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Mosquito species on the Island of Baltrum in the southern North Sea (Germany) including information on the culicids from the Islands of Langeoog and Mellum (Diptera: Culicidae)

[Die Stechmücken-Arten der Insel Baltrum in der südlichen Nordsee (Deutschland) einschließlich Informationen zu den Culiciden der Inseln Langeoog und Mellum (Diptera: Culicidae)]

by
Renke LÜHKEN, Ellen KIEL, Tammo LIECKWEG and Rolf NIEDRINGHAUS

Oldenburg (Germany)

Abstract During the summer of 2008, the species composition of mosquitoes (Diptera: Culicidae) was studied for three East Frisian Islands in northern Germany. On the Island of Baltrum, 47 pools and ditches within a salt marsh and dune complex were sampled with sweep nets approximately every two weeks from April to July 2008. Adult mosquitoes were collected with a fixed light trap from July to November 2008. Additionally, random samples were taken from comparable waterbodies on the islands of Langeoog and Mellum between July and September 2008.
A total of nine taxa were identified: *Anopheles maculipennis* complex, *Anopheles claviger* complex, *Ochlerotatus caspius* (PALLAS, 1771), *Ochlerotatus detritus* (HALIDAY, 1833), *Ochlerotatus dorsalis* (MEIGEN, 1830), *Ochlerotatus rusticus* (ROSSI, 1790), *Culex pipiens* LINNAEUS, 1758, *Culex torrentium* MARTINI, 1925, and *Culiseta annulata* (SCHRANK, 1776). Five species were recorded for the first time on the East Frisian Islands: *Ochlerotatus caspius*, *Oc. detritus*, *Oc. dorsalis*, *Oc. rusticus* and *Culex torrentium*. Four mosquito taxa were recorded for the first time on Baltrum: *Anopheles maculipennis* complex, *An. claviger* complex, *Culex pipiens*, and *Culiseta annulata*. *Culex pipiens* was recorded for the first time on the Island of Langeoog, and the occurrence of *An. maculipennis* complex was confirmed for this island. Finally, *Culex pipiens* and *Oc. detritus* were recorded the first time on the Island of Mellum.

Key words Culicidae, mosquitoes, Palaearctic, northern Germany, North Sea, East Frisian Islands, Baltrum, Langeoog, Mellum, phenology, species composition, new records

Zusammenfassung Im Sommer 2008 wurde die Artenzusammensetzung der Stechmücken-Faunen (Diptera: Culicidae) dreier Ostfriesischer Inseln untersucht. Auf Baltrum wurden von April bis Juli 2008 in 47 Kleingewässern und Gräben des Salzmarsch- und Dünen-Komplexes etwa 14tägig Kescherproben genommen. Imagines wurden von Juli bis November mit Hilfe einer fest installierten Lichtfalle erfasst. Zwischen Juli und September wurden zusätzlich Stichproben von vergleichbaren Gewässern auf den Inseln Langeoog und Mellum erhoben.
Insgesamt wurden neun Taxa nachgewiesen: *Anopheles maculipennis*-Komplex, *Anopheles claviger*-Komplex, *Ochlerotatus caspius* (PALLAS, 1771), *Ochlerotatus detritus* (HALIDAY, 1833), *Ochlerotatus dorsalis* (MEIGEN, 1830), *Ochlerotatus rusticus* (ROSSI, 1790), *Culex pipiens* LINNAEUS, 1758, *Culex torrentium* MARTINI, 1925 und *Culiseta annulata* (SCHRANK, 1776). Die Funde von *Oc. caspius*, *Oc. detritus*, *Oc. dorsalis*, *Oc. rusticus* und *Culex torrentium* sind Erstnachweise für die Ostfriesischen Inseln. Vier Stechmückentaxa sind neu für Baltrum: *An. maculipennis*-Komplex, *An. claviger*-Komplex, *Culex pipiens* und *Culiseta annulata*. *Culex pipiens* wurde erstmals auf Langeoog nachgewiesen; das Vorkommen des *An. maculipennis*-Komplexes konnte für diese Insel bestätigt werden. Außerdem wurden *Culex pipiens* und *Oc. detritus* erstmals für Mellum nachgewiesen.

