantly, in terms of preservation in the fossil record, many foraminiferal tests are either partially dissolved or partially disintegrated during the reproductive process (Olney, 2002).

The diploid zygote grows to a diploid, microspheric agamont, which forms young haploid foraminifera via meiosis (see Fig. 13). The young foraminifers can either grow to a haploid, megalospheric gamont or form a schizont, which is able to reproduce asexually. The megalospheric gamont produces gametes via mitosis which subsequently turn into diploid zygotes.

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

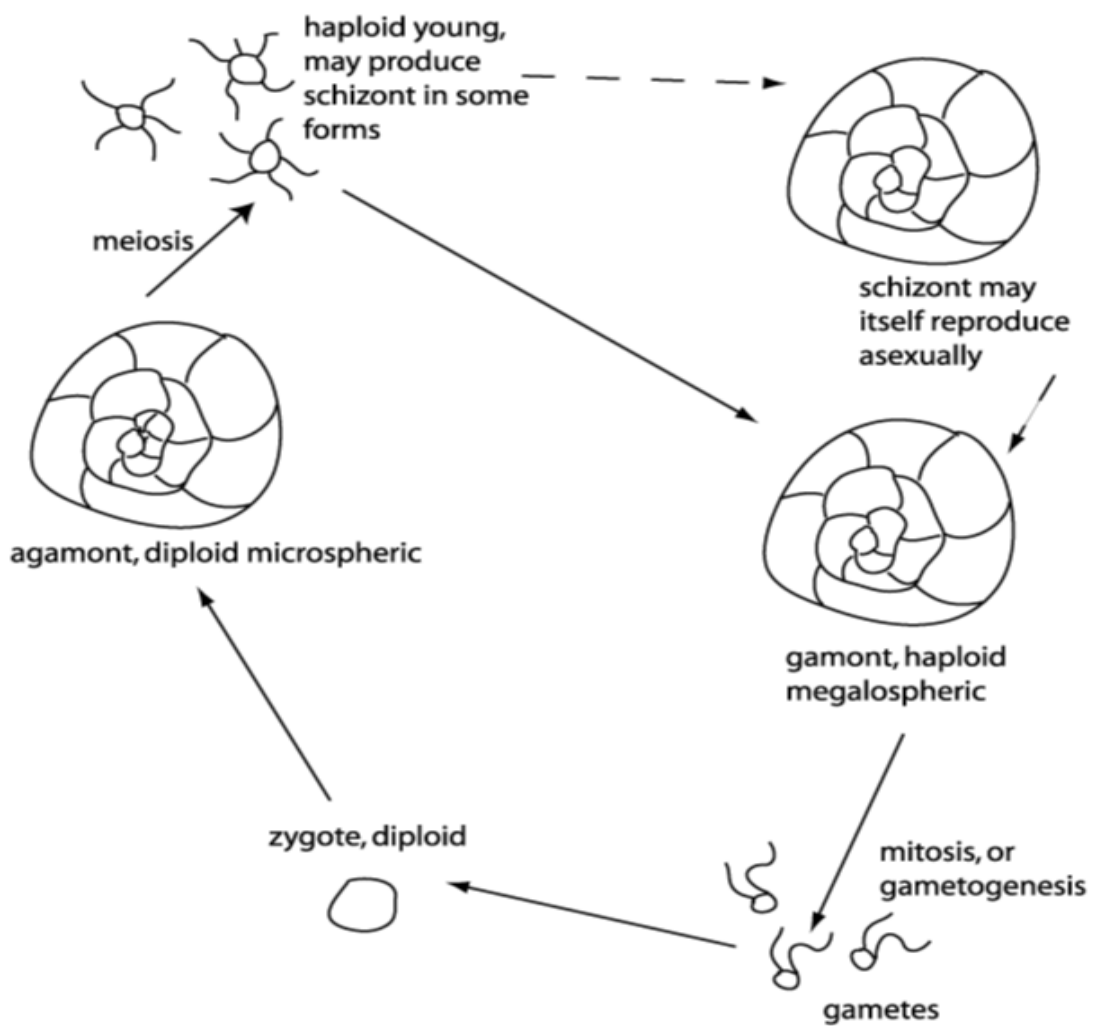


Figure 13: Generalized foraminifera life cycle. Redrawn from Goldstein (1999).

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

Residual calculations

The absolute numbers from the respective species are calculated from the size fraction data. Subsequently the relative abundance ($0 < x < 1$) is calculated. The residual values ($-1 < x < 1$) are then determined from the mean abundance. Finally, the percentage (%) deviation from of the standard residual values was calculated (see Figures 22-24 and supplemental data).

$$\frac{\text{residual value}}{\text{mean relative abundance} \times 100} = \text{percentage deviation of mean relative abundance}$$

The residual graphs allow a different way of representing the data and show the percentage change compared to the mean value as a function of grain size and time (Figs. 22-24).

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

Mg/Ca temperature calculation

Calculating the mean temperature from *Ammonia aomoriensis*, using a theoretical Mg/Ca calibration for *Cibicidoides* spp. of Elderfield et al. 2006. The calculated temperature is 23,4° C.

month	Temp	number of A.a.	percentage of A.a. to total number	
Sep		19	2	0,692041522
Oct		12	4	1,384083045
Nov		4	6	2,076124567
Dec		4	4	1,384083045
Jan		1	3	1,038062284
Feb		4	2	0,692041522
Mar		10	3	1,038062284
Apr		12	15	5,190311419
May		20	50	17,30103806
Jun		22	70	24,22145329
Jul		25	60	20,76124567
Aug		28	70	24,22145329
		13,41666667	289	
		measured average T	total number	

theoretical Mg/Ca using calibration for <i>Cibicidoides</i> spp. of Elderfield et al. 2006	
	7,276423648
	3,36907924
	1,397436497
	1,397436497
	1,004650263
	1,397436497
	2,703749422
	3,36907924
	8,122512149
	10,12127338
	14,0783687
	19,58256216

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

contribution of monthly Mg/Ca to annual Mg/Ca		
	0,050355873	
	0,046630855	
	0,029012522	
	0,019341682	
	0,010428895	
	0,009670841	
	0,028066603	
	0,174865704	
	1,405278919	
	2,451519505	
	2,922844712	
	4,743181145	
	11,89119726	23,46508105
	annual Mg/Ca	calculated average T

Formula for temperature calculation with Mg/Ca:

$$\frac{Mg(mmol)}{Ca(mol)} = 0.9 \times EXP(0.11 \times T)$$

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

RESULTS

Total abundance of foraminifers

Ammonia aomoriensis and *H. germanica*:

Analysis of the total numbers of living specimens (Figs. 14-17), reveals a peak starting in May through June at all sampling stations for *A. aomoriensis* and *H. germanica*. The abundance in this time period for *A. aomoriensis* and *H. germanica* ranges from 60 to 90 individuals/cm³, whereas during the rest of the sampling period it rarely exceeds 20 individuals/cm³. In fact, from November to March the total numbers of living *A. aomoriensis* and *H. germanica* predominantly remains below 5 individuals/cm³.

The number of living individuals, start to increase in March with its maximum in May and June can be observed for *A. aomoriensis* and *H. germanica* at all four stations (Fig. 14-17).

In contrast, living specimens of *E. williamsoni* show no peak during May and June, but have various peaks which are not uniform at all sampling stations.

Considering the total amount of dead foraminifers at sampling station 1, there is a significant peak for both *A. aomoriensis* and *H. germanica* in February with an average of 30 dead individuals/cm³. There is also a slight increase from April to July ranging from 1 to 7 dead individuals/cm³, which is present at all sampling stations.

Examining station 6 for the total amount of dead foraminifers, the quantity does not exceed 13 dead individuals/cm³ for all three species at any time, except *E. williamsoni* in May and June with 17 and 20 dead individuals/cm³, respectively (Fig. 15).

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

Sampling station 8 has one peak in November with 19 dead individuals/cm³ for *A. aomoriensis* and *H. germanica*.

Similarly to station 8, sampling station 9 has one peak in November with 12 dead individuals/cm³ for *A. aomoriensis* and *H. germanica*.

***Elphidium williamsoni*:**

At station 1, *E. williamsoni* exhibits two high peaks with 96 individuals/cm³ on September 20th and 90 individuals/cm³ on January 16th. This species also shows several smaller peaks throughout the year ranging from 20 to 40 individuals/cm³ (Fig. 14).

At sampling station 6, there is only one high peak with 80 individuals/cm³ on September 20th. From November to July, the total number of living specimen is between 10-20 individuals/cm³.

At sampling station 8, the highest abundance of *E. williamsoni* is also in September with 26 individuals/cm³. There are several smaller peaks in January, March, April and June, but none of them exceeds 20 individuals/cm³ (Fig. 16).

At sampling site 9, the total amount of living *E. williamsoni* does not exceed the 20 individuals/cm³ mark, the highest amounts can be registered in September, February, March and June, each with 16, 15, 18 and 17 individuals/cm³ (Fig. 17).

Considering the total amount of dead foraminifers at sampling station 1, *E. williamsoni* has a single peak in June with 38 dead individuals/cm³ (Fig. 14).

In sampling station 8, *E. williamsoni* has a peak in June with 20 individuals/cm³ and a second peak in November with 15 dead individuals/cm³ (Fig. 16).

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

In sampling station 9, *E. williamsoni* has a peak in June with 14 dead individuals/cm³ and a second peak in November with 15 dead individuals/cm³ (Fig. 17).

Size fractions

The four sampling sites can be divided into close-to-shore (station 6), mid-shore (station 1, 8) and off-shore sampling sites (station 9) (Fig. 2). Regardless of the location and distance to the shore, all four sites show a major peak from May through June for *A. aomoriensis* and *H. germanica*.

At sampling station 1 (mid-shore) *A. aomoriensis* and *H. germanica* have their highest abundance in the 125-250 µm size class with 47 individuals/cm³ in May and June. In the smallest size class with 90-125 µm there is also a rise from April to May and a decline afterwards until July.

The abundance in the biggest size class (>350 µm) is very small to zero. *E. williamsoni* is the most frequent species in this size class with an average of less than 1 individual/cm³.

Elphidium williamsoni has several high peaks in the 125-250 µm size class with more than 50 individuals/cm³ in September and January and three smaller peaks with roughly 20 individuals/cm³ in December, March and June (Fig. 18).

In the 250-350 µm size class, there are three peaks, the highest in January with 36 individuals/cm³, the second highest in March with 29 individuals/cm³ and the lowest in April with 21 individuals/cm³.

The abundances at sampling station 6 (close to shore) are similar to station 1 (mid-shore), except that the peak in the smallest size class with 90-125 µm is smaller in May with 26 individuals/cm³, compared to ~40 individuals/cm³ at station 1. There is only

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

one peak of *E. williamsoni* in September with more than 50 individuals/cm³ instead of several peaks as in station 1.

Station 8, which is another mid-shore sampling site (such as station 1), shows similar patterns as station 1, but has lower total numbers (Figs. 18 and 20). Compared to station 1, *E. williamsoni* shows no high peaks at station 8, but is more equally abundant with 10 individuals/cm³ on average, which is not the case in station 1 (Fig. 18).

The off-shore station 9 is similar to the other three stations, which are spatially different. *Ammonia aomoriensis* and *H. germanica* have their highest abundance in the 125-250 µm size class with 30 and 40 individuals/cm³, respectively, in May and June. In the smallest size class with 90-125 µm, there is also a rise which begins in April with a maximum in May and a decline afterwards until July.

Elphidium williamsoni displays medium peaks in September with 15 individuals/cm³ in the 125-250 µm size class and in March with 14 individuals/cm³ in the 250-350 µm size class (Fig. 21).

Temporal variation of foraminifers

Ammonia aomoriensis and *H. germanica* have their highest total abundance in spring and summer, throughout all four sampling sites, whereas in autumn and winter until the end of March low abundance predominates. A clear increase in both species can be observed with its maximum in May and June (Fig. 14-17).

Elphidium williamsoni does not show such an increase, but reaches peaks in total abundance throughout the rest of the season; it has two high peaks with 96 individuals/cm³ in September and 90 individuals/cm³ in January. *Elphidium williamsoni* is generally more abundant in autumn and winter than *A. aomoriensis* and *H. germanica*, especially at station 1 (Fig. 14).

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

Regarding seasonal differences in size classes, the smallest size fraction of 90-125 μm for *A. aomoriensis* and *H. germanica* tends to increase not as much as the 125-250 μm size class and also tends to decrease in June, whereas the larger size class with 125-250 μm is more abundant during this month.

For example, at station 8 (Fig. 20), the maximum peak in the smallest size class for *A. aomoriensis* and *H. germanica* is at 34 individuals/ cm^3 in May, which is almost identical to the peak in the larger size class above (125-250 μm). In the next sampling period in June, the abundance decreases in the smallest size class (90-125 μm) down to 23 individuals/ cm^3 , whereas in the larger size class (125-250 μm) a clear increase up to 38 individuals/ cm^3 is observed.

Section Marine Biogeosciences
 Alfred Wegener Institute for Polar and Marine Research
 Am Handelshafen 12, 27570 Bremerhaven
 Germany

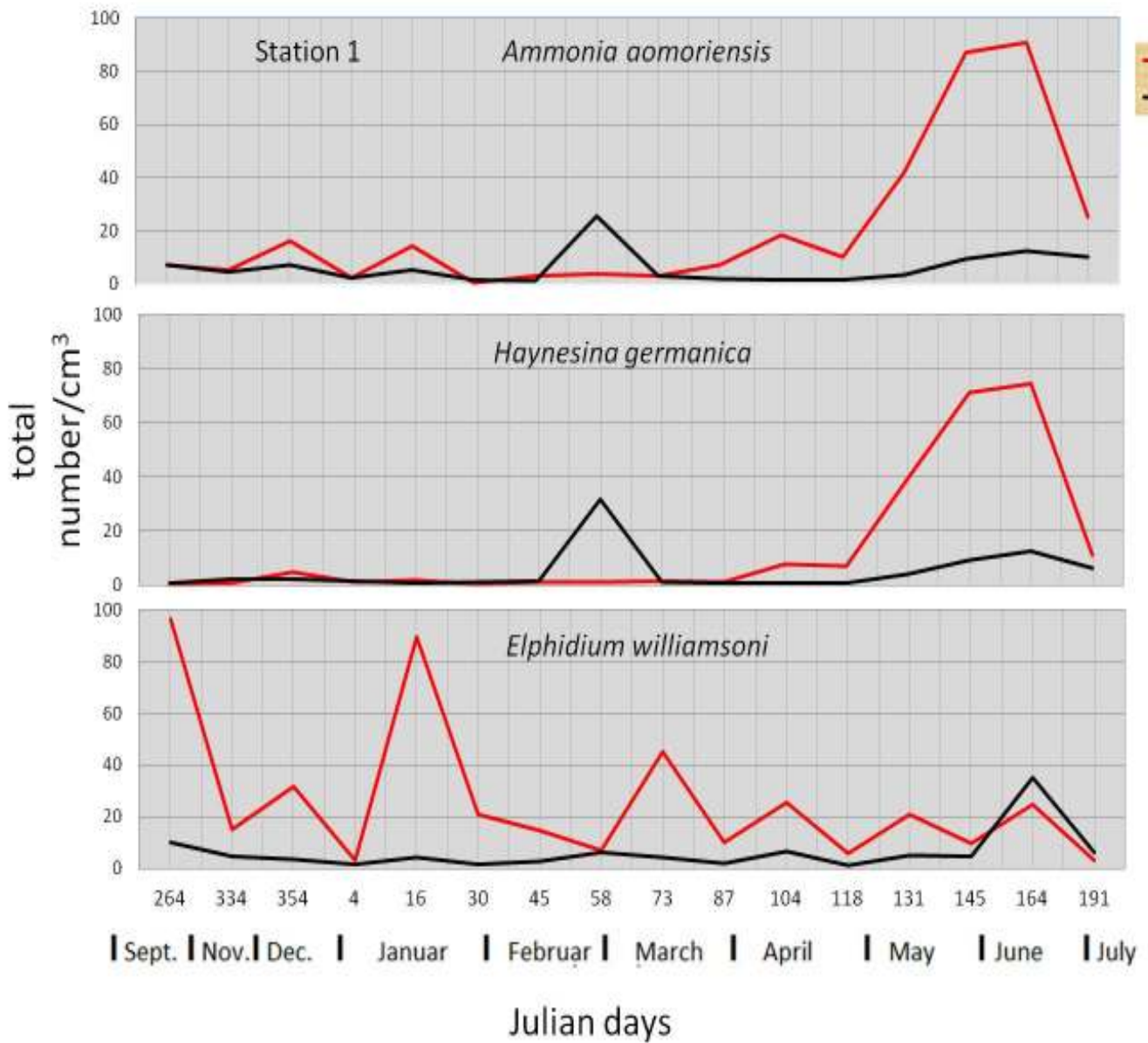


Figure 14: Total numbers of individual foraminifers per cm³ for each species from September to July at Station 1. Living and dead foraminifers are shown in red and black, respectively.

Section Marine Biogeosciences
 Alfred Wegener Institute for Polar and Marine Research
 Am Handelshafen 12, 27570 Bremerhaven
 Germany

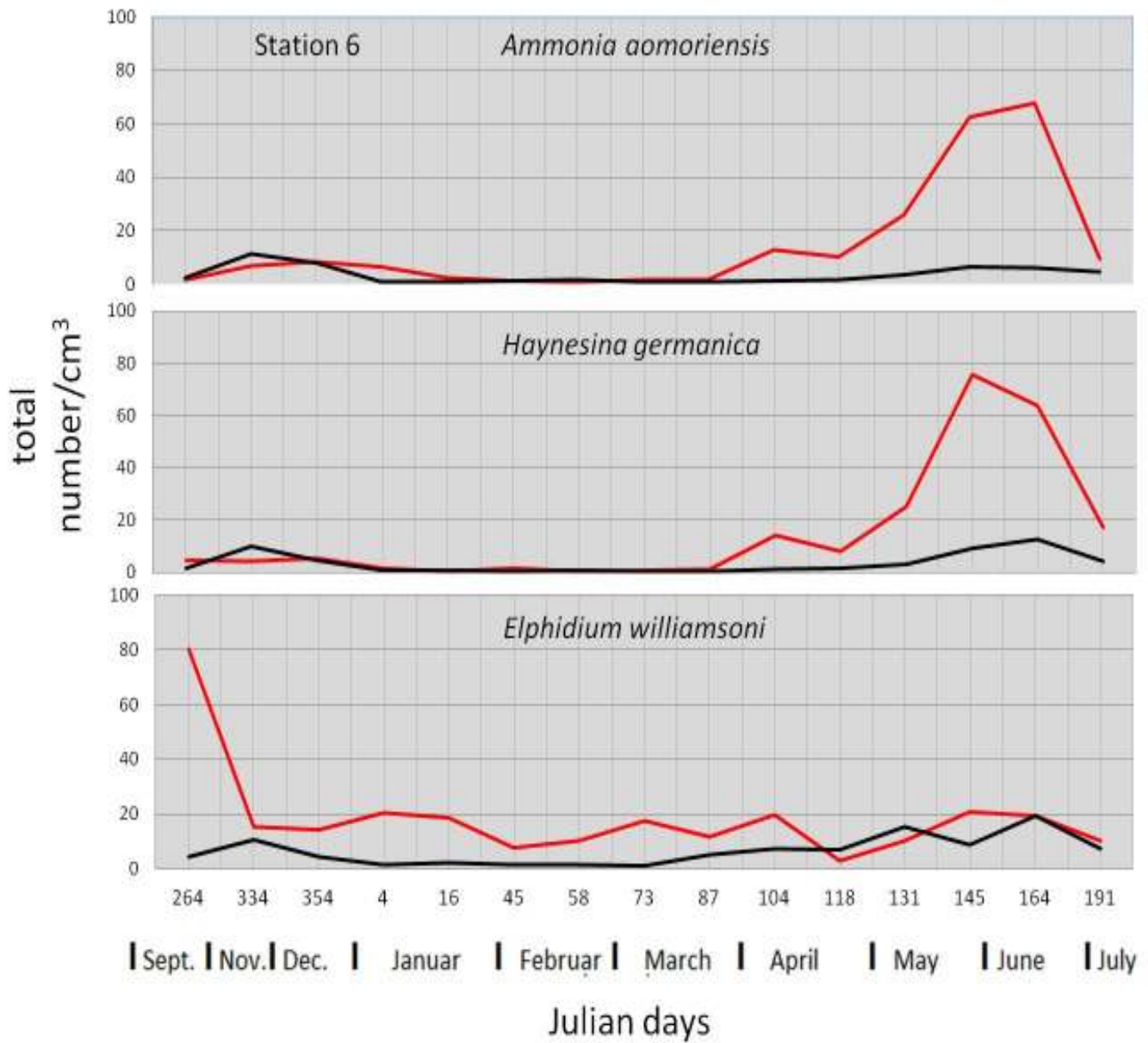


Figure 15: Total numbers of individual foraminifers per cm³ for each species from September to July at Station 6. Living and dead foraminifers are shown in red and black, respectively.

Section Marine Biogeosciences
 Alfred Wegener Institute for Polar and Marine Research
 Am Handelshafen 12, 27570 Bremerhaven
 Germany

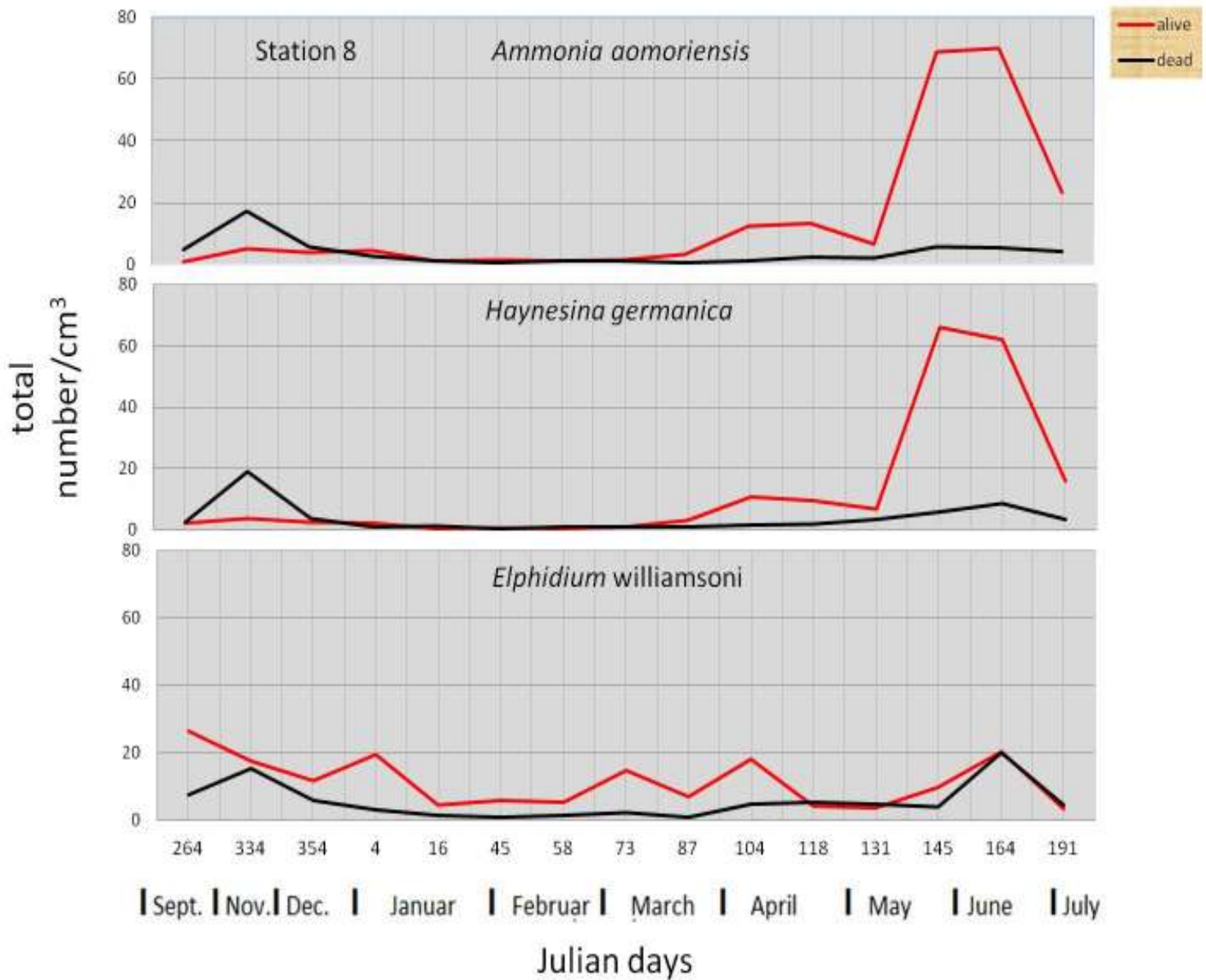


Figure 16: Total numbers of individual foraminifers per cm³ for each species from September to July at Station 8. Living and dead foraminifers are shown in red and black, respectively.

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

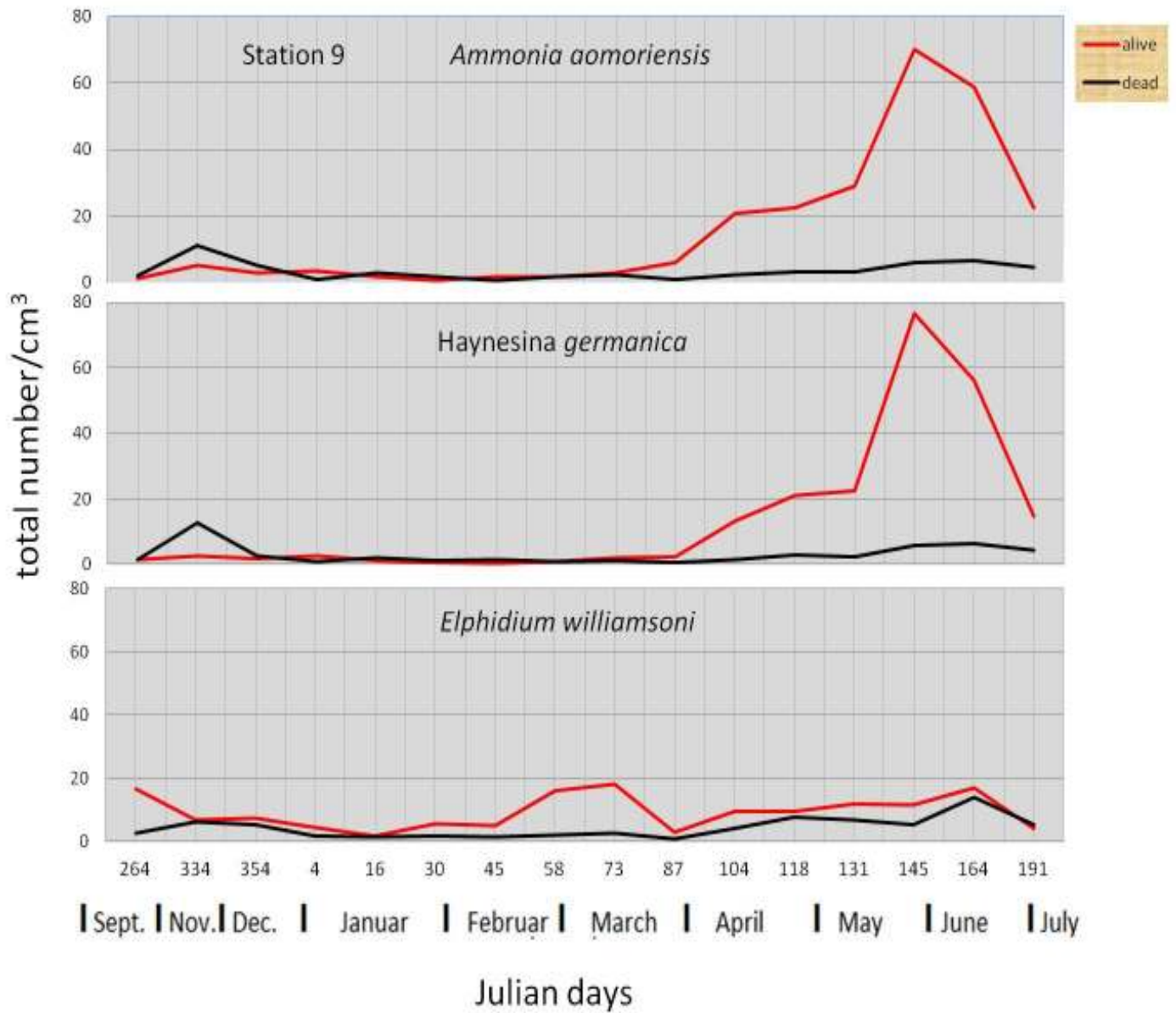


Figure 17: Total numbers of individual foraminifers per cm³ for each species from September to July at Station 9. Living and dead foraminifers are shown in red and black, respectively.

Section Marine Biogeosciences
 Alfred Wegener Institute for Polar and Marine Research
 Am Handelshafen 12, 27570 Bremerhaven
 Germany

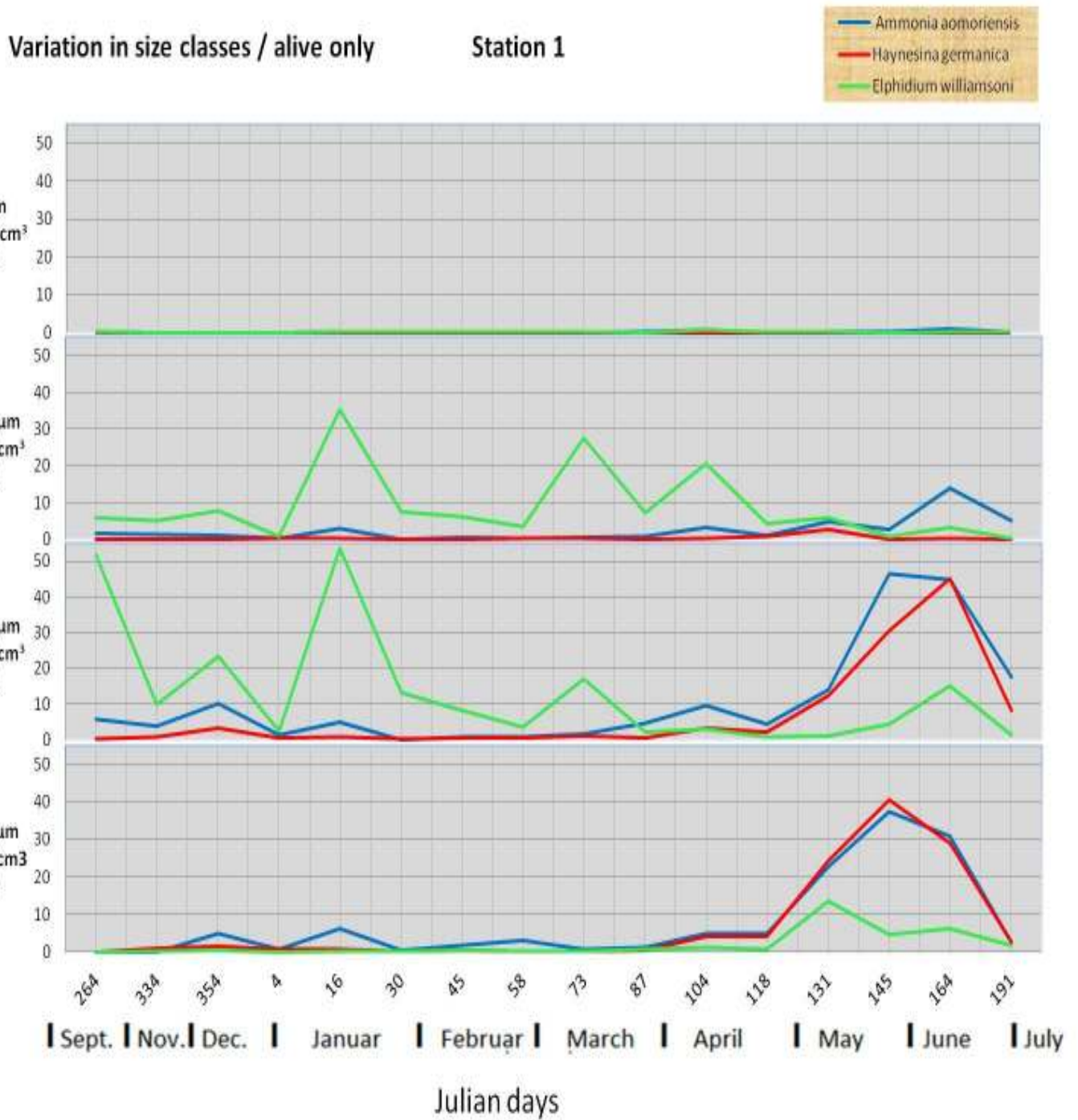


Figure 18: Foraminifer abundance in four different size classes from station 1. Only living individuals are shown.

Section Marine Biogeosciences
 Alfred Wegener Institute for Polar and Marine Research
 Am Handelshafen 12, 27570 Bremerhaven
 Germany

Variation in size classes / alive only

Station 6

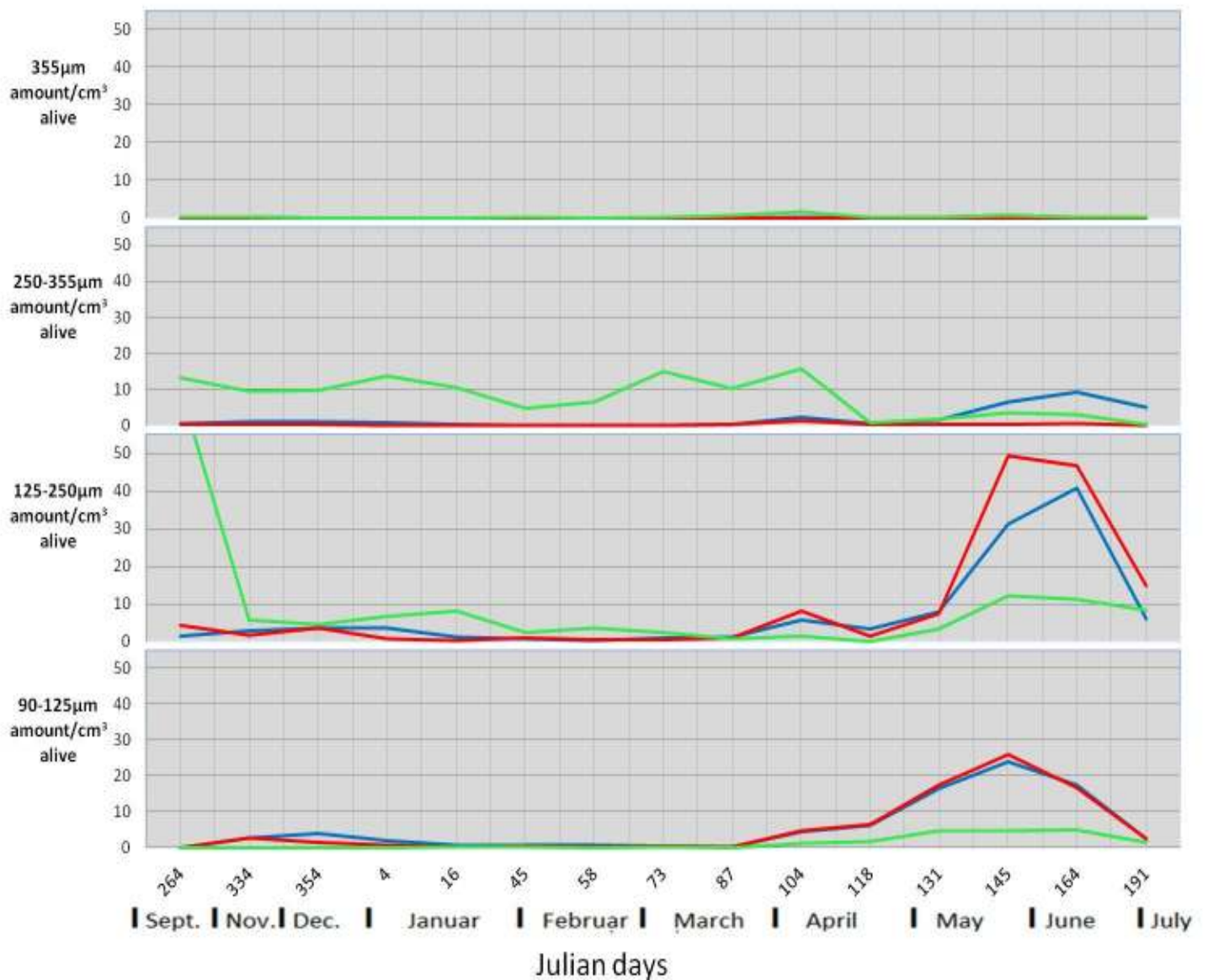
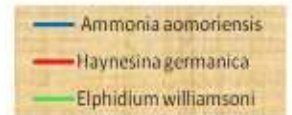


Figure 19: Foraminifer abundance in four different size classes from station 6. Only living individuals are shown.

Section Marine Biogeosciences
 Alfred Wegener Institute for Polar and Marine Research
 Am Handelshafen 12, 27570 Bremerhaven
 Germany

Variation in size classes / alive only

Station 8

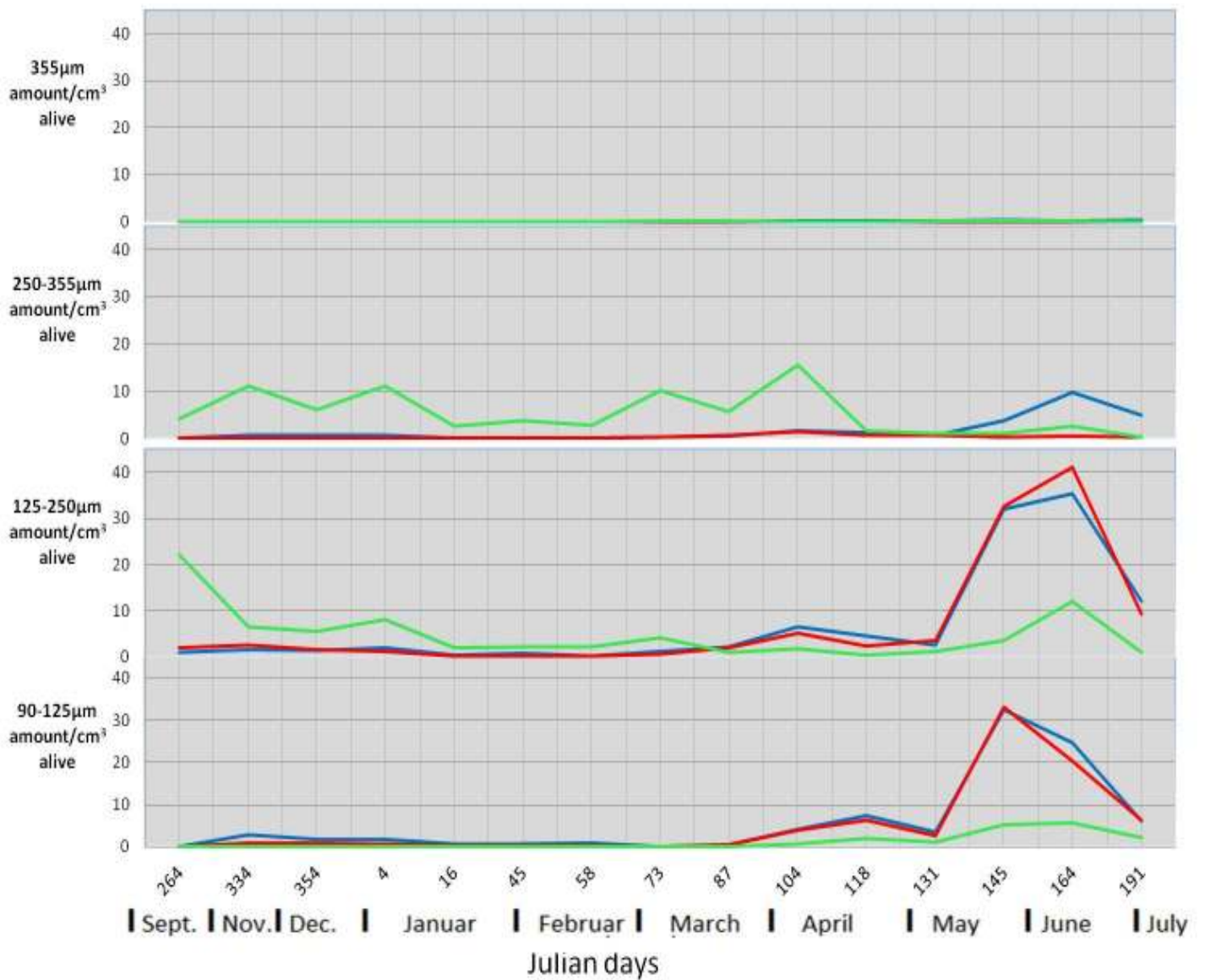
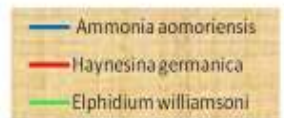


Figure 20: Foraminifer abundance in four different size classes from station 8. Only living individuals are shown.

Section Marine Biogeosciences
 Alfred Wegener Institute for Polar and Marine Research
 Am Handelshafen 12, 27570 Bremerhaven
 Germany

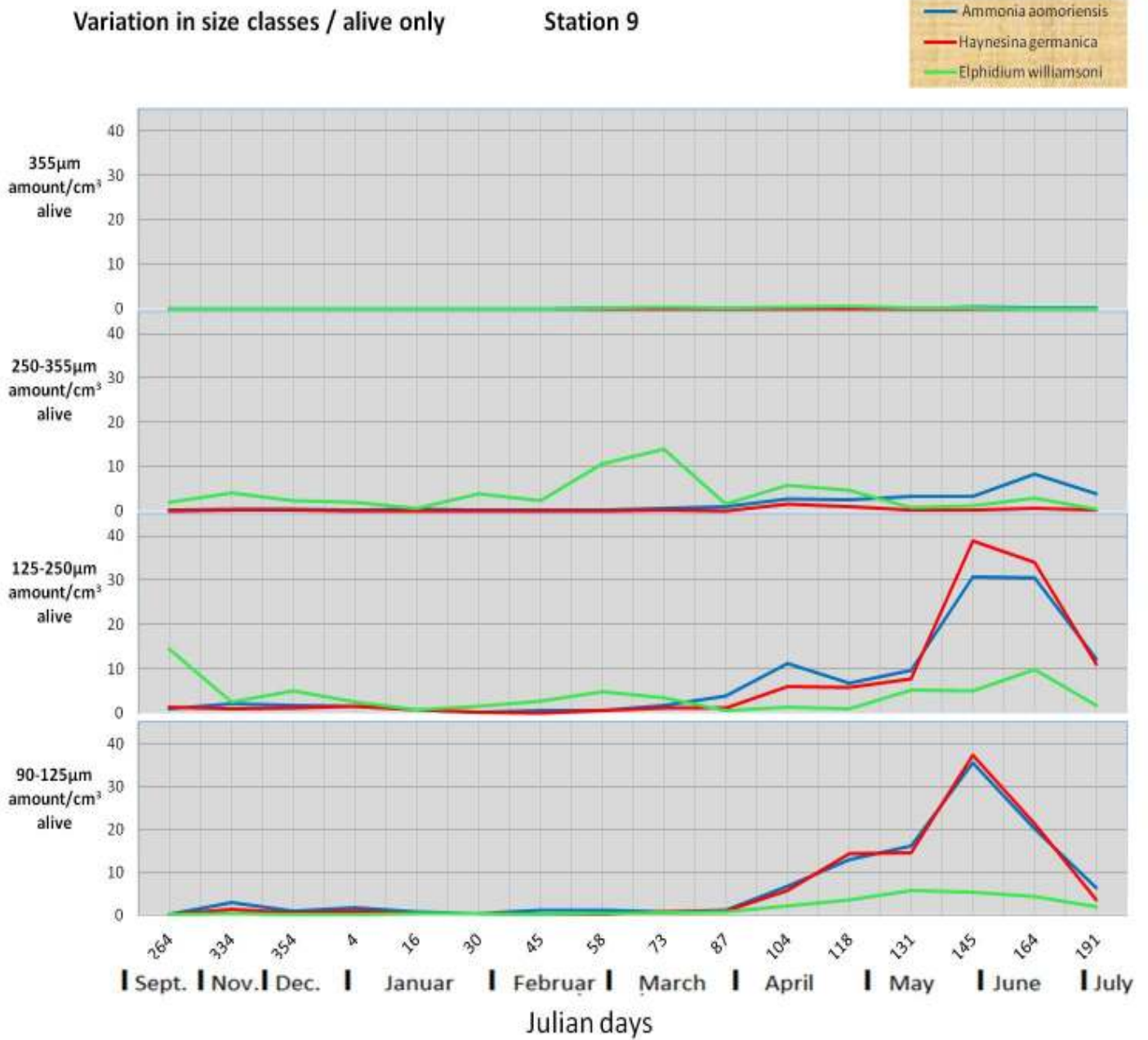


Figure 21: Foraminifer abundance in four different size classes from station 9. Only living individuals are shown.