Stichwörter Culicidae, Stechmücken, Paläarktis, Norddeutschland, Nordsee, Ostfriesische Inseln, Baltrum, Langeoog, Mellum, Phänologie, Artenzusammensetzung, neue Nachweise

Introduction

Due to the eradication of malaria in Germany in the middle of the 20th century scientific research into mosquitoes became a neglected field in Germany (WEYER 1956). This eradication was accomplished mainly by the intensive drainage of marshes, swamps and fens (MAIER 2004). Additionally, housing and sanitation were improved, and advances in diagnostic methods and in the treatment of malaria were made (e. g. BRUCE-CHWATT & DE ZULUETA 1980).

The present spread of vectors and of several pathogens throughout Europe, such as the mosquito *Aedes albopictus* (SKUSE, 1895) (e. g. KNUDSEN et al. 1996, SCHAFFNER et al. 2001) or the West Nile virus (ROMI et al. 2004) has revealed a severe lack of information about mosquito species and their breeding sites in Germany. Sporadic studies in North Rhine-Westphalia (KÜPPER et al. 2006) or the monitoring carried out in the course of mosquito control activities along the River Rhine (BECKER et al. 1996), however, have shown that potential malaria vectors still do occur in Germany, thus demonstrating the necessity for studies on mosquito species composition and distribution in Germany.

Particularly for northern Germany, two deficits in mosquito research are obvious. First, only few recent studies focus on species distribution, ecology, or on species phenology (e. g. WILKE 2005, WILKE et al. 2006). Instead many authors prefer a more theoretical approach (e. g. SCHRÖDER et al. 2007, SCHRÖDER & SCHMIDT 2007). Second, the latest profound entomological studies on the moquito fauna of the East Frisian Islands were carried out before 1950. These old records of culicids were reviewed by NIEDRINGHAUS (2008), who reported six mosquito species on these islands: *Ochlerotatus annulipes* (MEIGEN, 1830), *Anopheles atroparvus* VAN THIEL, 1927, *Anopheles claviger* complex, *Anopheles maculipennis* complex, *Culex pipiens* LINNAEUS, 1758, and *Culiseta annulata* (SCHRANK, 1776).

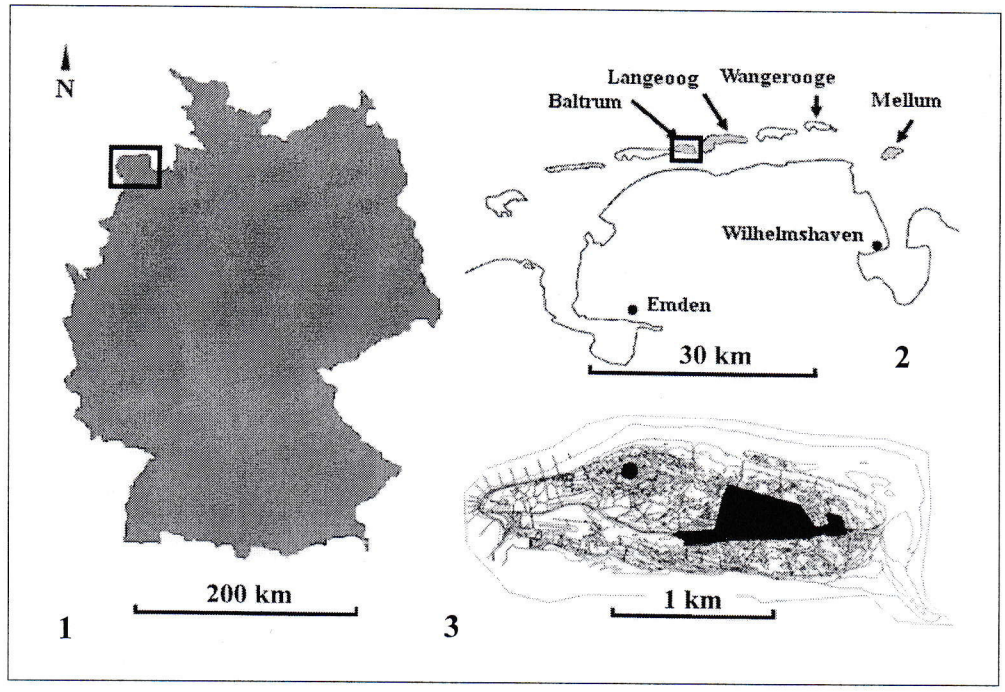
The lack of research on the current culicid fauna on the East Frisian Islands has motivated this study. The aim was to characterize the mosquito species composition with a special focus on the Island of Baltrum. Moreover, additional insights into the mosquito fauna of the islands of Langeoog and Mellum should be gained.