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

Residuals

The residuals for *A. aomoriensis*, *H. germanica* and *E. williamsoni* are diagrammed in size class, sampling day and the percentage deviation from the mean relative abundance (Figs. 22-24).

The residuals of *A. aomoriensis* show the maximum deviation in size class 125-250 μm , 250-355 μm and $\geq 355 \mu\text{m}$ at sampling day 267 (12.06.12) with over 450% higher than the mean relative abundance (represented with 0%). The highest deviation in size class 90-125 μm is at sampling day 248 (24.05.12) with over 450% higher than the mean relative abundance. From sampling day 1 to 234 (20.09.11 - 10.05.12) the deviation is below the mean abundance through all size classes.

The residuals of *H. germanica* show their maximum deviation in size class 125-250 μm at sampling day 267 (12.06.12) with over 500% higher than the mean relative abundance (see Figure 23). The highest deviation of the 90-125 μm size fraction is similar to *A. aomoriensis* with over 450% higher than the mean relative abundance at sampling day 248 (24.05.12). In size class 250-355 μm , the highest deviation is between day 200 (06.04.12) and 240 (16.05.12) with 300-350% over the mean abundance. From sampling day 1 (20.09.11) to 200 (06.04.12) the deviation is below the mean abundance through all size classes. No data were recorded for size fraction $\geq 355 \mu\text{m}$ because no foraminifera were collected in this size class for *H. germanica*.

The residuals of *E. williamsoni* show the maximum deviation in size classes 90-125 μm , 125-250 μm and $\geq 355 \mu\text{m}$ at different time periods. The size class of 90-125 μm has its highest residual value around sampling day 230 (06.05.12) – 280 (25.06.12) with 200-350% over the relative mean abundance. The size class of 125-250 μm has its highest residual value around day 1 (20.09.11) – 30 (20.10.11) with the average of 400% over the mean abundance. It is the only size class that has high residuals in the early

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

sampling period. The size class of $\geq 355 \mu\text{m}$ has its highest residual value around the days of 200 (06.04.12) – 220 (26.04.12) with 450%. Size class 250- 355 μm shows its highest deviation at day 180 (17.03.12) with 150% over the mean abundance (Fig. 24).

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

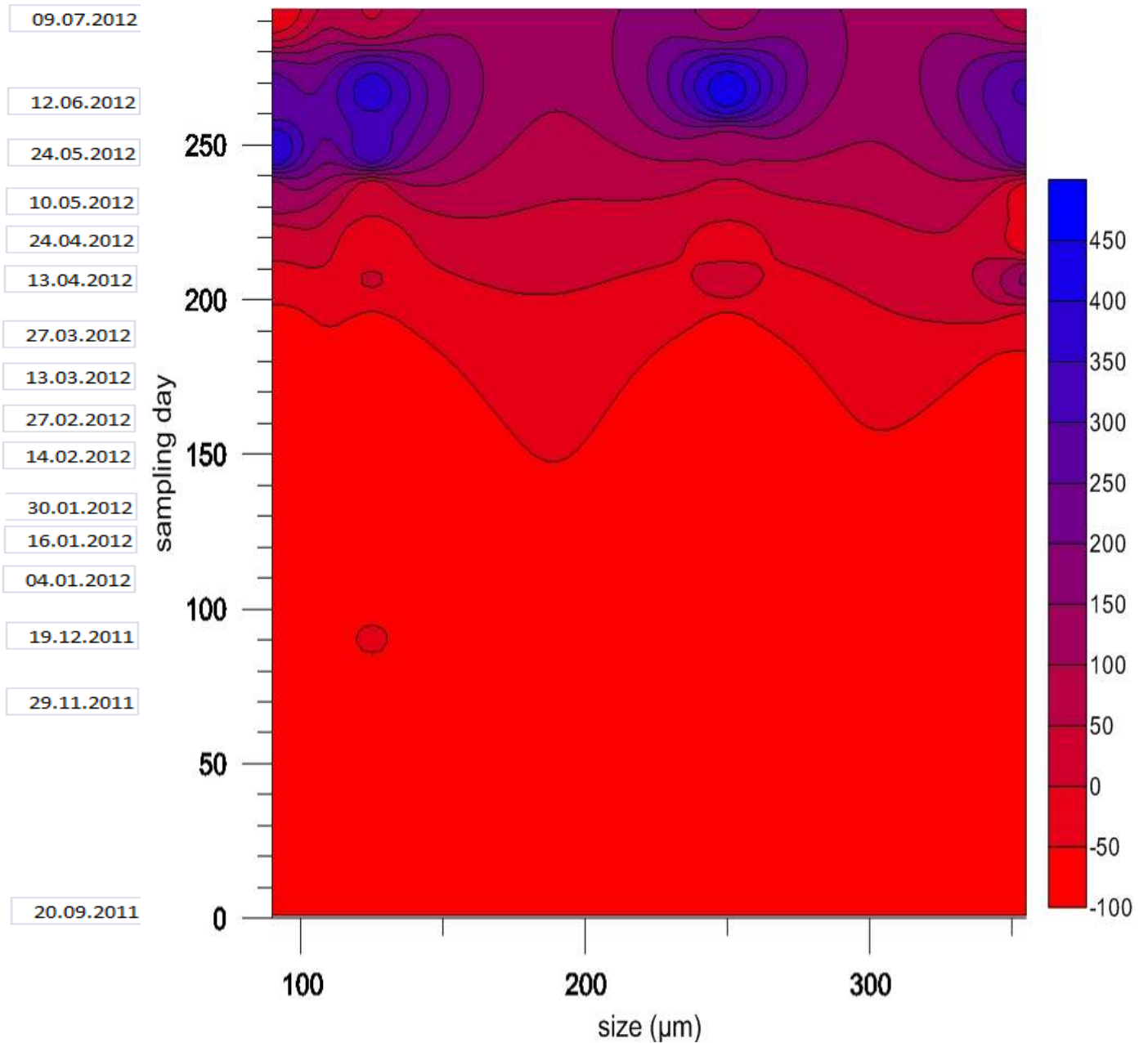


Figure 22: Residuals of *A. aomoriensis*. Left side shows all sampling dates and sampling day. Right side bar shows percentage deviation from the mean relative abundance.

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

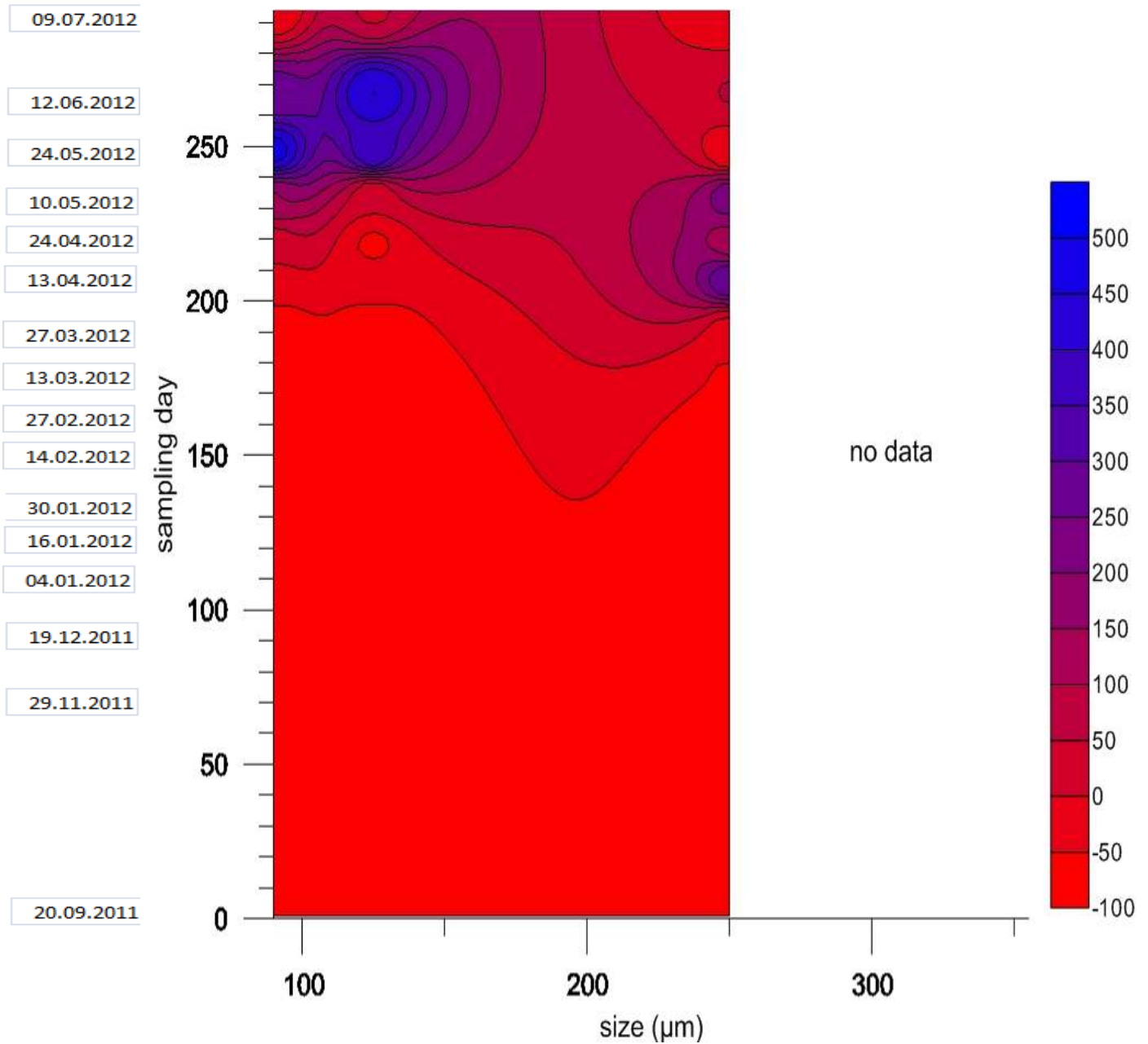


Figure 23: Residuals of *H. germanica*. Left side shows all sampling dates and sampling day. Right side bar shows percentage deviation from the mean relative abundance.

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

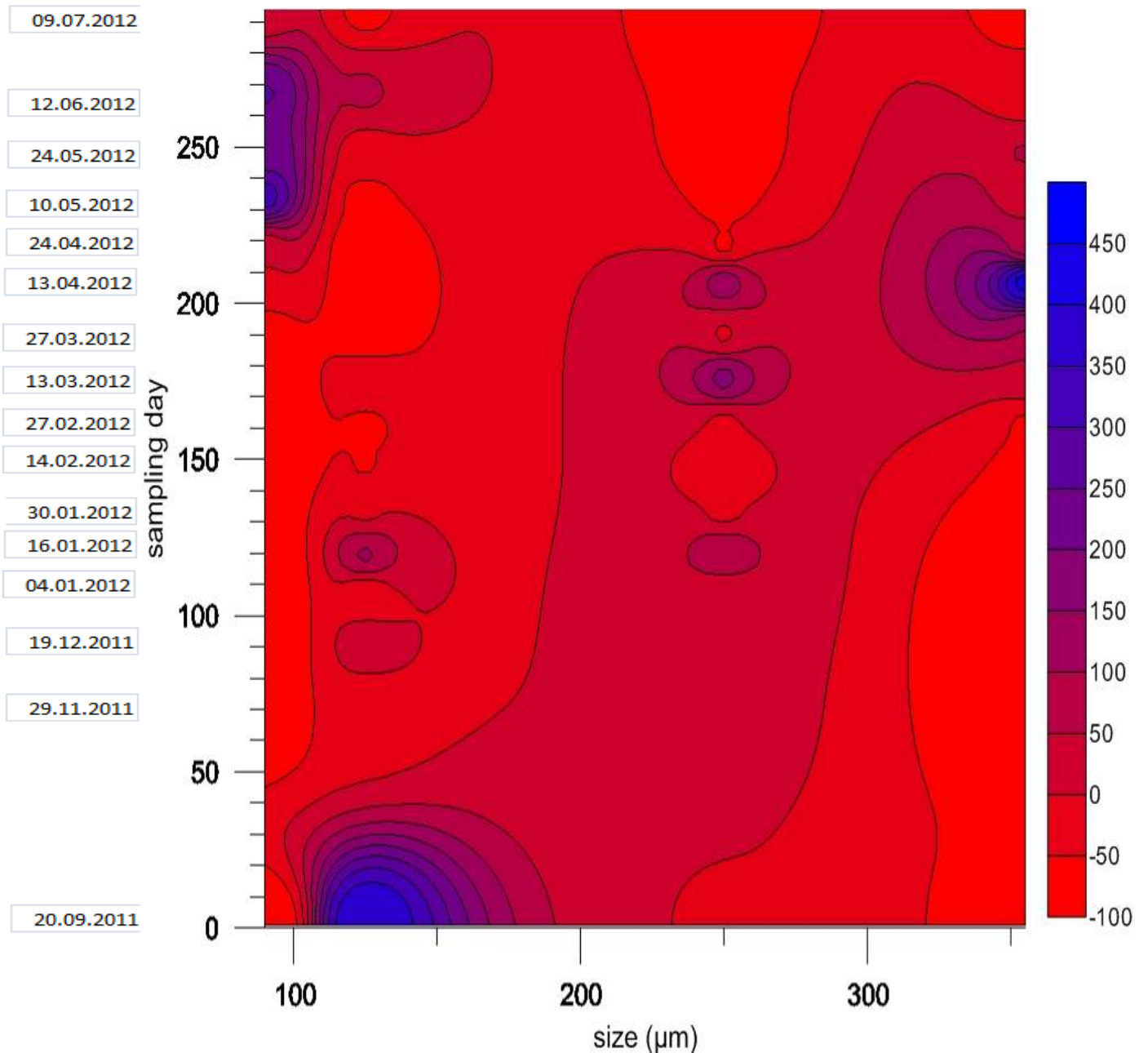


Figure 24: Residuals of *E. williamsoni*. Left side shows all sampling dates and sampling day. Right side bar shows percentage deviation from the mean relative abundance.

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

DISCUSSION

The results provide an overview of the population dynamics of the three dominant foraminifer species; with an 11-month examination period from September 20th to July 9th, this study gives a rich and detailed look of the annual distribution and abundance of the foraminifers coexisting in the intertidal mudflat near Dorum-Neufeld in North Germany.

The high abundance of living foraminifers in the mudflat in May and June with its maximum in May for both *A. aomoriensis* and *H. germanica* can be clearly seen in the results (Figs. 10-17) and shows that the time of highest reproduction is within these two months. The fact that this peak, starting in spring and declining in summer can be observed at all four sampling locations substantiates this finding. Before this study this information was not systematically analyzed and confirms now assumptions previously derived from observations in laboratory stock cultures. The high abundance of foraminifers in May and June could be related to more food sources, such as spring blooms or the increase of fresh water discharges. It should be noted, however, that the smallest size class with 90-125 μm (considered to be the juvenile fraction of foraminifers) has its highest peak of reproduction in May at all sampling stations (Figs. 18-21) and after this period the amount decreases, whereas in the size class above (125-250 μm), the high peak lasts longer. In some cases (Figs. 20 and 21) the peak from the 125-250 μm size class begins soon after the juvenile peak of abundance. These two events are possibly caused by the growing juveniles that add to the 125-250 μm size class later on. In laboratory cultures of *A. aomoriensis* and *H. germanica* at the AWI, practical knowledge shows that a growing juvenile foraminifer builds approximately one new chamber per day in the early life phase. This knowledge could enable the determination of the exact time of highest reproduction via back calculation of the existing chambers of growing juvenile foraminifers. For example a foraminifer with 10 existing chambers, was juvenile 10 - 20 days before.

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

When considering the dead specimens of *A. aomoriensis* and *H. germanica* during this high reproduction period, no considerable increase can be observed. This suggests that a higher input of sediment at this time can be excluded, because otherwise the amount of dead foraminifers/cm³ would also be higher. This is not the case, so the higher abundance must be related to higher reproduction occurring at these sampling stations (Figs. 14-17). Another possibility, regarding the low number of dead specimens throughout the study could be test dissolution as a taphonomic process caused by low water pH.

The high peaks of living specimens of *H. germanica* and *A. aomoriensis* in May and June come along with a low abundance of dead foraminifers during this period. This fact lets the question arise where the dead assemblages have gone? Intertidal mudflats are known for their high productivities. The top sediment layer goes through the guts of deposit feeding organisms, such as the lugworm *Arenicola marina*. This large marine worm habitats the coasts of Europe and can be detected by its highly coiled casts of sand. *Arenicola marina* lies in its burrow with its head at the base of the head shaft, swallowing and digesting sediment, which makes the column of sand drop slightly. It is possible that the dead foraminifer shells dissolve in the guts of the lugworm, which would explain the low abundance of dead foraminifers. Another and probably more reasonable explanation might be that the dead shells are transported away by the currents, because they are not attached to the sediment anymore with the absence of pseudopodia.

Elphidium williamsoni has a completely different life cycle than *A. aomoriensis* and *H. germanica* with higher reproduction in colder months such as September, January and March (Fig. 14), but it is also present throughout the year and not equally distributed at all stations (Figs. 14-17). *Elphidium williamsoni* does not show a clear peak during May and June like *A. aomoriensis* and *H. germanica*, suggesting that either *E. williamsoni* competes with *A. aomoriensis* and *H. germanica* or that a colder climate favors the reproduction of this species. *Elphidium williamsoni* abundance related to high peaks is

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

not equally distributed at stations 8 and 9 (Figs. 16 and 13), so there it cannot be clearly concluded whether competition between the species, living conditions or both are the dominant factors. The similar reproduction peak of *A. aomoriensis* and *H. germanica* suggest that these species coexist and maybe do not share the same food sources, because *H. germanica* is a cleptoplast and *A. aomoriensis* is not.

Only a few studies included foraminifera in assessing the benthic community structure in the North Sea, despite their high abundances and ecological importance (de Nooijer et al., 2008). However, a comparison of foraminifer densities determined in this study with foraminifer densities obtained from the continental shelf of the northern Gulf of Cadiz shows the following: For the northern Gulf of Cadiz continental shelf, Mendes et al. (2012) showed that the highest value (1173 specimens/10 cm³) was obtained in the area off the Tinto-Odiel mouth, in muddy sediments at 27.5 m water depth. In contrast, the lowest value (14 specimens/10 cm³) in the same area was found at 87 m depth, also in muddy sediments. Population density averaged 225 specimens/10 cm³ in the study area. For comparison, the highest value found in this study is about 800-900 specimens/10 cm³ and averaged density is about 210 specimens/10 cm³. Hence, the highest and average foraminifer densities are comparable between this study and the one by Mendes (2012).

Both studies also demonstrate that the number of foraminifers is highly variable in shallow waters within a relatively small area (Fig. 5), potentially depending on a complex set of physical, chemical, and biological parameters that control the spatial and temporal distribution of foraminifer abundances. These may include temperature, salinity, water depth, sediment type, oxygen concentration, food availability, water currents, and interactions with other organisms (e.g., Loubere and Fariduddin, 1999; Murray, 2006).

Interestingly, temperature and salinity that was measured each sampling day in a tidal flat channel (Fig. 25) changed contemporaneously and in the same direction as the abundance of *A. aomoriensis* and *H. germanica* (Figs. 14-17). More precisely, the total

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

numbers of living *A. aomoriensis* and *H. germanica* increased approximately 7 times (from roughly 10 to 70 individuals/cm³) between April and June, when temperature and salinity increased from 13 to 28°C and from 22 to 34 psu, respectively (Fig. 25). This suggests that both species favor warmer temperatures and/or higher salinity for reproduction. However, it is known from stock sediments in the AWI culture lab that reproduction of these species takes place at approximately the same time, putting into question this hypothesis, because the stock sediments are isolated from variations of external influences, such as temperature, salinity or light/dark cycles. However, based on the dataset of this study, it is not possible to exclude these factors as triggers for foraminiferal reproduction, but there are more potential factors that may have a control on the spatial and temporal distribution of the foraminifer population.

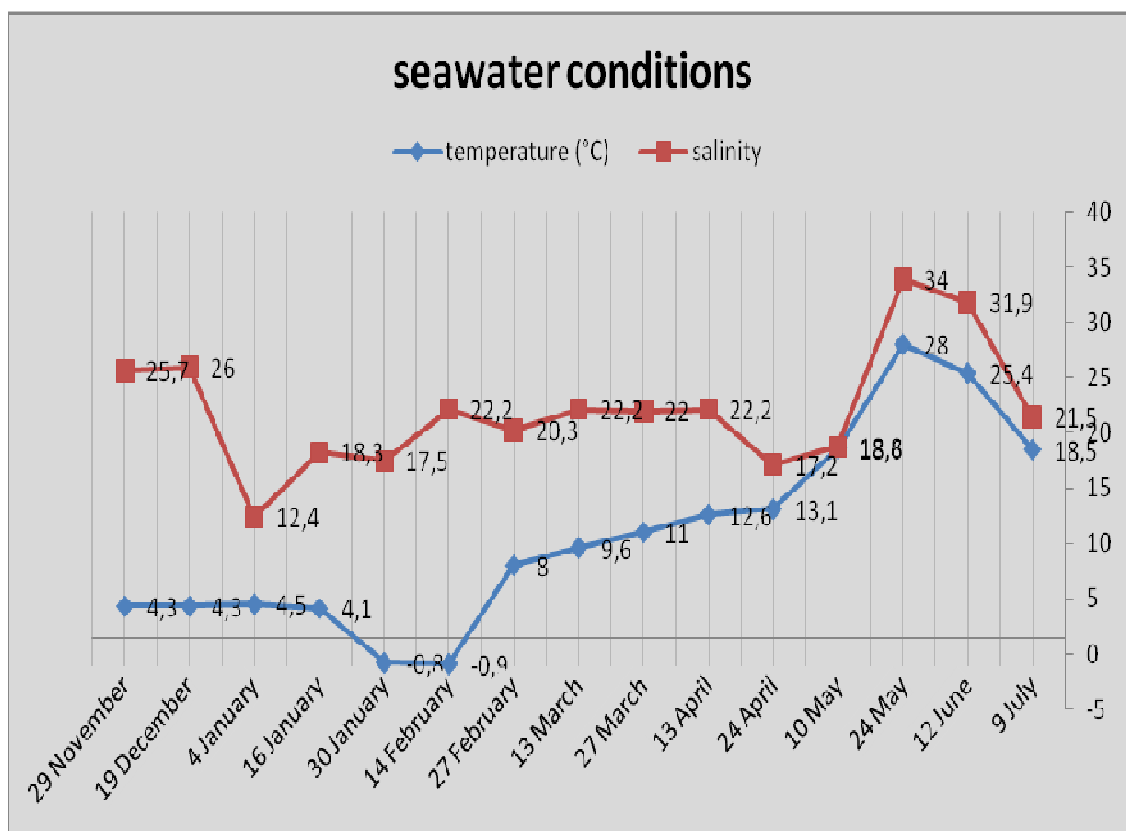


Figure 25: Measured temperature and salinity over the sampling period.

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

For instance, the effects of sediment grain-size on foraminiferal density and diversity are still a matter of debate. Generally, in an environment with strong currents, the grain size is coarse due to removal of finer sediments (winnowing), whereas weak currents allow fine grains to settle. Strong tidal elevation in an intertidal mudflat may also be an important limiting parameter, owing to the variable energy that controls sediment sorting, resulting in fine grains laying on top of the coarse grains (upward fining) (e.g., Horton and Murray, 2007). This is in broad agreement with the mudflat surface sediments from Dorum that exclusively consist of muddy non-cohesive silt to fine sand. Based on the observations of faunal density and diversity, Diz et al. (2004) suggest that very coarse substrates (silt + clay < 12–13%) provide a favorable settlement for epibenthic foraminifera, with attached forms that dominate the living assemblage. Moreover, large particles characterizing shelly sands apparently provide both shelter and attachment, and constitute a stable substrate for epifaunal feeding (Murray, 1986). In contrast, other studies reveal that benthic foraminifera favor a high proportion of fine particles (e.g., Debenay et al., 2001). Similarly, the study by Arminot du Châtelet et al. (2009) showed that both density and species richness are clearly linked to sediment grain-size: the coarser the grain-size is, the lower the density and species richness are and vice versa.

The results from this study show a somewhat different picture. Foraminifer densities are relatively high, but species richness is very low. Why do only three foraminifer species inhabit the intertidal mudflat near Dorum? The water depth is low to non-existent at low tide, leaving the foraminifers exposed to a relatively dry environment for several hours. It might be that the harsh physical conditions of hydrodynamic turbulences only allow highly tolerant species to survive. According to Alve (1995), the colonization pattern of the tidal marsh is biologically controlled whereas the mudflat must be physically controlled. The physical control on test construction is mainly hydrodynamic and consequently of sediment dynamic origin. It allows only highly tolerant species like *H. germanica* to survive and develop (Cearreta, 1988; Debenay et al., 2000). This could explain the existence of *H. germanica* in a physically controlled environment such as

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

the mudflat of Dorum, where high hydrodynamic turbulence exists. Another explanation is that *H. germanica* and *E. williamsoni* are both cleptoplasts, they are able to use diatom chloroplasts for photosynthesis (see Fig. 11 for detailed information). This adaptation might grant these two species an ecological niche alongside *A. aomoriensis* in the intertidal mudflat ecosystem.

The organic matter content of mudflat sediments of Dorum-Neufeld is very high, and may enable as an important food source for the high densities of these three species. A few studies indicate that organic waste seems to favor both diversity and density of the foraminiferal populations (Debenay et al., 2001). By contrast, other authors observe a decrease of density, specific richness and/or diversity index when the OM content increases (Schafer et al., 1995). Food availability in form of nutrients, driven by tidal circulation, may also promote enhanced primary production. Except for species that feed on live food or have endosymbionts, labile organic matter and the bacteria feeding on it are primary food sources for benthic foraminiferal assemblages (e.g., Murray, 2006).

Another important factor for the survival and therefore the distribution of benthic foraminifers is the availability of sufficient oxygen. Dissolved oxygen and organic carbon flux are generally considered to be the main factors controlling the depth distribution of benthic foraminifera in sediments (van der Zwaan et al., 1999), particularly in deep waters where there tends to be minimal spatial and temporal variability (Murray, 2001). In the intertidal mudflat of Dorum-Neufeld, the oxygenation is higher than in the deep sea, due to the constant mixing of surface water with oxygen and the energy of the currents that oxygenates the sediment. On the other hand, the intertidal mudflat sediments are characterized by higher sedimentation rates and a very high organic matter content of the sediments due to high primary production, resulting in relatively high oxygen consumption within the sediment surface layer (occasionally within 1-2 cm sediment depth). Consequently, sediments below this horizon are black due to low oxygen, hampering the foraminifera to inhabit deeper sediment layers.

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

Apart from the above mentioned factors that might have a control on the spatial and temporal distribution of foraminifers, also river discharge and suspended particulate matter contribute towards a high density of living benthic foraminifera, as observed around the Guadiana and Guadalquivir Rivers mouths (Mendes et al., 2012). Spatial and seasonal variability may be biologically induced (Alve and Murray, 2001) and responds to predation (Buzas, 1982), reproduction mode (Stouff et al., 1999), sources and distribution pattern of food particles (Alve and Murray, 2001) and species interactions (Hayward et al., 1996).

Regarding temperature reconstruction with the help of fossil Foraminifera, population dynamics have a significant influence on possible temperature reconstructions with proxy signals (e. g. Mg/Ca). In this study, the calculated average temperature is $\sim 10^{\circ}\text{C}$ higher, than the measured average temperature (see Mg/Ca temperature calculation in materials and methods). The measured mean temperature from this study is $13,4^{\circ}\text{C}$. When calculating the mean temperature, using a theoretical Mg/Ca calibration for *Cibicidoides* spp. of Elderfield et al. 2006, the temperature is $23,4^{\circ}\text{C}$.

The reason for this is that *A. aomoriensis* population abundance is higher during the summer in addition to the higher temperature and Mg/Ca in the tests. In this case, when taking all the tests out of a sediment core that covers a one year span, the summer population would be more abundant than the winter population. When measuring the Mg/Ca from all tests out of this deposit, consequently the Mg/Ca would be relatively high. The Mg/Ca measurement would result in a higher annual average temperature as the “true” annual mean actually is. The influence of foraminifer population dynamic on the interpretation of an Mg/Ca proxy is significant, especially when the population is not equally distributed throughout the year.

When investigating fossil Foraminifera, for most benthic foraminifera, it is not known, where the abundance peaks lie during the year, therefore it is important to carry out population dynamic studies to fill the knowledge gap and avoid errors in paleothermometry.

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

GLOSSARY

- › secondary calcite / lamellar wall: test-wall built of layers of calcite or aragonite formed at consecutive instars and covering exposed surfaces of previously formed test. Most lamellar genera are bilamellar and some primarily multilamellar.
- › folium: in spiral lamellar foraminifera the mostly triangular in outline and often texturally differentiated portion of the lateral chamber wall.
- › bosses: round and raised knob-like inflational structure in axial position.
- › suture: line of adherence of chamber wall(s) to previously formed test.
- › spiral side: that side of the test in trochospiral forms which comprises the proloculus or towards which the proloculus is displaced.
- › umbilical side: in trochospiral tests the side opposite to the spiral one.
- › epibenthic: living upon or in the bottom of the continental shelf or littoral zone of the ocean.
- › endobenthic: refers to meiofaunal-sized organisms that move within the sediments.
- › papillae: papilla (plural: papillae); hemispherical to subconical inflational protuberance of the outer lamella.
- › gamont: specimen producing gametes in the process of reproduction irrespective of its involvement in meiosis (diploid gamonts) or not (haploid gamonts). Foraminiferal gamonts, produced by asexual reproduction, are megalospheric
- › agamont: specimen grown from the zygote, producing either gamonts or schizonts in an asexual process involving apogamous nuclear divisions and/or meiosis. Foraminiferal agamonts, produced by a sexual reproduction, are microspheric.

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

›schizont: apogamic offspring of an agamont reproducing either by again apogamous nuclear divisions and cytotomy or undergoing meiosis. Foraminiferal schizonts, produced by asexual reproduction, are megalospheric.

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

REFERENCES

- Alve E. 1995. Benthic foraminiferal distribution and recolonization of formerly anoxic environments in Drammensfjord, southern Norway. *Marine Micropaleontology*, 25:169–186.
- Alve E, Murray JW. 2001. Temporal variability in vertical distributions of live (stained) intertidal foraminifera, southern England. *Journal of Foraminiferal Research*, 31:12–24.
- Armynot du Châtelet E, et al. 2004. Foraminiferal proxies for pollution monitoring in moderately polluted harbors. *Environmental pollution*, 127(1):27-40.
- Armynot du Châtelet E, et al. 2009. Sediment (grain size and clay mineralogy) and organic matter quality control on living benthic foraminifera. *Revue de micropaléontologie*, 52: 75–84.
- Banner FT, Culver, SJ. 1978. Quaternary *Haynesina* n. gen. and Paleogene *Protoelphidium* Haynes; their morphology, affinities and distribution. *Journal of Foraminiferal Research*, 8(3):177–207.
- Beck M, Brumsack HJ. 2012. Biogeochemical cycles in sediment and water column of the Wadden Sea: The example Spiekeroog Island in a regional context. *Ocean and Coastal Management*, 68:102–113.
- Bijma J, Burhop D. 2010. Ozeanversauerung – das weniger bekannte CO₂ – Problem. *Geographische Rundschau* 5.
- Black KS, et al. 1998. Working with natural cohesive sediments. *J. Hydraulic Eng. Forum* 128:1-7.
- Buzas MA. 1982. Regulation of foraminiferal densities by predation in the Indian River, Florida. *Journal of Foraminiferal Research* 12:66–71.

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

- Calvo-Marcilese L, Langer MR. 2010. Breaching biogeographic barriers: the invasion of *Haynesina germanica* (Foraminifera, Protista) in the Bahía Blanca estuary, Argentina. *Biological Invasions*, 12:3299-3306.
- Cearreta A. 1988. Distribution and ecology of benthic foraminifera in the Santona estuary, Spain. *Revista Espanola de Paleontología* 3:23–38.
- Culver SJ. 1991. Early cambrian foraminifera from west Africa. *Science*, 254(5032):689-691.
- Cushing JM. 1998. *An Introduction to Structured Population Dynamics*. CBMS-NSF Regional Conference Series in Applied Mathematics.
- Debenay JP, et al. 2000. Distribution trends of foraminiferal assemblages in paralic environments. A base for using foraminifera as bioindicators. In: Ronald, E., Kluver, M. (Eds.), *Environmental Micropaleontology*. Geobiology, New York: 39–67.
- Debenay, JP, et al. 2001. Factors determining the distribution of foraminiferal assemblages in Port Joinville Harbor: the influence of pollution: *Marine Micropaleontology*, 43:75–118.
- de Nooijer LJ, et al. 2008. The ecology of benthic foraminifera across the Frisian Front, southern North Sea. *Estuarine, Coastal and Shelf Science*, 78:715-726.
- Dissard D, et al. 2010. The impact of salinity on the Mg/Ca and Sr/Ca ratio in the benthic foraminifera *Ammonia tepida*: Results from culture experiments. *Geochimica et Cosmochimica Acta*, 74: 928–940.
- Diz P. 2004. Foraminiferos benticos en la Ria De Vigo: Unpublished Ph.D. Dissertation, Universidade de Vigo, Spain, 630.
- Diz P, et al. 2009. Interpretation of benthic foraminiferal stable isotopes in subtidal estuarine environments. *Biogeosciences*, 6:2549-2560.

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

- Doney SC. 2006. Ocean Acidification: The Other CO₂ Problem. *Annual Review of Marine Science*, 1:169-192.
- Duijnste IAP, et al. 2003. Effect of anoxia on the vertical migration of benthic foraminifera. *Marine Ecology Progress Series*, 246: 85–94.
- Dyer KR, et al. 2000. The classification of mudflats. *Cont. Shelf Res.* 20:1061-1078.
- Elderfield H, et al. 2006. Calibrations for benthic foraminiferal Mg/Ca paleothermometry and the carbonate ion hypothesis. *Earth Planet Sci Lett*, 250: 633–649.
- Fabry VJ, et al. 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. *ICES J. Mar. Sci.*, 65:414-432.
- Gebhardt K. 2009. Ecology of recent benthic foraminifera and their response to pollution in the harbour of Bolougne-sur- Mer (France). Unpublished Master thesis, University Bonn:112.
- Gooday AJ, et al. 1992. The role of benthic foraminifera in deep-sea food webs and carbon cycling. *Kluwer Academic Publishers Dordrecht*:63–91.
- Graf G. 1992. Benthic-pelagic coupling: a benthic review. *Marine Biology Annual Review Oceanography*, 30:149–190.
- Gruber N, Sarimonto JL. 2002. Sinks for anthropogenic carbon. *Physics Today*, 1-7.
- Hayward BW, et al. 1996. Environmental controls on benthic foraminiferal and Thecamoebian associations in a New Zealand tidal inlet. *Journal of Foraminiferal Research*, 26:150–171.
- Hayward BW, et al. 1997. Recent Elphidiidae (Foraminiferida) of the south-west Pacific and fossil Elphidiidae of New Zealand. *New Zealand Geol. Surv. Paleontol. Bull.*, 72, Institute of Geological and Nuclear Sciences monograph 16.

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

- Hayward BW, et al. 2004. Morphological distinction of molecular types in Ammonia-
towards a taxonomic revision of the world's most commonly misidentified
foraminifera. *Marine Micropaleontology*, 50:237-271.
- Hönisch B, et al. 2008. Modern and Pleistocene boron isotope composition of the
benthic foraminifer *Cibicides wuellerstorfi*. *Earth and Planetary Science
Letters*, 272(1-2):309-318.
- Horton BP, Murray JW. 2007. The roles of elevation and salinity as primary controls on
living foraminiferal distributions: Cowpen Marsh, Tees Estuary, UK. *Marine
Micropaleontology*, 63:169–186.
- Hottinger L, et al. 2001. Spiral canals of some Elphidiidae. *Micropaleontol* 47(2):5–34.
- IPCC. 2007. Contribution of Working Group III to the Fourth Assessment Report of
the Intergovernmental Panel on Climate Change. Cambridge University Press.
- Jorissen FJ. 1999. Benthic foraminiferal microhabitats below the sediment-water
interface. Kluwer Academic Publishers, Dordrecht: 161–179.
- Keeling P. 2004. A brief history of plastids and their hosts. *Protist*, 155:3–7
- Lipps JH. 1970. The role of foraminifera in the trophic structure of marine
communities. *Lethaia*, 3: 279–286.
- Lipps JH. 1983. Biotic interactions in benthic foraminifera. Plenum Press, New York:
331–376.
- Loebl M, et al. 2007. Annual dynamics of pelagic primary production and respiration in
a shallow coastal basin. *Journal of Sea Research* 58:269.
- Loubere P, and Fariduddin M. 1999. Benthic foraminifera and the flux of organic
carbon to the seabed., in Sen Gupta, B. (ed.), *Modern Foraminifera*: Kluwer
Academic Publishers, Dordrecht: 181–199.

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

- Lutze GF. 1965. Zur Foraminiferen: Fauna der Ostsee. *Meyniana*, 15:75–142.
- Martin PA, et al. 2002. Quaternary deep sea temperature histories derived from benthic foraminiferal Mg/Ca. *Earth Planet Sci Lett*, 198:193-209.
- McNeil BI, et al. 2004. Coral reef calcification and climate change: The effect of ocean warming. *Geophysical Research Letters*, 31:L22309.
- Mendes I, et al. 2012. Distribution of living benthic foraminifera on the northern Gulf of Cadiz continental shelf. *Journal of Foraminiferal Research*, 42(1):18–38.
- Moodley L, et al. 1998. Subsurface activity of benthic foraminifera in relation to porewater oxygen content: laboratory experiments. *Mar Micropaleontol*, 34:91–106.
- Munsterman D, Kersthold, S. 1996. Sodium polytungstate, a new non-toxic alternative to bromoform in heavy liquid separation. *Review of Palaeobotany and Palynology*, 91: 417-422.
- Murray JW. 1986. Living and dead Holocene foraminifera of Lyme Bay, Southern England. *Journal of Foraminiferal Research*, 16:347–352.
- Murray JW. 1991. Ecology and paleoecology of benthic foraminifera. Longman, Harlow.
- Murray JW, Bowser SS. 2000. Mortality, protoplasm decay rate, and reliability of staining techniques to recognize ‘living’ foraminifera: a review. *J Foraminiferal Research*, 30:66–70.
- Murray JW. 2001. The niche of benthic foraminifera, critical thresholds and proxies: *Marine Micropaleontology*, 41:1–7.
- Murray JW. 2006. Ecology and Applications of Benthic Foraminifera: Cambridge University Press, Cambridge, 426:1-31.

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany

- Olney M. 2002. MIRACLE. <<http://www.ucl.ac.uk/GeolSci/micropal/foram.html>>. Web. 10 Feb. 2013.
- Pillet L, et al. 2010. Molecular Identification of Sequestered Diatom Chloroplasts and Kleptoplastidy in Foraminifera. *Protist*, 162:394-404.
- Riebeek H. 2011. The Carbon Cycle. NASA, Earth Observatory.
- Sachs HM, et al. 1977. Paleocological Transfer Functions. *Earth Planet Science*, 5:159-178.
- Schafer CT, et al. 1995. Survey of living foraminifera and polychaete populations at some Canadian aquaculture sites: potential for impact mapping and monitoring. *Journal of Foraminiferal Research*, 25:236–259.
- Severin KP, Erskian, MG. 1981. Laboratory experiments on the vertical movement of *Quinqueloculina impressa* Reuss through sand. *J Foraminifer Res*, 11:133–136.
- Stouff V, et al. 1999. Laboratory observations on asexual reproduction (Schizogony) and ontogeny of *Ammonia tepida* with comments on the life cycle. *Journal of Foraminiferal Research*, 29:75–84.
- Stutz ML, Pilkey OH. 2002. Global distribution and morphology of deltaic barrier island systems. *J. Coast. Res.* 36:694-707.
- van der Zwaan GJ, et al. 1999. Benthic foraminifers: proxies or problems? A review of paleoecological concepts. *Earth-Science Reviews*, 46:213–236.
- Wood HL, et al. 2008. Ocean acidification may increase calcification rates, but at a cost. *Proc. Biol. Sci.* 275(1644):1767–1773.
- Yu J, Elderfield, H. 2007. Benthic foraminiferal B/Ca ratios reflect deep water carbonate saturation state. *Earth and Planetary Science Letters*, 258:73-86.

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

Zachos JZ, et al. 2001. Trends, Rhythms, and Aberrations in Global Climate 65 Ma to Present. *Science*, 292(5517):686-693.

Zachos JZ, et al. 2005. Rapid Acidification of the Ocean During the Paleocene-Eocene Thermal Maximum. *Science*, 308:1611-1615.

Zeebe RE, Wolf-Gladrow, DA. 2001. *CO₂ in Seawater: Equilibrium, Kinetics, Isotopes*. Elsevier Oceanography Series, Amsterdam.