East Frisian Islands (Study Site)

The East Frisian Islands are situated in the 278,000 ha Wadden Sea National Park of Lower Saxony (Fig. 1). The climate within this region is maritime, semi-humid and moderately temperate (BAUER 1996), with the average temperature about 10 °C and the annual precipitation between 600 to 800 mm.

Having a total area of 7 km² (5 km in maximum length, 1.4 km in maximum width), Baltrum is the smallest of the permanently inhabited islands (Figs 2, 3). The 63 ha area, where most of the studies were carried out, is situated in the most eastern part of Baltrum. Due to seasonal flooding by tidal saltwater, soil salinities here rise to about 5–20 ‰ (SCHEFFER & SCHACHTSCHABEL 2002), thus causing the typical vegetation types of salt marshes and dunes (POTT 1995, NATIONALPARKVERWALTUNG NIEDERSÄCHSISCHES WATTENMEER 2004). Except for a few trails and drainage ditches, there is no anthropogenic use in this part of the island.

The Island of Langeoog, which is about three times the size (of 22 km²), is situated quite close (1.4 km) to Baltrum, while Mellum is most eastern island, 11 km in distance to the Island of Wangerooge. Contrary to the others, Mellum is not permanently inhabited and has a total area of 500 ha only.



Figs 1–3: Study area. – **1**: Location of the studied East Frisian Island in northern Germany; – **2**: Location of Baltrum, Langeoog and Mellum; – **3**: Study area on Baltrum (black zone) and location of the light trap (black dot).

All islands are quite close to the German mainland, with maximum distances ranging from 4.5 km (Baltrum) to 6 km (Mellum) (Figs 1, 2).

Material and methods

Intensive study (Baltrum)

In the study area, forty seven pools and ditches were regularly sampled from April to July 2008 (every 14–19 days). All of these pools were temporary waters, exposed to seasonal flooding by tidal seawater. As long as the study sites remained wet, immature mosquitoes were collected with a 500 µm mesh sweep net (frame height and width 250 mm) at a maximal depth of 125 mm. Pools and ditches were sampled on one immersion that covered the whole surface area. The net was rinsed out into a white tray (30 cm x 24 cm x 5 cm). Every replicate was kept separate and transported to the laboratory in 3 l Zipploc bags (Toppits®, Minden).

A maximum of 400 larvae were randomly chosen and reared to adults. These larvae were transferred to a 1500 ml plastic beaker with a plastic pipette. The beaker was filled with 1000 ml tap water that had been allowed to stand for 24 hours in order to reduce the amount of volatile chemicals. Larvae were fed *ad libitum* with fish food (TetraMin® Wafer Mix, Tetra, Melle, Germany). Adults emerging from the beaker were caught with emergence traps. These traps were filled with saturated salt solution mixed with a few dashes of washing-up liquid. Cadavers, adults and exuviae were removed from the emergence traps every day and preserved in 70 % ethanol. Larvae which were sampled in the field but not used for rearing experiments were preserved directly in 70 % ethanol.

A light trap was installed close to the urban area on the Island of Baltrum (Fig. 3). The BG-Sentinel© UV-light trap (BioGents GmbH, Regensburg, Germany) (GEIER et al. 2004, KROECKEL et al. 2006) was baited with BioGent Lure© (BioGents GmbH, Regensburg, Germany). Being a mixture of lactic acid, ammonia and capronic acid (BioGents GmbH, Regensburg, Germany), this bait mimics human perspiration. UV-light trap catches were carried out around-the-clock from July to November and were checked twice a week. All light trap catches were preserved in 70 % ethanol. After determination they were archived at the University of Oldenburg (working group Aquatic Ecology and Nature Conservation).