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

SUPPLEMENTAL MATERIAL

Excel table with original data:

Table 1. Number of *A. aomoriensis* per cm³ sediment for different size classes

Date/Station		<i>A. aomoriensis</i> (standardized)							
		90-125µm		125-250 µm		250-355µm		>355µm	
20.09.2011		alive	dead	alive	dead	alive	dead	alive	dead
	1	N/A	N/A	5,85	5,85	1,50	1,23	0,04	0,04
	2	0,00	0,00	1,91	2,15	0,85	1,39	0,00	0,00
	3	0,00	0,00	0,79	9,27	0,52	4,39	0,03	0,09
	4	0,00	0,00	0,52	5,84	0,08	0,40	0,00	0,00
	5	0,00	0,00	2,43	2,57	0,71	0,46	0,00	0,00
	6	0,00	0,00	1,33	1,07	0,47	1,37	0,00	0,00
	7	0,00	0,00	0,71	2,45	0,32	1,94	0,00	0,00
	8	0,00	0,00	0,94	3,63	0,06	1,16	0,00	0,00
	9	0,00	0,00	1,04	1,92	0,23	0,27	0,00	0,00
29.11.2011		90-125µm		125-250 µm		250-355µm		355µm	
		alive	dead	alive	dead	alive	dead	alive	dead
	1	N/A	N/A	3,92	3,86	1,39	0,58	0,00	0,03
	2	N/A	N/A	0,77	6,31	0,43	2,49	0,00	0,00
	3	0,65	1,43	0,92	2,19	0,41	0,89	0,00	0,08
	4	0,47	1,37	0,43	6,03	0,07	0,60	0,00	0,00
	5	1,22	4,44	1,28	4,91	0,38	1,03	0,00	0,00
	6	2,69	1,94	2,94	8,13	1,09	1,22	0,09	0,00
	7	2,93	9,47	2,07	11,93	0,33	2,30	0,00	0,00
	8	2,87	4,33	1,67	11,27	0,70	1,60	0,00	0,03
9	2,80	1,87	2,13	9,00	0,33	0,37	0,00	0,00	

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

	90-125µm		125-250 µm		250-355µm		355µm	
19.12.2011	alive	dead	alive	dead	alive	dead	alive	dead
1	5,00	1,80	10,30	5,10	1,10	0,25	0,00	0,00
2	3,40	1,60	5,40	4,95	0,50	1,15	0,05	0,00
3	1,40	1,80	1,40	9,20	0,15	2,90	0,00	0,00
4	2,80	2,60	1,10	8,10	0,15	0,30	0,00	0,00
5	0,73	1,09	1,91	2,73	0,32	0,32	0,00	0,00
6	4,00	3,60	3,50	3,70	0,90	0,75	0,00	0,00
7	0,95	1,90	0,95	0,67	0,29	0,38	0,05	0,00
8	1,82	0,91	1,36	3,91	0,68	1,00	0,00	0,00
9	0,80	1,80	1,70	2,70	0,45	0,70	0,00	0,00
	90-125µm		125-250 µm		250-355µm		355µm	
04.01.2012	alive	dead	alive	dead	alive	dead	alive	dead
1	0,80	0,60	1,45	1,55	0,20	0,15	0,00	0,00
6	2,00	0,50	3,65	0,40	0,75	0,20	0,00	0,00
8	1,85	0,75	2,00	0,85	0,60	1,15	0,00	0,00
9	1,71	0,00	1,57	1,00	0,19	0,05	0,00	0,00
	90-125µm		125-250 µm		250-355µm		355µm	
16.01.2012	alive	dead	alive	dead	alive	dead	alive	dead
1	6,16	0,88	5,04	3,76	3,04	0,56	0,08	0,16
6	0,75	0,25	1,21	0,79	0,29	0,04	0,00	0,00
8	0,67	0,33	0,42	0,63	0,13	0,21	0,00	0,00
9	0,77	0,32	0,77	2,41	0,32	0,14	0,00	0,00
	90-125µm		125-250 µm		250-355µm		355µm	
30.01.2012	alive	dead	alive	dead	alive	dead	alive	dead
1	0,48	0,29	0,05	0,90	0,05	0,48	0,00	0,00
9	0,38	0,05	0,24	0,86	0,14	0,95	0,00	0,00
	90-125µm		125-250 µm		250-355µm		355µm	
14.02.2012	alive	dead	alive	dead	alive	dead	alive	dead
1	1,65	0,41	0,88	0,65	0,53	0,35	0,00	0,00
6	0,75	0,25	0,65	0,55	0,05	0,65	0,00	0,00
8	0,75	0,17	0,75	0,21	0,13	0,38	0,00	0,00
9	1,15	0,40	0,55	0,15	0,15	0,15	0,00	0,00

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

	90-125µm		125-250 µm		250-355µm		355µm	
27.02.2012	alive	dead	alive	dead	alive	dead	alive	dead
1	3,00	0,62	0,71	19,57	0,33	5,43	0,00	0,05
6	0,74	0,59	0,30	0,78	0,04	0,19	0,00	0,04
8	0,93	0,33	0,19	0,67	0,11	0,41	0,00	0,00
9	1,00	0,29	0,57	0,95	0,19	0,67	0,10	0,00
	90-125µm		125-250 µm		250-355µm		355µm	
13.03.2012	alive	dead	alive	dead	alive	dead	alive	dead
1	0,84	0,65	1,68	1,23	0,48	1,16	0,00	0,06
6	0,43	0,18	1,07	0,54	0,00	0,39	0,00	0,00
8	0,16	0,10	1,13	0,90	0,26	0,32	0,00	0,00
9	0,67	0,38	1,81	1,43	0,48	0,48	0,05	0,00
	90-125µm		125-250 µm		250-355µm		355µm	
27.03.2012	alive	dead	alive	dead	alive	dead	alive	dead
1	1,29	0,50	4,79	1,17	0,92	0,46	0,17	0,00
6	0,15	0,11	1,26	0,41	0,37	0,30	0,00	0,04
8	0,58	0,08	2,21	0,33	0,54	0,17	0,04	0,00
9	1,17	0,21	3,83	0,54	0,92	0,08	0,08	0,00
	90-125µm		125-250 µm		250-355µm		355µm	
13.04.2012	alive	dead	alive	dead	alive	dead	alive	dead
1	4,90	0,30	9,75	1,05	3,15	0,35	0,55	0,00
6	4,48	0,26	5,83	0,52	2,30	0,39	0,17	0,13
8	4,20	0,28	6,52	0,72	1,64	0,28	0,08	0,00
9	6,60	0,44	11,32	1,72	2,72	0,12	0,20	0,00
	90-125µm		125-250 µm		250-355µm		355µm	
24.04.2012	alive	dead	alive	dead	alive	dead	alive	dead
1	4,79	0,46	4,46	0,96	1,17	0,33	0,00	0,00
6	6,20	0,36	3,40	1,32	0,60	0,16	0,00	0,00
8	7,33	0,50	4,67	1,71	1,21	0,25	0,08	0,00
9	12,96	1,58	6,88	1,00	2,46	0,46	0,21	0,04

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

	90-125µm		125-250 µm		250-355µm		355µm	
10.05.2012	alive	dead	alive	dead	alive	dead	alive	dead
1	22,86	2,29	14,11	1,07	4,93	0,21	0,18	0,00
6	16,40	0,88	7,80	2,32	1,52	0,44	0,04	0,00
8	3,44	0,32	2,68	1,36	0,56	0,36	0,08	0,00
9	16,00	0,48	9,64	2,20	3,36	0,40	0,00	0,04
	90-125µm		125-250 µm		250-355µm		355µm	
24.05.2012	alive	dead	alive	dead	alive	dead	alive	dead
1	37,50	2,50	46,50	6,56	2,75	0,47	0,22	0,03
6	23,91	2,17	31,30	3,91	6,48	0,48	0,65	0,00
8	32,58	2,19	31,94	2,74	3,84	0,74	0,26	0,03
9	35,52	2,79	30,86	2,52	3,31	0,76	0,38	0,00
	90-125µm		125-250 µm		250-355µm		355µm	
12.06.2012	alive	dead	alive	dead	alive	dead	alive	dead
1	30,95	2,14	44,76	9,05	13,95	1,24	1,00	0,05
6	17,50	1,25	40,83	3,33	9,29	1,58	0,21	0,00
8	24,62	1,73	35,38	2,69	9,77	1,00	0,23	0,00
9	20,00	1,52	30,52	3,79	8,21	1,34	0,14	0,03
	90-125µm		125-250 µm		250-355µm		355µm	
09.07.2012	alive	dead	alive	dead	alive	dead	alive	dead
1	2,67	0,23	17,67	7,00	4,97	2,93	0,07	0,00
6	2,60	0,16	6,00	3,20	0,80	1,36	0,04	0,04
8	6,06	0,24	12,12	2,73	4,94	1,15	0,33	0,15
9	6,21	0,28	12,24	3,28	3,79	1,03	0,17	0,03

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

Table 2. Number of *H. germanica* per cm³ sediment for different size classes

Date/Station		<i>Haynesina germanica</i> (standardized)							
		90-125µm		125-250µm		250-355µm		>355µm	
		alive	dead	alive	dead	alive	dead	alive	dead
20.09.2011									
	1	N/A	N/A	0,35	0,62	0,04	0,08	0,00	0,00
	2	0,00	0,00	0,09	0,24	0,03	0,12	0,00	0,00
	3	0,00	0,00	0,85	20,36	0,06	0,33	0,00	0,00
	4	0,00	0,00	0,76	2,56	0,00	0,28	0,00	0,00
	5	0,00	0,00	0,86	1,71	0,00	0,07	0,00	0,00
	6	0,00	0,00	4,40	1,53	0,37	0,17	0,00	0,00
	7	0,00	0,00	2,00	2,58	0,03	0,26	0,00	0,00
	8	0,00	0,00	1,94	2,25	0,06	0,16	0,00	0,00
	9	0,00	0,00	1,46	1,23	0,04	0,08	0,00	0,00
		90-125µm		125-250 µm		250-355µm		355µm	
29.11.2011									
	1	N/A	N/A	0,92	2,00	0,06	0,11	0,00	0,00
	2	N/A	N/A	0,34	3,20	0,03	0,31	0,00	0,00
	3	0,27	1,03	0,49	2,51	0,00	0,19	0,00	0,03
	4	0,37	2,13	0,23	3,87	0,00	0,03	0,00	0,00
	5	0,88	10,19	0,78	5,13	0,06	0,41	0,00	0,00
	6	2,63	5,75	1,63	3,94	0,16	0,28	0,00	0,00
	7	2,73	10,80	2,60	12,53	0,23	0,33	0,00	0,10
	8	0,87	7,33	2,67	11,27	0,10	0,20	0,00	0,00
	9	1,33	5,47	1,00	7,07	0,20	0,17	0,00	0,00
		90-125µm		125-250 µm		250-355µm		355µm	
19.12.2011									
	1	1,40	2,20	3,40	0,10	0,10	0,00	0,00	0,00
	2	2,20	2,40	2,80	3,90	0,10	0,55	0,00	0,00
	3	1,60	1,80	2,30	12,10	0,15	1,60	0,00	0,00
	4	2,00	2,20	1,30	9,40	0,00	0,35	0,00	0,00
	5	0,18	0,91	1,18	2,73	0,05	0,00	0,00	0,00
	6	1,60	2,20	3,50	2,50	0,20	0,10	0,00	0,00
	7	1,14	1,71	1,14	0,48	0,14	0,10	0,00	0,00
	8	0,91	1,27	1,64	2,18	0,00	0,05	0,00	0,00
	9	0,40	1,00	1,20	1,60	0,10	0,05	0,00	0,00

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

	90-125µm		125-250 µm		250-355µm		355µm	
04.01.2012	alive	dead	alive	dead	alive	dead	alive	dead
1	0,60	0,60	0,55	0,75	0,15	0,15	0,00	0,00
6	0,80	0,30	0,75	0,50	0,10	0,15	0,00	0,00
8	0,75	0,55	1,30	0,25	0,10	0,20	0,00	0,00
9	0,95	0,00	1,67	0,86	0,05	0,00	0,00	0,00
	90-125µm		125-250 µm		250-355µm		355µm	
16.01.2012	alive	dead	alive	dead	alive	dead	alive	dead
1	0,72	0,24	0,88	0,48	0,20	0,12	0,00	0,00
6	0,21	0,29	0,17	0,33	0,13	0,04	0,00	0,00
8	0,17	0,38	0,21	0,63	0,04	0,04	0,00	0,00
9	0,36	0,45	0,77	1,45	0,00	0,14	0,00	0,00
	90-125µm		125-250 µm		250-355µm		355µm	
30.01.2012	alive	dead	alive	dead	alive	dead	alive	dead
1	0,19	0,43	0,14	0,71	0,00	0,14	0,00	0,00
9	0,24	0,33	0,29	0,62	0,00	0,10	0,00	0,00
	90-125µm		125-250 µm		250-355µm		355µm	
14.02.2012	alive	dead	alive	dead	alive	dead	alive	dead
1	0,41	0,53	0,53	1,06	0,06	0,12	0,00	0,00
6	0,40	0,10	1,05	0,25	0,00	0,20	0,00	0,00
8	0,33	0,13	0,13	0,13	0,00	0,00	0,00	0,00
9	0,10	0,25	0,10	0,90	0,00	0,10	0,00	0,00
	90-125µm		125-250 µm		250-355µm		355µm	
27.02.2012	alive	dead	alive	dead	alive	dead	alive	dead
1	0,24	0,38	0,52	31,10	0,38	0,24	0,00	0,00
6	0,19	0,41	0,41	0,56	0,00	0,04	0,00	0,00
8	0,22	0,30	0,15	0,41	0,00	0,04	0,00	0,00
9	0,14	0,19	0,62	0,38	0,00	0,10	0,00	0,00
	90-125µm		125-250 µm		250-355µm		355µm	
13.03.2012	alive	dead	alive	dead	alive	dead	alive	dead
1	0,19	0,13	1,03	0,71	0,16	0,23	0,00	0,00
6	0,36	0,29	0,39	0,29	0,00	0,07	0,00	0,00

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

8	0,13	0,13	0,58	0,42	0,23	0,19	0,00	0,00
9	0,76	0,52	1,19	0,52	0,14	0,19	0,00	0,00

		90-125µm		125-250 µm		250-355µm		355µm	
		alive	dead	alive	dead	alive	dead	alive	dead
27.03.2012									
1		0,58	0,33	0,63	0,33	0,00	0,13	0,00	0,00
6		0,11	0,07	1,04	0,22	0,15	0,11	0,00	0,00
8		0,50	0,17	2,04	0,38	0,63	0,25	0,00	0,00
9		0,92	0,25	1,25	0,13	0,08	0,04	0,00	0,00

		90-125µm		125-250 µm		250-355µm		355µm	
		alive	dead	alive	dead	alive	dead	alive	dead
13.04.2012									
1		4,25	0,35	3,25	0,45	0,40	0,15	0,05	0,00
6		4,78	0,13	8,17	0,91	1,35	0,22	0,00	0,00
8		3,92	0,36	5,24	0,68	1,44	0,32	0,00	0,00
9		5,72	0,28	5,96	1,16	1,52	0,08	0,00	0,00

		90-125µm		125-250 µm		250-355µm		355µm	
		alive	dead	alive	dead	alive	dead	alive	dead
24.04.2012									
1		4,08	0,33	2,08	0,33	0,71	0,25	0,00	0,00
6		6,48	0,36	1,52	1,28	0,24	0,16	0,00	0,00
8		6,38	0,33	2,42	1,00	0,71	0,33	0,00	0,00
9		14,29	1,42	5,79	1,21	1,00	0,21	0,00	0,00

		90-125µm		125-250 µm		250-355µm		355µm	
		alive	dead	alive	dead	alive	dead	alive	dead
10.05.2012									
1		24,29	1,71	12,50	2,29	2,75	0,14	0,00	0,00
6		17,60	0,96	7,48	1,92	0,28	0,44	0,00	0,00
8		2,64	0,24	3,52	2,52	0,60	0,44	0,00	0,00
9		14,40	0,40	7,68	1,68	0,24	0,12	0,00	0,00

		90-125µm		125-250 µm		250-355µm		355µm	
		alive	dead	alive	dead	alive	dead	alive	dead
24.05.2012									
1		40,63	2,50	30,63	5,94	0,00	0,84	0,00	0,00
6		26,09	2,61	49,30	6,09	0,13	0,65	0,00	0,00
8		33,23	1,42	32,58	3,94	0,19	0,32	0,00	0,00
9		37,24	1,66	38,97	3,97	0,28	0,17	0,00	0,00

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

		90-125µm		125-250 µm		250-355µm		355µm	
		alive	dead	alive	dead	alive	dead	alive	dead
12.06.2012									
	1	29,05	2,38	45,24	8,57	0,19	1,67	0,00	0,00
	6	16,67	1,92	46,67	10,42	0,58	0,38	0,00	0,00
	8	20,38	2,12	41,15	5,77	0,38	0,58	0,00	0,00
	9	21,21	1,59	34,14	4,48	0,62	0,34	0,00	0,00
		90-125µm		125-250 µm		250-355µm		355µm	
		alive	dead	alive	dead	alive	dead	alive	dead
09.07.2012									
	1	2,50	0,30	8,33	5,67	0,13	0,27	0,00	0,00
	6	2,40	0,12	14,80	3,80	0,08	0,52	0,00	0,00
	8	6,36	0,21	9,39	2,73	0,24	0,45	0,00	0,00
	9	3,45	0,28	11,03	3,62	0,17	0,34	0,00	0,00

Table 3. Number of *E. williamsoni* per cm³ sediment for different size classes

<i>Elphidium williamsoni</i> (standardized)									
Date/Station		90-125µm		125-250µm		250-355µm		>355µm	
		alive	dead	alive	dead	alive	dead	alive	dead
20.09.2011									
	1	N/A	N/A	90,62	8,31	5,85	1,85	0,04	0,04
	2	0,00	0,00	33,18	5,91	2,73	1,30	0,03	0,06
	3	0,00	0,00	52,42	10,61	3,67	4,30	0,00	0,12
	4	0,00	0,00	1,80	2,04	0,00	0,08	0,04	0,00
	5	0,00	0,00	87,93	2,29	5,11	0,79	0,04	0,00
	6	0,00	0,00	66,93	2,87	13,30	1,63	0,13	0,00
	7	0,00	0,00	45,16	3,10	4,10	1,81	0,00	0,03
	8	0,00	0,00	22,25	2,50	4,16	4,84	0,00	0,06
	9	0,00	0,00	14,54	2,23	2,00	0,38	0,00	0,00

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

		90-125µm		125-250 µm		250-355µm		355µm	
		alive	dead	alive	dead	alive	dead	alive	dead
29.11.2011	1	N/A	N/A	9,83	3,81	5,08	0,78	0,00	0,08
	2	N/A	N/A	3,91	4,46	1,29	2,57	0,00	0,00
	3	0,19	0,51	1,19	1,62	1,08	1,73	0,03	0,08
	4	0,00	0,33	0,07	2,50	0,03	0,80	0,00	0,03
	5	0,00	0,69	5,91	4,31	3,50	1,19	0,00	0,00
	6	0,00	1,81	5,75	6,56	9,47	2,25	0,06	0,06
	7	0,00	1,33	10,60	10,13	8,37	2,87	0,00	0,13
	8	0,00	1,60	6,47	7,80	11,07	5,87	0,03	0,13
	9	0,27	1,47	2,53	4,00	3,97	0,70	0,00	0,07
		90-125µm		125-250 µm		250-355µm		355µm	
		alive	dead	alive	dead	alive	dead	alive	dead
19.12.2011	1	0,40	0,40	23,40	2,50	7,75	0,50	0,00	0,00
	2	0,00	0,20	2,60	3,45	1,00	1,80	0,00	0,00
	3	0,00	0,10	0,70	1,80	0,15	3,50	0,00	0,15
	4	0,00	0,20	0,20	2,40	0,05	0,45	0,00	0,00
	5	0,00	0,18	1,73	1,18	1,27	0,18	0,00	0,00
	6	0,00	0,60	4,50	3,10	9,65	0,80	0,00	0,00
	7	0,00	0,19	10,95	0,86	8,57	0,33	0,00	0,00
	8	0,00	0,18	5,64	3,91	6,09	1,86	0,00	0,05
	9	0,00	0,40	5,10	4,10	2,25	0,90	0,00	0,00
		90-125µm		125-250 µm		250-355µm		355µm	
		alive	dead	alive	dead	alive	dead	alive	dead
04.01.2012	1	0,00	0,00	2,60	1,35	0,70	0,25	0,00	0,00
	6	0,00	0,30	6,60	0,55	13,65	0,55	0,00	0,00
	8	0,15	0,25	8,20	1,80	11,05	1,00	0,00	0,05
	9	0,00	0,38	2,52	0,57	1,95	0,67	0,00	0,00
		90-125µm		125-250 µm		250-355µm		355µm	
		alive	dead	alive	dead	alive	dead	alive	dead
16.01.2012	1	0,24	0,16	53,76	1,72	35,28	2,20	0,08	0,16
	6	0,17	0,29	8,00	1,50	10,42	0,29	0,00	0,00
	8	0,13	0,17	1,96	0,79	2,50	0,42	0,00	0,00
	9	0,23	0,23	0,86	0,73	0,55	0,50	0,00	0,00

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

		90-125µm		125-250 µm		250-355µm		355µm	
30.01.2012		alive	dead	alive	dead	alive	dead	alive	dead
	1	0,19	0,33	13,14	0,71	7,43	0,52	0,05	0,00
	9	0,19	0,19	1,57	1,00	3,76	0,71	0,00	0,00
		90-125µm		125-250 µm		250-355µm		355µm	
14.02.2012		alive	dead	alive	dead	alive	dead	alive	dead
	1	0,35	0,47	8,12	1,59	6,18	0,76	0,12	0,00
	6	0,15	0,05	2,50	0,65	4,85	0,75	0,10	0,00
	8	0,04	0,21	2,13	0,29	3,83	0,46	0,00	0,00
	9	0,10	0,15	2,70	0,55	2,25	0,75	0,00	0,00
		90-125µm		125-250 µm		250-355µm		355µm	
27.02.2012		alive	dead	alive	dead	alive	dead	alive	dead
	1	0,14	0,24	3,57	4,00	3,43	1,90	0,05	0,05
	6	0,04	0,33	3,48	1,07	6,48	0,15	0,00	0,00
	8	0,15	0,33	2,30	0,59	2,85	0,37	0,00	0,00
	9	0,29	0,48	4,90	0,86	10,57	0,67	0,19	0,00
		90-125µm		125-250 µm		250-355µm		355µm	
13.03.2012		alive	dead	alive	dead	alive	dead	alive	dead
	1	0,32	0,26	17,10	2,71	27,52	1,26	0,16	0,10
	6	0,11	0,18	2,39	0,43	15,00	0,43	0,14	0,00
	8	0,16	0,10	4,26	1,06	10,19	0,94	0,10	0,06
	9	0,52	0,24	3,48	1,19	13,81	1,05	0,29	0,10
		90-125µm		125-250 µm		250-355µm		355µm	
27.03.2012		alive	dead	alive	dead	alive	dead	alive	dead
	1	0,67	0,33	2,21	0,75	7,13	0,75	0,00	0,00
	6	0,07	0,11	0,74	0,30	10,22	4,48	0,70	0,11
	8	0,13	0,08	1,04	0,04	5,71	0,83	0,13	0,00
	9	0,63	0,21	0,63	0,25	1,46	0,50	0,21	0,04

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

		90-125µm		125-250 µm		250-355µm		355µm	
		alive	dead	alive	dead	alive	dead	alive	dead
13.04.2012									
	1	1,15	0,15	2,95	0,50	20,60	5,95	0,80	0,00
	6	1,13	0,17	1,48	0,22	15,57	6,09	1,52	0,61
	8	0,72	0,20	1,80	0,16	15,52	4,44	0,04	0,04
	9	2,12	0,32	1,36	0,08	5,80	3,84	0,36	0,04

		90-125µm		125-250 µm		250-355µm		355µm	
		alive	dead	alive	dead	alive	dead	alive	dead
24.04.2012									
	1	0,67	0,13	0,83	0,29	4,17	0,88	0,25	0,00
	6	1,72	0,28	0,08	0,28	0,84	5,64	0,16	0,56
	8	2,00	0,46	0,50	0,58	1,63	4,29	0,00	0,08
	9	3,50	1,08	1,04	0,25	4,54	6,29	0,46	0,13

		90-125µm		125-250 µm		250-355µm		355µm	
		alive	dead	alive	dead	alive	dead	alive	dead
10.05.2012									
	1	13,57	1,71	1,14	1,39	5,89	2,07	0,21	0,00
	6	4,80	0,32	3,44	2,88	1,84	10,64	0,24	1,36
	8	1,20	0,16	1,20	1,68	1,00	2,76	0,12	0,24
	9	5,60	0,24	5,24	1,32	0,84	5,16	0,08	0,20

		90-125µm		125-250 µm		250-355µm		355µm	
		alive	dead	alive	dead	alive	dead	alive	dead
24.05.2012									
	1	4,69	0,94	4,38	0,94	0,75	3,00	0,00	0,03
	6	4,78	0,43	12,17	1,96	3,43	6,13	0,52	0,22
	8	5,16	0,26	3,55	1,03	0,97	2,74	0,10	0,03
	9	5,31	0,48	5,03	1,48	1,14	3,21	0,17	0,07

		90-125µm		125-250 µm		250-355µm		355µm	
		alive	dead	alive	dead	alive	dead	alive	dead
12.06.2012									
	1	6,19	0,71	15,24	8,10	3,29	25,29	0,19	0,95
	6	5,00	0,58	11,25	7,92	3,00	10,63	0,04	0,25
	8	5,58	0,69	12,12	6,35	2,62	12,69	0,12	0,31
	9	4,31	0,52	9,83	6,72	2,93	6,72	0,00	0,10

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

09.07.2012	90-125µm		125-250 µm		250-355µm		355µm	
	alive	dead	alive	dead	alive	dead	alive	dead
1	1,50	0,17	1,50	2,17	0,30	3,70	0,03	0,03
6	1,60	0,12	8,40	3,32	0,20	3,76	0,04	0,16
8	2,12	0,24	1,06	2,12	0,18	2,00	0,03	0,18
9	1,90	0,10	1,83	2,24	0,31	2,93	0,03	0,10

Excel table with Residual data:

Residual data of *A. aomoriensis*:

date	Julian day	sampling day	size fraction	individuals in size fraction	relative abundance	residuals	residuals%
20.09.2011	40806	1	90	0	0	- 0,01612903	-100
29.11.2011	40876	71	90	0	0	- 0,01612903	-100
19.12.2011	40896	91	90	5	0,01246685	- 0,00366218	- 22,7055166
04.01.2012	40912	107	90	0,8	0,0019947	- 0,01413434	- 87,6328827
16.01.2012	40924	119	90	6,16	0,01535916	- 0,00076987	- 4,77319648
30.01.2012	40938	133	90	0,47619048	0,00118732	- 0,01494171	- 92,6386206
14.02.2012	40953	148	90	1,64705882	0,00410673	-0,0120223	- 74,5382878
27.02.2012	40966	161	90	3	0,00748011	- 0,00864892	-53,62331
13.03.2012	40981	176	90	0,83870968	0,00209121	- 0,01403782	- 87,0344738
27.03.2012	40995	190	90	1,29166667	0,0032206	- 0,01290843	- 80,0322585

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

13.04.2012	41012	207	90	4,9	0,01221752	-	-
						0,00391152	24,2514063
24.04.2012	41023	218	90	4,79166667	0,0119474	-	-
						0,00418163	25,9261201
10.05.2012	41039	234	90	22,8571429	0,05699132	0,04086229	253,34621
24.05.2012	41053	248	90	37,5	0,09350139	0,07737236	479,708625
12.06.2012	41072	267	90	30,952381	0,07717575	0,06104672	378,489659
09.07.2012	41099	294	90	2,66666667	0,00664899	-	-
						0,00948004	58,7762755
20.09.2011	40806	1	90	0	0	-	-100
						0,01612903	
29.11.2011	40876	71	90	2,6875	0,00670093	-0,0094281	-
							58,4542152
19.12.2011	40896	91	90	4	0,00997348	-	-
						0,00615555	38,1644133
04.01.2012	40912	107	90	2	0,00498674	-	-
						0,01114229	69,0822066
16.01.2012	40924	119	90	0,75	0,00187003	-0,014259	-
							88,4058275
14.02.2012	40953	148	90	0,75	0,00187003	-0,014259	-
							88,4058275
27.02.2012	40966	161	90	0,74074074	0,00184694	-	-
						0,01428209	88,5489654
13.03.2012	40981	176	90	0,42857143	0,00106859	-	-
						0,01506044	93,3747586
27.03.2012	40995	190	90	0,14814815	0,00036939	-	-
						0,01575964	97,7097931
13.04.2012	41012	207	90	4,47826087	0,01116596	-	-
						0,00496307	30,7710279
24.04.2012	41023	218	90	6,2	0,0154589	-	-
						0,00067014	4,15484061
10.05.2012	41039	234	90	16,4	0,04089128	0,02476224	153,525905
24.05.2012	41053	248	90	23,9130435	0,05962408	0,04349504	269,669268
12.06.2012	41072	267	90	17,5	0,04363398	0,02750495	170,530692
09.07.2012	41099	294	90	2,6	0,00648276	-	-
						0,00964627	59,8068686
20.09.2011	40806	1	90	0	0	-	-100
						0,01612903	
29.11.2011	40876	71	90	2,86666667	0,00714766	-	-
						0,00898137	55,6844962
19.12.2011	40896	91	90	1,81818182	0,0045334	-	-

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

						0,01159563	71,8929151
04.01.2012	40912	107	90	1,85	0,00461274	-0,0115163	- 71,4010412
16.01.2012	40924	119	90	0,66666667	0,00166225	- 0,01446679	- 89,6940689
14.02.2012	40953	148	90	0,75	0,00187003	-0,014259	- 88,4058275
27.02.2012	40966	161	90	0,92592593	0,00230868	- 0,01382036	- 85,6862068
13.03.2012	40981	176	90	0,16129032	0,00040216	- 0,01572688	- 97,5066296
27.03.2012	40995	190	90	0,58333333	0,00145447	- 0,01467457	- 90,9823103
13.04.2012	41012	207	90	4,2	0,01047216	- 0,00565688	- -35,072634
24.04.2012	41023	218	90	7,33333333	0,01828472	0,00215568	13,3652423
10.05.2012	41039	234	90	3,44	0,00857719	- 0,00755184	- 46,8213954
24.05.2012	41053	248	90	32,5806452	0,08123562	0,06510659	403,660827
12.06.2012	41072	267	90	24,6153846	0,06137527	0,04524624	280,526687
09.07.2012	41099	294	90	6,06060606	0,01511134	-0,0010177	- 6,30971712
20.09.2011	40806	1	90	0	0	- 0,01612903	-100
29.11.2011	40876	71	90	2,8	0,00698144	-0,0091476	- 56,7150893
19.12.2011	40896	91	90	0,8	0,0019947	- 0,01413434	- 87,6328827
04.01.2012	40912	107	90	1,71428571	0,00427435	- 0,01185468	- 73,4990343
16.01.2012	40924	119	90	0,77272727	0,0019267	- 0,01420234	- 88,0544889
30.01.2012	40938	133	90	0,38095238	0,00094986	- 0,01517918	- 94,1108965
14.02.2012	40953	148	90	1,15	0,00286738	- 0,01326166	- 82,2222688
27.02.2012	40966	161	90	1	0,00249337	- 0,01363566	- 84,5411033
13.03.2012	40981	176	90	0,66666667	0,00166225	- 0,01446679	- 89,6940689
27.03.2012	40995	190	90	1,16666667	0,00290893	-0,0132201	- 81,9646205

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

13.04.2012	41012	207	90	6,6	0,01645624	0,00032721	2,02871806
24.04.2012	41023	218	90	12,9583333	0,03230993	0,01618089	100,321536
10.05.2012	41039	234	90	16	0,03989393	0,02376489	147,342347
24.05.2012	41053	248	90	35,5172414	0,08855764	0,07242861	449,057365
12.06.2012	41072	267	90	20	0,04986741	0,03373838	209,177934
09.07.2012	41099	294	90	6,20689655	0,01547609	-	-
						0,00065294	4,04822753
				401,063551	0,01612903		
20.09.2011	40806	1	125	5,84615385	0,01163138	-	-27,88545
						0,00449765	
29.11.2011	40876	71	125	3,91666667	0,00779251	-	-
						0,00833652	51,6864144
19.12.2011	40896	91	125	10,3	0,02049265	0,00436362	27,0544505
04.01.2012	40912	107	125	1,45	0,00288489	-	-
						0,01324414	82,1136939
16.01.2012	40924	119	125	5,04	0,01002747	-	-
						0,00610156	37,8296669
30.01.2012	40938	133	125	0,04761905	9,4742E-05	-	-
						0,01603429	99,4126008
14.02.2012	40953	148	125	0,88235294	0,00175551	-	-89,115838
						0,01437352	
27.02.2012	40966	161	125	0,71428571	0,00142113	-	-
						0,01470791	91,1890118
13.03.2012	40981	176	125	1,67741935	0,00333736	-	-
						0,01279168	79,3083889
27.03.2012	40995	190	125	4,79166667	0,00953339	-	-
						0,00659564	40,8929538
13.04.2012	41012	207	125	9,75	0,01939839	0,00326935	20,2699896
24.04.2012	41023	218	125	4,45833333	0,0088702	-	-
						0,00725883	45,0047484
10.05.2012	41039	234	125	14,1071429	0,02806726	0,01193823	74,0170179
24.05.2012	41053	248	125	46,5	0,09251538	0,07638634	473,595335
12.06.2012	41072	267	125	44,7619048	0,0890573	0,07292827	452,155263
09.07.2012	41099	294	125	17,6666667	0,03514921	0,01902018	117,925109
20.09.2011	40806	1	125	1,33333333	0,00265277	-	-
						0,01347626	83,5528219
29.11.2011	40876	71	125	2,9375	0,00584439	-	-
						0,01028465	63,7648108
19.12.2011	40896	91	125	3,5	0,00696352	-	-
						0,00916551	56,8261576

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

04.01.2012	40912	107	125	3,65	0,00726196	-	-
						0,00886707	54,9758501
16.01.2012	40924	119	125	1,20833333	0,00240407	-	-
						0,01372496	85,0947449
14.02.2012	40953	148	125	0,65	0,00129323	-	-
						0,01483581	91,9820007
27.02.2012	40966	161	125	0,2962963	0,0005895	-	-
						0,01553953	96,3450715
13.03.2012	40981	176	125	1,07142857	0,00213169	-	-
						0,01399734	86,7835176
27.03.2012	40995	190	125	1,25925926	0,00250539	-	-
						0,01362364	84,4665541
13.04.2012	41012	207	125	5,82608696	0,01159145	-	-
						0,00453758	28,1329828
24.04.2012	41023	218	125	3,4	0,00676457	-	-
						0,00936447	58,0596959
10.05.2012	41039	234	125	7,8	0,01551871	-	-
						0,00061032	3,78400835
24.05.2012	41053	248	125	31,3043478	0,06228244	0,04615341	286,151137
12.06.2012	41072	267	125	40,83333333	0,0812411	0,06511207	403,694828
09.07.2012	41099	294	125	6	0,01193747	-	-
						0,00419156	25,9876987
20.09.2011	40806	1	125	0,9375	0,00186523	-0,0142638	-
							88,4355779
29.11.2011	40876	71	125	1,66666667	0,00331596	-	-
						0,01281307	79,4410274
19.12.2011	40896	91	125	1,36363636	0,00271306	-	-
						0,01341597	83,1790224
04.01.2012	40912	107	125	2	0,00397916	-	-
						0,01214988	75,3292329
16.01.2012	40924	119	125	0,41666667	0,00082899	-	-
						0,01530004	94,8602569
14.02.2012	40953	148	125	0,75	0,00149218	-	-
						0,01463685	90,7484623
27.02.2012	40966	161	125	0,18518519	0,00036844	-	-
						0,01576059	97,7156697
13.03.2012	40981	176	125	1,12903226	0,0022463	-	-
						0,01388273	86,0729541
27.03.2012	40995	190	125	2,20833333	0,00439365	-	-
						0,01173538	72,7593613
13.04.2012	41012	207	125	6,52	0,01297205	-	-
						0,00315698	19,5732993
24.04.2012	41023	218	125	4,66666667	0,0092847	-	-

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

						0,00684433	42,4348768
10.05.2012	41039	234	125	2,68	0,00533207	-	-
						0,01079696	66,9411721
24.05.2012	41053	248	125	31,9354839	0,06353814	0,0474091	293,936442
12.06.2012	41072	267	125	35,3846154	0,07040045	0,05427142	336,482802
09.07.2012	41099	294	125	12,1212121	0,0241161	0,00798706	49,5198006
20.09.2011	40806	1	125	1,03846154	0,0020661	-	-
						0,01406293	87,1901786
29.11.2011	40876	71	125	2,13333333	0,00424443	-0,0118846	-
							73,6845151
19.12.2011	40896	91	125	1,7	0,00338228	-	-79,029848
						0,01274675	
04.01.2012	40912	107	125	1,57142857	0,00312648	-	-
						0,01300255	80,6158259
16.01.2012	40924	119	125	0,77272727	0,0015374	-	-
						0,01459163	90,4681127
30.01.2012	40938	133	125	0,23809524	0,00047371	-	-
						0,01565532	97,0630039
14.02.2012	40953	148	125	0,55	0,00109427	-	-
						0,01503476	93,2155391
27.02.2012	40966	161	125	0,57142857	0,0011369	-	-
						0,01499213	92,9512094
13.03.2012	40981	176	125	1,80952381	0,00360019	-	-
						0,01252884	77,6788298
27.03.2012	40995	190	125	3,83333333	0,00762672	-	-
						0,00850232	52,7143631
13.04.2012	41012	207	125	11,32	0,02252202	0,00639299	39,6365417
24.04.2012	41023	218	125	6,875	0,01367835	-	-
						0,00245068	15,1942381
10.05.2012	41039	234	125	9,64	0,01917953	0,0030505	18,9130974
24.05.2012	41053	248	125	30,862069	0,06140249	0,04527346	280,695458
12.06.2012	41072	267	125	30,5172414	0,06071643	0,0445874	276,441877
09.07.2012	41099	294	125	12,2413793	0,02435518	0,00822615	51,0021089
			125	502,619151	0,01612903		
20.09.2011	40806	1	250	1,5	0,01229962	-	-
						0,00382951	23,7427978
29.11.2011	40876	71	250	1,38888889	0,01138854	-	-
						0,00474059	29,3914795
19.12.2011	40896	91	250	1,1	0,00901972	-0,0071094	-
							44,0780517

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

04.01.2012	40912	107	250	0,2	0,00163995	- 0,01448917	-89,832373
16.01.2012	40924	119	250	3,04	0,02492723	0,0087981	54,5479297
30.01.2012	40938	133	250	0,04761905	0,00039046	- 0,01573866	- 97,5791364
14.02.2012	40953	148	250	0,52941176	0,00434104	- 0,01178808	- 73,0856934
27.02.2012	40966	161	250	0,33333333	0,00273325	- 0,01339588	- 83,0539551
13.03.2012	40981	176	250	0,48387097	0,00396762	- 0,01216151	- 75,4009025
27.03.2012	40995	190	250	0,91666667	0,00751643	- 0,00861269	- 53,3983765
13.04.2012	41012	207	250	3,15	0,0258292	0,00970008	60,1401246
24.04.2012	41023	218	250	1,16666667	0,00956637	- 0,00656275	- 40,6888428
10.05.2012	41039	234	250	4,92857143	0,04041303	0,02428391	150,559379
24.05.2012	41053	248	250	2,75	0,0225493	0,00642018	39,8048706
12.06.2012	41072	267	250	13,952381	0,11440598	0,09827685	609,313023
09.07.2012	41099	294	250	4,96666667	0,0407254	0,02459628	152,496069
20.09.2011	40806	1	250	0,46666667	0,00382655	- 0,01230258	- 76,2755371
29.11.2011	40876	71	250	1,09375	0,00896847	- 0,00716065	- 44,3957901
19.12.2011	40896	91	250	0,9	0,00737977	- 0,00874935	- 54,2456787
04.01.2012	40912	107	250	0,75	0,00614981	- 0,00997931	- 61,8713989
16.01.2012	40924	119	250	0,29166667	0,00239159	- 0,01373753	- 85,1722107
14.02.2012	40953	148	250	0,05	0,00040999	- 0,01571914	- 97,4580933
27.02.2012	40966	161	250	0,03703704	0,00030369	- 0,01582543	- 98,1171061
13.03.2012	40981	176	250	0	0	- 0,01612912	-100
27.03.2012	40995	190	250	0,37037037	0,00303694	- 0,01309218	- 81,1710612
13.04.2012	41012	207	250	2,30434783	0,01889507	0,00276594	17,1487454
24.04.2012	41023	218	250	0,6	0,00491985	- 0,01120928	- 69,4971191
10.05.2012	41039	234	250	1,52	0,01246361	-	-

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

						0,00366551	22,7260351
24.05.2012	41053	248	250	6,47826087	0,05312009	0,03699097	229,342699
12.06.2012	41072	267	250	9,29166667	0,0761893	0,06006018	372,371002
09.07.2012	41099	294	250	4,93939394	0,04050177	0,02437265	151,109575
20.09.2011	40806	1	250	0,0625	0,00051248	-	-
						0,01561664	96,8226166
29.11.2011	40876	71	250	0,7	0,00573982	-0,0103893	-
							64,4133057
19.12.2011	40896	91	250	0,68181818	0,00559074	-	-
						0,01053839	65,3376354
04.01.2012	40912	107	250	0,6	0,00491985	-	-
						0,01120928	69,4971191
16.01.2012	40924	119	250	0,125	0,00102497	-	-
						0,01510416	93,6452332
14.02.2012	40953	148	250	0,125	0,00102497	-	-
						0,01510416	93,6452332
27.02.2012	40966	161	250	0,11111111	0,00091108	-	-
						0,01521804	94,3513184
13.03.2012	40981	176	250	0,25806452	0,00211606	-	-
						0,01401306	86,8804813
27.03.2012	40995	190	250	0,54166667	0,00444153	-0,0116876	-72,462677
13.04.2012	41012	207	250	1,64	0,01344758	-	-16,625459
						0,00268154	
24.04.2012	41023	218	250	1,20833333	0,00990803	-0,0062211	-
							38,5705871
10.05.2012	41039	234	250	0,56	0,00459186	-	-
						0,01153727	71,5306445
24.05.2012	41053	248	250	3,83870968	0,03147644	0,01534732	95,15284
12.06.2012	41072	267	250	9,76923077	0,08010521	0,06397609	396,649471
09.07.2012	41099	294	250	4,93939394	0,04050177	0,02437265	151,109575
20.09.2011	40806	1	250	0,23076923	0,00189225	-	-
						0,01423687	88,2681227
29.11.2011	40876	71	250	0,33333333	0,00273325	-	-
						0,01339588	83,0539551
19.12.2011	40896	91	250	0,45	0,00368989	-	-
						0,01243924	77,1228393
04.01.2012	40912	107	250	0,19047619	0,00156186	-	-
						0,01456727	90,3165458
16.01.2012	40924	119	250	0,31818182	0,00260901	-	-
						0,01352011	83,8242298
30.01.2012	40938	133	250	0,14285714	0,00117139	-	-

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

						0,01495773	92,7374093
14.02.2012	40953	148	250	0,15	0,00122996	-	-
						0,01489916	92,3742798
27.02.2012	40966	161	250	0,19047619	0,00156186	-	-
						0,01456727	90,3165458
13.03.2012	40981	176	250	0,47619048	0,00390464	-	-
						0,01222448	75,7913644
27.03.2012	40995	190	250	0,91666667	0,00751643	-	-
						0,00861269	53,3983765
13.04.2012	41012	207	250	2,72	0,02230331	0,00617418	38,2797266
24.04.2012	41023	218	250	2,45833333	0,02015771	0,00402858	24,9770813
10.05.2012	41039	234	250	3,36	0,02755115	0,01142202	70,8161329
24.05.2012	41053	248	250	3,31034483	0,02714399	0,01101486	68,2917565
12.06.2012	41072	267	250	8,20689655	0,06729447	0,05116534	317,223313
09.07.2012	41099	294	250	3,79310345	0,03110248	0,01497336	92,8343043
			250	121,955694	0,01612912		
20.09.2011	40806	1	355	0,03846154	0,0063632	-	-
						0,00976586	60,5482205
29.11.2011	40876	71	355	0	0	-	-100
						0,01612906	
19.12.2011	40896	91	355	0	0	-	-100
						0,01612906	
04.01.2012	40912	107	355	0	0	-	-100
						0,01612906	
16.01.2012	40924	119	355	0,08	0,01323546	-0,0028936	-
							17,9402986
30.01.2012	40938	133	355	0	0	-	-100
						0,01612906	
14.02.2012	40953	148	355	0	0	-	-100
						0,01612906	
27.02.2012	40966	161	355	0	0	-	-100
						0,01612906	
13.03.2012	40981	176	355	0	0	-	-100
						0,01612906	
27.03.2012	40995	190	355	0,16666667	0,02757387	0,01144481	70,9577113
13.04.2012	41012	207	355	0,55	0,09099377	0,07486471	464,160447
24.04.2012	41023	218	355	0	0	-	-100
						0,01612906	
10.05.2012	41039	234	355	0,17857143	0,02954343	0,01341437	83,1689764
24.05.2012	41053	248	355	0,21875	0,0361907	0,02006164	124,381996
12.06.2012	41072	267	355	1	0,16544321	0,14931416	925,746268

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

09.07.2012	41099	294	355	0,17241379	0,02852469	0,01239563	76,8528048
20.09.2011	40806	1	355	0	0	- 0,01612906	-100
29.11.2011	40876	71	355	0,09375	0,0155103	- 0,00061876	- 3,83628738
19.12.2011	40896	91	355	0	0	- 0,01612906	-100
04.01.2012	40912	107	355	0	0	- 0,01612906	-100
16.01.2012	40924	119	355	0	0	- 0,01612906	-100
14.02.2012	40953	148	355	0	0	- 0,01612906	-100
27.02.2012	40966	161	355	0	0	- 0,01612906	-100
13.03.2012	40981	176	355	0	0	- 0,01612906	-100
27.03.2012	40995	190	355	0	0	- 0,01612906	-100
13.04.2012	41012	207	355	0,17391304	0,02877273	0,01264367	78,3906553
24.04.2012	41023	218	355	0	0	- 0,01612906	-100
10.05.2012	41039	234	355	0,04	0,00661773	- 0,00951133	- 58,9701493
24.05.2012	41053	248	355	0,65217391	0,10789775	0,09176869	568,964957
12.06.2012	41072	267	355	0,20833333	0,03446734	0,01833828	113,697139
09.07.2012	41099	294	355	0,04	0,00661773	- 0,00951133	- 58,9701493
20.09.2011	40806	1	355	0	0	- 0,01612906	-100
29.11.2011	40876	71	355	0	0	- 0,01612906	-100
19.12.2011	40896	91	355	0	0	- 0,01612906	-100
04.01.2012	40912	107	355	0	0	- 0,01612906	-100
16.01.2012	40924	119	355	0	0	- 0,01612906	-100
14.02.2012	40953	148	355	0	0	- 0,01612906	-100
27.02.2012	40966	161	355	0	0	-	-100

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

						0,01612906	
13.03.2012	40981	176	355	0	0	-	-100
						0,01612906	
27.03.2012	40995	190	355	0,04166667	0,00689347	-	-
						0,00923559	57,2605722
13.04.2012	41012	207	355	0,08	0,01323546	-0,0028936	-
							17,9402986
24.04.2012	41023	218	355	0,08333333	0,01378693	-	-
						0,00234212	14,5211443
10.05.2012	41039	234	355	0,08	0,01323546	-0,0028936	-
							17,9402986
24.05.2012	41053	248	355	0,25806452	0,04269502	0,02656596	164,708714
12.06.2012	41072	267	355	0,23076923	0,0381792	0,02205014	136,710677
09.07.2012	41099	294	355	0,33333333	0,05514774	0,03901868	241,915423
20.09.2011	40806	1	355	0	0	-	-100
						0,01612906	
29.11.2011	40876	71	355	0	0	-	-100
						0,01612906	
19.12.2011	40896	91	355	0	0	-	-100
						0,01612906	
04.01.2012	40912	107	355	0	0	-	-100
						0,01612906	
16.01.2012	40924	119	355	0	0	-	-100
						0,01612906	
30.01.2012	40938	133	355	0	0	-	-100
						0,01612906	
14.02.2012	40953	148	355	0	0	-	-100
						0,01612906	
27.02.2012	40966	161	355	0,0952381	0,0157565	-	-
						0,00037256	2,30987925
13.03.2012	40981	176	355	0,04761905	0,00787825	-	-
						0,00825081	51,1549396
27.03.2012	40995	190	355	0,08333333	0,01378693	-	-
						0,00234212	14,5211443
13.04.2012	41012	207	355	0,2	0,03308864	0,01695958	105,149254
24.04.2012	41023	218	355	0,20833333	0,03446734	0,01833828	113,697139
10.05.2012	41039	234	355	0	0	-	-100
						0,01612906	
24.05.2012	41053	248	355	0,37931034	0,06275432	0,04662526	289,076171
12.06.2012	41072	267	355	0,13793103	0,02281975	0,0066907	41,4822439
09.07.2012	41099	294	355	0,17241379	0,02852469	0,01239563	76,8528048
			355	6,04437978	0,01612906		

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

Residual data of *H. germanica*:

date	Julian day	sampling day	size fraction	individuals in size fraction	relative abundance	residuals	residuals%
20.09.2011	40806	1	90	0	0	- 0,01612903	-100
29.11.2011	40876	71	90	1	0,00271197	- 0,01341706	- 83,1857591
19.12.2011	40896	91	90	1,4	0,00379676	- 0,01233227	- 76,4600627
04.01.2012	40912	107	90	0,6	0,00162718	- 0,01450185	- 89,9114554
16.01.2012	40924	119	90	0,72	0,00195262	- 0,01417641	- 87,8937465
30.01.2012	40938	133	90	0,19047619	0,00051657	- 0,01561247	- 96,7972874
14.02.2012	40953	148	90	0,41176471	0,0011167	- 0,01501234	- -93,076489
27.02.2012	40966	161	90	0,23809524	0,00064571	- 0,01548333	- 95,9966093
13.03.2012	40981	176	90	0,19354839	0,0005249	- 0,01560414	- 96,7456308
27.03.2012	40995	190	90	0,58333333	0,00158199	- 0,01454705	- 90,1916928
13.04.2012	41012	207	90	4,25	0,01152589	- 0,00460314	- 28,5394761
24.04.2012	41023	218	90	4,08333333	0,0110739	- 0,00505514	- 31,3418496
10.05.2012	41039	234	90	24,2857143	0,06586224	0,04973321	308,345851
24.05.2012	41053	248	90	40,625	0,11017397	0,09404494	583,078537
12.06.2012	41072	267	90	29,047619	0,07877641	0,06264737	388,413665
09.07.2012	41099	294	90	2,5	0,00677994	-0,0093491	- 57,9643977
20.09.2011	40806	1	90	0	0	- 0,01612903	-100
29.11.2011	40876	71	90	2,625	0,00711893	-0,0090101	- 55,8626176
19.12.2011	40896	91	90	1,6	0,00433916	-	-

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

						0,01178987	73,0972145
04.01.2012	40912	107	90	0,8	0,00216958	-	-
						0,01395945	86,5486073
16.01.2012	40924	119	90	0,20833333	0,00056499	-	-
						0,01556404	96,4970331
14.02.2012	40953	148	90	0,4	0,00108479	-	-
						0,01504424	93,2743036
27.02.2012	40966	161	90	0,18518519	0,00050222	-	-
						0,01562682	96,8862517
13.03.2012	40981	176	90	0,35714286	0,00096856	-	-93,994914
						0,01516047	
27.03.2012	40995	190	90	0,11111111	0,00030133	-0,0158277	-98,131751
13.04.2012	41012	207	90	4,7826087	0,01297031	-	-
						0,00315872	19,5840652
24.04.2012	41023	218	90	6,48	0,0175736	0,00144456	8,95628116
10.05.2012	41039	234	90	17,6	0,04773076	0,03160172	195,93064
24.05.2012	41053	248	90	26,0869565	0,07074717	0,05461813	338,632372
12.06.2012	41072	267	90	16,6666667	0,04519958	0,02907054	180,237349
09.07.2012	41099	294	90	2,4	0,00650874	-0,0096203	-
							59,6458218
20.09.2011	40806	1	90	0	0	-	-100
						0,01612903	
29.11.2011	40876	71	90	0,86666667	0,00235038	-	-
						0,01377866	85,4276579
19.12.2011	40896	91	90	0,90909091	0,00246543	-0,0136636	-
							84,7143264
04.01.2012	40912	107	90	0,75	0,00203398	-	-
						0,01409505	87,3893193
16.01.2012	40924	119	90	0,16666667	0,000452	-	-
						0,01567704	97,1976265
14.02.2012	40953	148	90	0,33333333	0,00090399	-	-94,395253
						0,01522504	
27.02.2012	40966	161	90	0,22222222	0,00060266	-	-96,263502
						0,01552637	
13.03.2012	40981	176	90	0,12903226	0,00034993	-0,0157791	-
							97,8304205
27.03.2012	40995	190	90	0,5	0,00135599	-	-
						0,01477305	91,5928795
13.04.2012	41012	207	90	3,92	0,01063094	-	-
						0,00549809	34,0881756
24.04.2012	41023	218	90	6,375	0,01728884	0,0011598	7,19078587

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

10.05.2012	41039	234	90	2,64	0,00715961	- 0,00896942	-55,610404
24.05.2012	41053	248	90	33,2258065	0,09010755	0,07397851	458,666714
12.06.2012	41072	267	90	20,3846154	0,05528256	0,03915353	242,751834
09.07.2012	41099	294	90	6,36363636	0,01725802	0,00112899	6,99971495
20.09.2011	40806	1	90	0	0	- 0,01612903	-100
29.11.2011	40876	71	90	1,33333333	0,00361597	- 0,01251307	- 77,5810121
19.12.2011	40896	91	90	0,4	0,00108479	- 0,01504424	- 93,2743036
04.01.2012	40912	107	90	0,95238095	0,00258283	-0,0135462	- 83,9864372
16.01.2012	40924	119	90	0,36363636	0,00098617	- 0,01514286	- 93,8857306
30.01.2012	40938	133	90	0,23809524	0,00064571	- 0,01548333	- 95,9966093
14.02.2012	40953	148	90	0,1	0,0002712	- 0,01585784	- 98,3185759
27.02.2012	40966	161	90	0,14285714	0,00038742	- 0,01574161	- 97,5979656
13.03.2012	40981	176	90	0,76190476	0,00206627	- 0,01406277	- 87,1891498
27.03.2012	40995	190	90	0,91666667	0,00248598	- 0,01364306	- 84,5869458
13.04.2012	41012	207	90	5,72	0,0155125	- 0,00061654	- 3,82254194
24.04.2012	41023	218	90	14,2916667	0,03875864	0,0226296	140,303526
10.05.2012	41039	234	90	14,4	0,03905244	0,0229234	142,125069
24.05.2012	41053	248	90	37,2413793	0,10099768	0,08486864	526,185524
12.06.2012	41072	267	90	21,2068966	0,05751257	0,04138353	256,577868
09.07.2012	41099	294	90	3,44827586	0,00935164	-0,0067774	- 42,0198589
			90	368,735052	0,01612903		
20.09.2011	40806	1	125	0,34615385	0,000736	- 0,01539303	- 95,4367736
29.11.2011	40876	71	125	0,91666667	0,00194905	- 0,01417998	- 87,9159004
19.12.2011	40896	91	125	3,4	0,0072292	- 0,00889983	- 55,1789762

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

04.01.2012	40912	107	125	0,55	0,00116943	-0,0149596	-
							92,7495403
16.01.2012	40924	119	125	0,88	0,00187109	-	-
						0,01425795	88,3992644
30.01.2012	40938	133	125	0,14285714	0,00030375	-	-
						0,01582528	98,1167637
14.02.2012	40953	148	125	0,52941176	0,00112565	-	-
						0,01500338	93,0209478
27.02.2012	40966	161	125	0,52380952	0,00111374	-	-
						0,01501529	93,0948002
13.03.2012	40981	176	125	1,03225806	0,00219482	-	-86,392099
						0,01393421	
27.03.2012	40995	190	125	0,625	0,0013289	-	-
						0,01480014	91,7608412
13.04.2012	41012	207	125	3,25	0,00691026	-	-
						0,00921877	57,1563743
24.04.2012	41023	218	125	2,08333333	0,00442966	-	-
						0,01169938	72,5361374
10.05.2012	41039	234	125	12,5	0,02657793	0,0104489	64,7831759
24.05.2012	41053	248	125	30,625	0,06511593	0,0489869	303,718781
12.06.2012	41072	267	125	45,2380952	0,0961868	0,08005777	496,35816
09.07.2012	41099	294	125	8,33333333	0,01771862	0,00158959	9,85545058
20.09.2011	40806	1	125	4,4	0,00935543	-0,0067736	-
							41,9963221
29.11.2011	40876	71	125	1,625	0,00345513	-0,0126739	-
							78,5781871
19.12.2011	40896	91	125	3,5	0,00744182	-	-
						0,00868721	53,8607108
04.01.2012	40912	107	125	0,75	0,00159468	-	-
						0,01453436	90,1130094
16.01.2012	40924	119	125	0,16666667	0,00035437	-	-97,802891
						0,01577466	
14.02.2012	40953	148	125	1,05	0,00223255	-	-
						0,01389649	86,1582132
27.02.2012	40966	161	125	0,40740741	0,00086624	-	-
						0,01526279	94,6292891
13.03.2012	40981	176	125	0,39285714	0,00083531	-	-
						0,01529373	94,8211002
27.03.2012	40995	190	125	1,03703704	0,00220498	-	-
						0,01392405	86,3290995
13.04.2012	41012	207	125	8,17391304	0,01737966	0,00125062	7,75386805
24.04.2012	41023	218	125	1,52	0,00323188	-	-

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

						0,01289716	79,9623658
10.05.2012	41039	234	125	7,48	0,01590423	-0,0002248	- 1,39374756
24.05.2012	41053	248	125	49,3043478	0,10483261	0,08870358	549,962162
12.06.2012	41072	267	125	46,6666667	0,09922428	0,08309525	515,190523
09.07.2012	41099	294	125	14,8	0,03146827	0,01533924	95,1032802
20.09.2011	40806	1	125	1,9375	0,00411958	-	-
						0,01200945	74,4586077
29.11.2011	40876	71	125	2,66666667	0,00566996	-	-
						0,01045907	64,8462558
19.12.2011	40896	91	125	1,63636364	0,00347929	-	-
						0,01264974	78,4283842
04.01.2012	40912	107	125	1,3	0,0027641	-	-
						0,01336493	82,8625497
16.01.2012	40924	119	125	0,20833333	0,00044297	-	-
						0,01568607	97,2536137
14.02.2012	40953	148	125	0,125	0,00026578	-	-
						0,01586325	98,3521682
27.02.2012	40966	161	125	0,14814815	0,000315	-	-
						0,01581403	98,0470142
13.03.2012	40981	176	125	0,58064516	0,00123459	-	-
						0,01489444	92,3455557
27.03.2012	40995	190	125	2,04166667	0,00434106	-	-
						0,01178797	73,0854146
13.04.2012	41012	207	125	5,24	0,01114147	-	-
						0,00498756	30,9228927
24.04.2012	41023	218	125	2,41666667	0,0051384	-	-
						0,01099063	68,1419193
10.05.2012	41039	234	125	3,52	0,00748435	-	-
						0,00864469	53,5970577
24.05.2012	41053	248	125	32,5806452	0,06927409	0,05314506	329,499375
12.06.2012	41072	267	125	41,1538462	0,08750273	0,0713737	442,516917
09.07.2012	41099	294	125	9,39393939	0,01997372	0,00384469	23,8370534
20.09.2011	40806	1	125	1,46153846	0,00310757	-	-
						0,01302146	80,7330441
29.11.2011	40876	71	125	1	0,00212623	-0,0140028	-
							86,8173459
19.12.2011	40896	91	125	1,2	0,00255148	-	-
						0,01357755	84,1808151

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

04.01.2012	40912	107	125	1,66666667	0,00354372	-	-
						0,01258531	78,0289099
16.01.2012	40924	119	125	0,77272727	0,001643	-	-
						0,01448603	89,8134037
30.01.2012	40938	133	125	0,28571429	0,0006075	-	-
						0,01552154	96,2335274
14.02.2012	40953	148	125	0,1	0,00021262	-	-
						0,01591641	98,6817346
27.02.2012	40966	161	125	0,61904762	0,00131624	-	-
						0,01481279	91,8393094
13.03.2012	40981	176	125	1,19047619	0,00253123	-0,0135978	-
							84,3063642
27.03.2012	40995	190	125	1,25	0,00265779	-	-
						0,01347124	83,5216824
13.04.2012	41012	207	125	5,96	0,01267236	-	-
						0,00345667	21,4313817
24.04.2012	41023	218	125	5,79166667	0,01231444	-	-
						0,00381459	23,6504618
10.05.2012	41039	234	125	7,68	0,01632948	0,00020045	1,24278325
24.05.2012	41053	248	125	38,9655172	0,08284983	0,0667208	413,668934
12.06.2012	41072	267	125	34,137931	0,07258525	0,05645622	350,028535
09.07.2012	41099	294	125	11,0344828	0,0234619	0,00733287	45,463769
			125	470,315004	0,01612903		
20.09.2011	40806	1	250	0,03846154	0,00210748	-	-86,933626
						0,01402157	
29.11.2011	40876	71	250	0,05555556	0,00304414	-	-
						0,01308491	81,1263486
19.12.2011	40896	91	250	0,1	0,00547945	-	-
						0,01064959	66,0274275
04.01.2012	40912	107	250	0,15	0,00821918	-	-
						0,00790987	49,0411413
16.01.2012	40924	119	250	0,2	0,0109589	-	-32,054855
						0,00517014	
30.01.2012	40938	133	250	0	0	-	-100
						0,01612905	
14.02.2012	40953	148	250	0,05882353	0,00322321	-	-
						0,01290584	80,0161338
27.02.2012	40966	161	250	0,38095238	0,0208741	0,00474506	29,4193238
13.03.2012	40981	176	250	0,16129032	0,00883783	-	-
						0,00729122	45,2055282
27.03.2012	40995	190	250	0	0	-	-100

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

						0,01612905	
13.04.2012	41012	207	250	0,4	0,02191781	0,00578876	35,89029
24.04.2012	41023	218	250	0,70833333	0,03881279	0,02268374	140,639055
10.05.2012	41039	234	250	2,75	0,15068493	0,13455588	834,245744
24.05.2012	41053	248	250	0	0	-	-100
						0,01612905	
12.06.2012	41072	267	250	0,19047619	0,01043705	-0,005692	-
							35,2903381
09.07.2012	41099	294	250	0,13333333	0,00730594	-	-
						0,00882311	54,7032367
20.09.2011	40806	1	250	0,36666667	0,02009132	0,00396228	24,5660992
29.11.2011	40876	71	250	0,15625	0,00856164	-0,0075674	-
							46,9178555
19.12.2011	40896	91	250	0,2	0,0109589	-	-32,054855
						0,00517014	
04.01.2012	40912	107	250	0,1	0,00547945	-	-
						0,01064959	66,0274275
16.01.2012	40924	119	250	0,125	0,00684932	-	-
						0,00927973	57,5342844
14.02.2012	40953	148	250	0	0	-	-100
						0,01612905	
27.02.2012	40966	161	250	0	0	-	-100
						0,01612905	
13.03.2012	40981	176	250	0	0	-	-100
						0,01612905	
27.03.2012	40995	190	250	0,14814815	0,00811771	-	-49,670263
						0,00801134	
13.04.2012	41012	207	250	1,34782609	0,07385348	0,05772444	357,891195
24.04.2012	41023	218	250	0,24	0,01315068	-	-18,465826
						0,00297836	
10.05.2012	41039	234	250	0,28	0,01534247	-	-
						0,00078658	4,87679701
24.05.2012	41053	248	250	0,13043478	0,00714711	-	-
						0,00898194	55,6879489
12.06.2012	41072	267	250	0,58333333	0,03196347	0,01583442	98,1733396
09.07.2012	41099	294	250	0,08	0,00438356	-	-72,821942
						0,01174548	
20.09.2011	40806	1	250	0,0625	0,00342466	-	-
						0,01270439	78,7671422
29.11.2011	40876	71	250	0,1	0,00547945	-	-

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

						0,01064959	66,0274275
19.12.2011	40896	91	250	0	0	-	-100
						0,01612905	
04.01.2012	40912	107	250	0,1	0,00547945	-	-
						0,01064959	66,0274275
16.01.2012	40924	119	250	0,04166667	0,00228311	-	-
						0,01384594	85,8447615
14.02.2012	40953	148	250	0	0	-	-100
						0,01612905	
27.02.2012	40966	161	250	0	0	-	-100
						0,01612905	
13.03.2012	40981	176	250	0,22580645	0,01237296	-	-
						0,00375609	23,2877395
27.03.2012	40995	190	250	0,625	0,03424658	0,01811753	112,328578
13.04.2012	41012	207	250	1,44	0,07890411	0,06277506	389,205044
24.04.2012	41023	218	250	0,70833333	0,03881279	0,02268374	140,639055
10.05.2012	41039	234	250	0,6	0,03287671	0,01674767	103,835435
24.05.2012	41053	248	250	0,19354839	0,01060539	-	-
						0,00552366	34,2466339
12.06.2012	41072	267	250	0,38461538	0,02107482	0,00494577	30,6637404
09.07.2012	41099	294	250	0,24242424	0,01328352	-	-
						0,00284553	17,6422485
20.09.2011	40806	1	250	0,03846154	0,00210748	-	-86,933626
						0,01402157	
29.11.2011	40876	71	250	0,2	0,0109589	-	-32,054855
						0,00517014	
19.12.2011	40896	91	250	0,1	0,00547945	-	-
						0,01064959	66,0274275
04.01.2012	40912	107	250	0,04761905	0,00260926	-	-
						0,01351978	83,8225845
16.01.2012	40924	119	250	0	0	-	-100
						0,01612905	
30.01.2012	40938	133	250	0	0	-	-100
						0,01612905	
14.02.2012	40953	148	250	0	0	-	-100
						0,01612905	
27.02.2012	40966	161	250	0	0	-	-100
						0,01612905	
13.03.2012	40981	176	250	0,14285714	0,00782779	-	-
						0,00830126	51,4677536
27.03.2012	40995	190	250	0,08333333	0,00456621	-	-

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

						0,01156284	71,6895229
13.04.2012	41012	207	250	1,52	0,08328767	0,06715862	416,383102
24.04.2012	41023	218	250	1	0,05479452	0,03866547	239,725725
10.05.2012	41039	234	250	0,24	0,01315068	-	-18,465826
						0,00297836	
24.05.2012	41053	248	250	0,27586207	0,01511573	-	-
						0,00101332	6,28255863
12.06.2012	41072	267	250	0,62068966	0,03401039	0,01788135	110,864243
09.07.2012	41099	294	250	0,17241379	0,00944733	-	-
						0,00668172	41,4265991
			250	18,2500162	0,01612905		

Residual data of *E. williamsoni*:

date	Julian day	sampling day	size fraction	individuals in size fraction	relative abundance	residuals	residuals %
20.09.2011	40806	1	90	0	0	-	-100
						0,01612904	
29.11.2011	40876	71	90	0,2	0,00215673	-0,0139723	-86,628251
19.12.2011	40896	91	90	0,4	0,00431347	-	-73,256502
						0,01181557	
04.01.2012	40912	107	90	0	0	-	-100
						0,01612904	
16.01.2012	40924	119	90	0,24	0,00258808	-	-
						0,01354095	83,9539012
30.01.2012	40938	133	90	0,19047619	0,00205403	-0,014075	-87,265001
14.02.2012	40953	148	90	0,35294118	0,003806	-	-
						0,01232303	76,4027959
27.02.2012	40966	161	90	0,14285714	0,00154052	-	-
						0,01458851	90,4487507
13.03.2012	40981	176	90	0,32258065	0,0034786	-	-
						0,01265043	78,4326629
27.03.2012	40995	190	90	0,66666667	0,00718911	-	-
						0,00893992	55,4275033
13.04.2012	41012	207	90	1,15	0,01240122	-	-
						0,00372781	23,1124433
24.04.2012	41023	218	90	0,66666667	0,00718911	-	-
						0,00893992	55,4275033

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

10.05.2012	41039	234	90	13,5714286	0,14634982	0,13022078	807,368682
24.05.2012	41053	248	90	4,6875	0,05054846	0,03441942	213,400367
12.06.2012	41072	267	90	6,19047619	0,06675606	0,05062702	313,887469
09.07.2012	41099	294	90	1,89655172	0,02045179	0,00432275	26,8010681
20.09.2011	40806	1	90	0	0	- 0,01612904	-100
29.11.2011	40876	71	90	0	0	- 0,01612904	-100
19.12.2011	40896	91	90	0	0	- 0,01612904	-100
04.01.2012	40912	107	90	0	0	- 0,01612904	-100
16.01.2012	40924	119	90	0,16666667	0,00179728	- 0,01433176	- 88,8568758
14.02.2012	40953	148	90	0,15	0,00161755	- 0,01451149	- 89,9711883
27.02.2012	40966	161	90	0,03703704	0,0003994	- 0,01572964	- 97,5237502
13.03.2012	40981	176	90	0,10714286	0,00115539	- 0,01497364	- -92,836563
27.03.2012	40995	190	90	0,07407407	0,00079879	- 0,01533025	- 95,0475004
13.04.2012	41012	207	90	1,13043478	0,01219024	- -0,0039388	- 24,4205491
24.04.2012	41023	218	90	1,72	0,01854791	0,00241888	14,9970414
10.05.2012	41039	234	90	4,8	0,05176162	0,03563258	220,921976
24.05.2012	41053	248	90	4,7826087	0,05157408	0,03544504	219,759215
12.06.2012	41072	267	90	5	0,05391835	0,03778932	234,293725
09.07.2012	41099	294	90	1,6	0,01725387	0,00112484	6,973992
20.09.2011	40806	1	90	0	0	- 0,01612904	-100
29.11.2011	40876	71	90	0	0	- 0,01612904	-100
19.12.2011	40896	91	90	0	0	- 0,01612904	-100
04.01.2012	40912	107	90	0,15	0,00161755	- 0,01451149	- 89,9711883
16.01.2012	40924	119	90	0,125	0,00134796	- 0,01478108	- 91,6426569

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

14.02.2012	40953	148	90	0,04166667	0,00044932	- 0,01567972	-97,214219
27.02.2012	40966	161	90	0,14814815	0,00159758	- 0,01453145	- 90,0950007
13.03.2012	40981	176	90	0,16129032	0,0017393	- 0,01438973	- 89,2163315
27.03.2012	40995	190	90	0,125	0,00134796	- 0,01478108	- 91,6426569
13.04.2012	41012	207	90	0,72	0,00776424	- 0,00836479	- 51,8617036
24.04.2012	41023	218	90	2	0,02156734	0,00543831	33,71749
10.05.2012	41039	234	90	1,2	0,01294041	- 0,00318863	-19,769506
24.05.2012	41053	248	90	5,16129032	0,05565766	0,03952862	245,077394
12.06.2012	41072	267	90	5,57692308	0,0601397	0,04401067	272,866078
09.07.2012	41099	294	90	2,12121212	0,02287445	0,00674542	41,8215803
20.09.2011	40806	1	90	0	0	- 0,01612904	-100
29.11.2011	40876	71	90	0,26666667	0,00287565	- 0,01325339	- 82,1710013
19.12.2011	40896	91	90	0	0	- 0,01612904	-100
04.01.2012	40912	107	90	0	0	- 0,01612904	-100
16.01.2012	40924	119	90	0,22727273	0,00245083	-0,0136782	- 84,8048307
30.01.2012	40938	133	90	0,19047619	0,00205403	-0,014075	-87,265001
14.02.2012	40953	148	90	0,1	0,00107837	- 0,01505067	- 93,3141255
27.02.2012	40966	161	90	0,28571429	0,00308105	- 0,01304799	- 80,8975014
13.03.2012	40981	176	90	0,52380952	0,00564859	- 0,01048045	- 64,9787526
27.03.2012	40995	190	90	0,625	0,00673979	- 0,00938924	- 58,2132844
13.04.2012	41012	207	90	2,12	0,02286138	0,00673235	41,7405394
24.04.2012	41023	218	90	3,5	0,03774285	0,02161381	134,005607
10.05.2012	41039	234	90	5,6	0,06038856	0,04425952	274,408972
24.05.2012	41053	248	90	5,31034483	0,05726501	0,04113598	255,042991
12.06.2012	41072	267	90	4,31034483	0,04648134	0,0303523	188,184246

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

09.07.2012	41099	294	90	1,89655172	0,02045179	0,00432275	26,8010681
			90	92,7328205	0,01612904		
20.09.2011	40806	1	125	51,8	0,10638429	0,09025523	559,581297
29.11.2011	40876	71	125	9,83333333	0,02019522	0,00406615	25,2100919
19.12.2011	40896	91	125	23,4	0,04805777	0,0319287	197,957575
04.01.2012	40912	107	125	2,6	0,00533975	-	-
						0,01078931	66,8936028
16.01.2012	40924	119	125	53,76	0,11040964	0,09428058	584,538428
30.01.2012	40938	133	125	13,1428571	0,02699215	0,01086309	67,3510187
14.02.2012	40953	148	125	8,11764706	0,01667162	0,00054256	3,36386446
27.02.2012	40966	161	125	3,57142857	0,00733482	-	-
						0,00879424	54,5241797
13.03.2012	40981	176	125	17,0967742	0,03511251	0,01898345	117,697153
27.03.2012	40995	190	125	2,20833333	0,00453537	-0,0115937	-
							71,8807845
13.04.2012	41012	207	125	2,95	0,00605856	-0,0100705	-
							62,4369724
24.04.2012	41023	218	125	0,83333333	0,00171146	-	-
						0,01441761	89,3889753
10.05.2012	41039	234	125	1,14285714	0,00234714	-	-
						0,01378192	85,4477375
24.05.2012	41053	248	125	4,375	0,00898516	-0,0071439	-
							44,2921201
12.06.2012	41072	267	125	15,2380952	0,03129525	0,01516619	94,0301666
09.07.2012	41099	294	125	1,5	0,00308063	-	-
						0,01304844	80,9001555
20.09.2011	40806	1	125	66,9333333	0,13746438	0,12133532	752,277507
29.11.2011	40876	71	125	5,75	0,01180907	-0,00432	-
							26,7839293
19.12.2011	40896	91	125	4,5	0,00924188	-	-
						0,00688719	42,7004664
04.01.2012	40912	107	125	6,6	0,01355476	-	-
						0,00257431	15,9606841
16.01.2012	40924	119	125	8	0,01643001	0,00030094	1,86583744
14.02.2012	40953	148	125	2,5	0,00513438	-	-
						0,01099469	68,1669258
27.02.2012	40966	161	125	3,48148148	0,0071501	-	-
						0,00897897	55,6694967
13.03.2012	40981	176	125	2,39285714	0,00491433	-	-
						0,01121473	69,5312004

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

27.03.2012	40995	190	125	0,74074074	0,0015213	- 0,01460777	-90,567978
13.04.2012	41012	207	125	1,47826087	0,00303598	- 0,01309308	- 81,1769648
24.04.2012	41023	218	125	0,08	0,0001643	- 0,01596476	- 98,9813416
10.05.2012	41039	234	125	3,44	0,0070649	- 0,00906416	- 56,1976899
24.05.2012	41053	248	125	12,173913	0,02500218	0,00887312	55,0132309
12.06.2012	41072	267	125	11,25	0,0231047	0,00697563	43,2488339
09.07.2012	41099	294	125	8,4	0,01725151	0,00112244	6,95912931
20.09.2011	40806	1	125	22,25	0,04569595	0,02956689	183,31436
29.11.2011	40876	71	125	6,46666667	0,01328092	- 0,00284814	- 17,6584481
19.12.2011	40896	91	125	5,63636364	0,01157569	- 0,00455338	- 28,2308873
04.01.2012	40912	107	125	8,2	0,01684076	0,00071169	4,41248338
16.01.2012	40924	119	125	1,95833333	0,00402193	- 0,01210714	- 75,0640919
14.02.2012	40953	148	125	2,125	0,00436422	- 0,01176484	- 72,9418869
27.02.2012	40966	161	125	2,2962963	0,00471602	- 0,01141304	- 70,7607318
13.03.2012	40981	176	125	4,25806452	0,008745	- 0,00738406	- 45,7810865
27.03.2012	40995	190	125	1,04166667	0,00213932	- 0,01398974	- 86,7362191
13.04.2012	41012	207	125	1,8	0,00369675	- 0,01243231	- 77,0801866
24.04.2012	41023	218	125	0,5	0,00102688	- 0,01510219	- 93,6333852
10.05.2012	41039	234	125	1,2	0,0024645	- 0,01366456	- 84,7201244
24.05.2012	41053	248	125	3,5483871	0,0072875	- 0,00884156	- 54,8175721
12.06.2012	41072	267	125	12,1153846	0,02488198	0,00875292	54,267975
09.07.2012	41099	294	125	1,06060606	0,00217822	- 0,01395084	- 86,4950594
20.09.2011	40806	1	125	14,5384615	0,02985838	0,01372931	85,12157

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

29.11.2011	40876	71	125	2,53333333	0,00520284	-	-
						0,01092623	67,7424848
19.12.2011	40896	91	125	5,1	0,01047413	-	-
						0,00565494	35,0605286
04.01.2012	40912	107	125	2,52380952	0,00518328	-	-
						0,01094579	67,8637537
16.01.2012	40924	119	125	0,86363636	0,00177369	-	-
						0,01435537	89,0031198
30.01.2012	40938	133	125	1,57142857	0,00322732	-	-
						0,01290174	79,9906391
14.02.2012	40953	148	125	2,7	0,00554513	-	-
						0,01058394	65,6202799
27.02.2012	40966	161	125	4,9047619	0,01007316	-	-
						0,00605591	37,5465401
13.03.2012	40981	176	125	3,47619048	0,00713923	-	-
						0,00898984	55,7368683
27.03.2012	40995	190	125	0,625	0,00128359	-	-
						0,01484547	92,0417314
13.04.2012	41012	207	125	1,36	0,0027931	-	-
						0,01333596	82,6828076
24.04.2012	41023	218	125	1,04166667	0,00213932	-	-
						0,01398974	86,7362191
10.05.2012	41039	234	125	5,24	0,01076165	-	-
						0,00536741	33,2778765
24.05.2012	41053	248	125	5,03448276	0,01033957	-	-
						0,00578949	35,8947747
12.06.2012	41072	267	125	9,82758621	0,02018341	0,00405435	25,1369124
09.07.2012	41099	294	125	1,82758621	0,00375341	-	-
						0,01237566	76,7289251
			125	486,914958	0,01612906		
20.09.2011	40806	1	250	5,84615385	0,01473563	-	-
						0,00139341	8,63913244
29.11.2011	40876	71	250	5,08333333	0,01281289	-	-
						0,00331615	20,5601228
19.12.2011	40896	91	250	7,75	0,0195344	0,00340536	21,1132553
04.01.2012	40912	107	250	0,7	0,0017644	-	-
						0,01436464	89,0607382
16.01.2012	40924	119	250	35,28	0,08892563	0,0727966	451,338793
30.01.2012	40938	133	250	7,42857143	0,01872422	0,00259518	16,0901249
14.02.2012	40953	148	250	6,17647059	0,01556821	-	-3,477102
						0,00056082	

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

27.02.2012	40966	161	250	3,42857143	0,00864195	-	-
						0,00748709	46,4199423
13.03.2012	40981	176	250	27,516129	0,06935627	0,05322723	330,008769
27.03.2012	40995	190	250	7,125	0,01795905	0,00183001	11,3460573
13.04.2012	41012	207	250	20,6	0,0519237	0,03579466	221,926846
24.04.2012	41023	218	250	4,16666667	0,01050237	-	-
						0,00562667	34,8853466
10.05.2012	41039	234	250	5,89285714	0,01485335	-	-
						0,00127569	7,90927589
24.05.2012	41053	248	250	0,75	0,00189043	-	-
						0,01423861	88,2793624
12.06.2012	41072	267	250	3,28571429	0,00828187	-	-
						0,00784717	48,6524447
09.07.2012	41099	294	250	0,3	0,00075617	-	-95,311745
						0,01537287	
20.09.2011	40806	1	250	13,3	0,03352355	0,01739452	107,845974
29.11.2011	40876	71	250	9,46875	0,02386663	0,00773759	47,9730499
19.12.2011	40896	91	250	9,65	0,02432348	0,00819444	50,8055373
04.01.2012	40912	107	250	13,65	0,03440575	0,01827671	113,315605
16.01.2012	40924	119	250	10,4166667	0,02625591	0,01012688	62,7866335
14.02.2012	40953	148	250	4,85	0,01222475	-	-
						0,00390428	24,2065434
27.02.2012	40966	161	250	6,48148148	0,01633701	0,00020798	1,28946086
13.03.2012	40981	176	250	15	0,03780852	0,02167948	134,412752
27.03.2012	40995	190	250	10,2222222	0,0257658	0,00963677	59,7479497
13.04.2012	41012	207	250	15,5652174	0,03923319	0,02310415	143,245697
24.04.2012	41023	218	250	0,84	0,00211728	-	-
						0,01401176	86,8728859
10.05.2012	41039	234	250	1,84	0,00463784	-	-
						0,01149119	71,2453691
24.05.2012	41053	248	250	3,43478261	0,0086576	-	-46,322877
						0,00747143	
12.06.2012	41072	267	250	3	0,0075617	-	-
						0,00856733	53,1174495
09.07.2012	41099	294	250	0,2	0,00050411	-	-
						0,01562492	96,8744966
20.09.2011	40806	1	250	4,15625	0,01047611	-	-
						0,00565293	35,0481332
29.11.2011	40876	71	250	11,0666667	0,02789428	0,01176525	72,9445195

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

19.12.2011	40896	91	250	6,09090909	0,01535255	-	-
						0,00077649	4,81421574
04.01.2012	40912	107	250	11,05	0,02785227	0,01172324	72,6840609
16.01.2012	40924	119	250	2,5	0,00630142	-	-60,931208
						0,00982762	
14.02.2012	40953	148	250	3,83333333	0,00966218	-	-
						0,00646686	40,0945189
27.02.2012	40966	161	250	2,85185185	0,00718829	-	-
						0,00894075	55,4326372
13.03.2012	40981	176	250	10,1935484	0,02569353	0,00956449	59,2998489
27.03.2012	40995	190	250	5,70833333	0,01438824	-	-
						0,00174079	10,7929248
13.04.2012	41012	207	250	15,52	0,03911921	0,02299018	142,539061
24.04.2012	41023	218	250	1,625	0,00409592	-	-
						0,01203311	74,6052852
10.05.2012	41039	234	250	1	0,00252057	-	-
						0,01360847	84,3724832
24.05.2012	41053	248	250	0,96774194	0,00243926	-	-
						0,01368978	84,8765966
12.06.2012	41072	267	250	2,61538462	0,00659225	-	-
						0,00953678	59,1280329
09.07.2012	41099	294	250	0,18181818	0,00045829	-	-
						0,01567075	97,1586333
20.09.2011	40806	1	250	2	0,00504114	-0,0110879	-
							68,7449664
29.11.2011	40876	71	250	3,96666667	0,00999825	-	-38,01085
						0,00613078	
19.12.2011	40896	91	250	2,25	0,00567128	-	-
						0,01045776	64,8380872
04.01.2012	40912	107	250	1,95238095	0,00492111	-	-
						0,01120793	69,4891338
16.01.2012	40924	119	250	0,54545455	0,00137486	-	-
						0,01475418	91,4758999
30.01.2012	40938	133	250	3,76190476	0,00948214	-0,0066469	-
							41,2107701
14.02.2012	40953	148	250	2,25	0,00567128	-	-
						0,01045776	64,8380872
27.02.2012	40966	161	250	10,5714286	0,026646	0,01051697	65,2051778
13.03.2012	40981	176	250	13,8095238	0,03480784	0,01867881	115,808566
27.03.2012	40995	190	250	1,45833333	0,00367583	-	-
						0,01245321	77,2098713

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

13.04.2012	41012	207	250	5,8	0,01461929	-	-
						0,00150974	9,36040245
24.04.2012	41023	218	250	4,54166667	0,01144758	-	-
						0,00468146	29,0250278
10.05.2012	41039	234	250	0,84	0,00211728	-	-
						0,01401176	86,8728859
24.05.2012	41053	248	250	1,13793103	0,00286823	-0,0132608	-
							82,2169636
12.06.2012	41072	267	250	2,93103448	0,00738787	-	-
						0,00874116	54,1952093
09.07.2012	41099	294	250	0,31034483	0,00078225	-	-95,150081
						0,01534679	
			250	396,736095	0,01612904		
20.09.2011	40806	1	355	0,03846154	0,0047501	-	-
						0,01137945	70,5503459
29.11.2011	40876	71	355	0	0	-	-100
						0,01612955	
19.12.2011	40896	91	355	0	0	-	-100
						0,01612955	
04.01.2012	40912	107	355	0	0	-	-100
						0,01612955	
16.01.2012	40924	119	355	0,08	0,0098802	-	-
						0,00624935	38,7447194
30.01.2012	40938	133	355	0,04761905	0,00588107	-	-
						0,01024848	63,5385235
14.02.2012	40953	148	355	0,11764706	0,01452971	-	-
						0,00159984	9,91870501
27.02.2012	40966	161	355	0,04761905	0,00588107	-	-
						0,01024848	63,5385235
13.03.2012	40981	176	355	0,16129032	0,01991976	0,00379021	23,4985496
27.03.2012	40995	190	355	0	0	-	-100
						0,01612955	
13.04.2012	41012	207	355	0,8	0,09880203	0,08267247	512,552806
24.04.2012	41023	218	355	0,25	0,03087563	0,01474608	91,4227519
10.05.2012	41039	234	355	0,21428571	0,02646483	0,01033528	64,0766445
24.05.2012	41053	248	355	0	0	-	-100
						0,01612955	
12.06.2012	41072	267	355	0,19047619	0,02352429	0,00739474	45,8459062
09.07.2012	41099	294	355	0,03333333	0,00411675	-0,0120128	-
							74,4769664
20.09.2011	40806	1	355	0,13333333	0,016467	0,00033745	2,09213433

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

29.11.2011	40876	71	355	0,0625	0,00771891	- 0,00841064	-52,144312
19.12.2011	40896	91	355	0	0	- 0,01612955	-100
04.01.2012	40912	107	355	0	0	- 0,01612955	-100
16.01.2012	40924	119	355	0	0	- 0,01612955	-100
14.02.2012	40953	148	355	0,1	0,01235025	-0,0037793	- 23,4308993
27.02.2012	40966	161	355	0	0	- 0,01612955	-100
13.03.2012	40981	176	355	0,14285714	0,01764322	0,00151367	9,38442963
27.03.2012	40995	190	355	0,7037037	0,08690919	0,07077964	438,819598
13.04.2012	41012	207	355	1,52173913	0,18793864	0,17180908	1065,18197
24.04.2012	41023	218	355	0,16	0,01976041	0,00363085	22,5105612
10.05.2012	41039	234	355	0,24	0,02964061	0,01351106	83,7658418
24.05.2012	41053	248	355	0,52173913	0,0644361	0,04830655	299,49096
12.06.2012	41072	267	355	0,04166667	0,00514594	- 0,01098361	-68,096208
09.07.2012	41099	294	355	0,04166667	0,00514594	- 0,01098361	-68,096208
20.09.2011	40806	1	355	0	0	- 0,01612955	-100
29.11.2011	40876	71	355	0,03333333	0,00411675	-0,0120128	- 74,4769664
19.12.2011	40896	91	355	0	0	- 0,01612955	-100
04.01.2012	40912	107	355	0	0	- 0,01612955	-100
16.01.2012	40924	119	355	0	0	- 0,01612955	-100
14.02.2012	40953	148	355	0	0	- 0,01612955	-100
27.02.2012	40966	161	355	0	0	- 0,01612955	-100
13.03.2012	40981	176	355	0,09677419	0,01195186	- 0,00417769	- 25,9008702
27.03.2012	40995	190	355	0,125	0,01543782	- 0,00069174	- 4,28862407
13.04.2012	41012	207	355	0,04	0,0049401	-	-

Section Marine Biogeosciences

Alfred Wegener Institute for Polar and Marine Research

Am Handelshafen 12, 27570 Bremerhaven

Germany

						0,01118945	69,3723597
24.04.2012	41023	218	355	0	0	-	-100
						0,01612955	
10.05.2012	41039	234	355	0,12	0,0148203	-	-
						0,00130925	8,11707911
24.05.2012	41053	248	355	0,09677419	0,01195186	-	-
						0,00417769	25,9008702
12.06.2012	41072	267	355	0,11538462	0,01425029	-	-
						0,00187926	11,6510376
09.07.2012	41099	294	355	0,03030303	0,0037425	-	-
						0,01238705	76,7972422
20.09.2011	40806	1	355	0	0	-	-100
						0,01612955	
29.11.2011	40876	71	355	0	0	-	-100
						0,01612955	
19.12.2011	40896	91	355	0	0	-	-100
						0,01612955	
04.01.2012	40912	107	355	0	0	-	-100
						0,01612955	
16.01.2012	40924	119	355	0	0	-	-100
						0,01612955	
30.01.2012	40938	133	355	0	0	-	-100
						0,01612955	
14.02.2012	40953	148	355	0	0	-	-100
						0,01612955	
27.02.2012	40966	161	355	0,19047619	0,02352429	0,00739474	45,8459062
13.03.2012	40981	176	355	0,28571429	0,03528644	0,01915689	118,768859
27.03.2012	40995	190	355	0,20833333	0,02572969	0,00960014	59,5189599
13.04.2012	41012	207	355	0,36	0,04446091	0,02833136	175,648763
24.04.2012	41023	218	355	0,45833333	0,05660533	0,04047577	250,941712
10.05.2012	41039	234	355	0,08	0,0098802	-	-
						0,00624935	38,7447194
24.05.2012	41053	248	355	0,17241379	0,02129354	0,00516399	32,0156909
12.06.2012	41072	267	355	0	0	-	-100
						0,01612955	
09.07.2012	41099	294	355	0,03448276	0,00425871	-	-
						0,01187084	73,5968618
			355	8,09726109	0,01612955		

Section Marine Biogeosciences
Alfred Wegener Institute for Polar and Marine Research
Am Handelshafen 12, 27570 Bremerhaven
Germany