Additional Samples (Baltrum, Langeoog and Mellum)

In addition to the studies at the regular sampling sites, other aquatic habitats were analysed. On the islands of Langeoog and Baltrum additional samples were carried out in areas with and without tidal flooding on three dates in summer 2008, and on Mellum, one sampling was rendered possible in August 2008. At every site the mosquito larvae were collected with a 500 µm mesh sweep net. Adult mosquitoes accidentally landing on human bait were also captured and preserved in 70 % ethanol. The larvae were transported to the laboratory in polyethylene bottles (100 ml) and reared to adults in the water from their natural habitats.

Identification

Adults and fourth instar larvae were identified by morphological characters to species or species complex level according to the key of BECKER et al. (2003). Pupae were identified to species or species complex level using the key of LECHTHALER (2005).

Results

Nine mosquito taxa were recorded: *Anopheles maculipennis* complex, *Anopheles claviger* complex, *Ochlerotatus caspius* (PALLAS, 1771), *Ochlerotatus detritus* (HALIDAY, 1833), *Ochlerotatus dorsalis* (MEIGEN, 1830), *Ochlerotatus rusticus* (ROSSI, 1790), *Culex pipiens* LINNAEUS, 1758,

Tab. 1: Mosquito species on Baltrum, Langeoog, and Mellum. Data from sampling between April and November 2008 (black: first record for the East Frisian Islands, dark-grey: first record for the specific island, light-grey: previous records existed).

species resp. species complex \ islands	Baltrum	Langeoog	Mellum
Anopheles (*Anopheles*) *maculipennis* complex			
Anopheles (*Anopheles*) *claviger* complex			
Ochlerotatus (*Ochlerotatus*) *caspius* (PALLAS, 1771)			
Ochlerotatus (*Ochlerotatus*) *detritus* (HALIDAY, 1833)			
Ochlerotatus (*Ochlerotatus*) *dorsalis* (MEIGEN, 1830)			
Ochlerotatus (*Rusticus*) *rusticus* (ROSSI, 1790)			
Culex (*Culex*) *pipiens* LINNAEUS, 1758			
Culex (*Culex*) *torrentium* MARTINI, 1925			
Culex (*Culex*) *pipiens* / *torrentium*			
Culiseta (*Culiseta*) *annulata* (SCHRANK, 1776)			
number of genera	4	2	2
number of species / species complexes	9	2	2

Tab. 2: Mosquito species on Baltrum. Data from pools and ditches with (black) or without (grey) tidal influence, sampled between April and July 2008 (* = no samples).

species resp. species complex \ month	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Anopheles maculipennis complex								
Anopheles claviger complex								
Ochlerotatus caspius								
Ochlerotatus detritus								
Ochlerotatus dorsalis								
Ochlerotatus rusticus								
Culex pipiens								
Culex torrentium								
Culex pipiens / torrentium								
Culiseta annulata								
number of genera	1	1	0	4	*	1	*	2
number of species / species complexes	2	1	0	8	*	1	*	4

Tab. 3: Mosquito species on Langeoog. Data from pools and ditches with tidal influence that were sampled in June, July and September 2008 (* = no samples).

species resp. species complex \ month	Jun	Jul	Aug	Sep
Anopheles maculipennis complex				
Anopheles claviger complex				
Ochlerotatus caspius				
Ochlerotatus detritus				
Ochlerotatus dorsalis				
Ochlerotatus rusticus				
Culex pipiens				
Culex torrentium				
Culex pipiens / torrentium				
Culiseta annulata				
number of genera	0	0	*	2
number of species / species complexes	0	0	*	2

Culex torrentium MARTINI, 1925, and *Culiseta annulata* (SCHRANK, 1776) (Tab. 1). We could not differentiate between *Culex pipiens* and *Culex torrentium* in many specimens and classified those specimens as *Culex pipiens / torrentium* (Tab. 1–5).

The genus *Anopheles* was represented by two species complexes. Specimens of the *Anopheles maculipennis* complex were found on the islands of Baltrum and Langeoog (Tab. 1–3). The *Anopheles claviger* complex was found on Baltrum only (Tab. 1, 2).

We recorded four species of the genus *Ochlerotatus*: *Oc. detritus, Oc. caspius, Oc. dorsalis* and *Oc. rusticus*. *Oc. detritus* was found on the islands of Baltrum and Mellum (Tab. 1, 2, 5). Except for a dry period in June 2008, this species was recorded at every sampling date on the Island of Baltrum (Tab. 2). *Ochlerotatus dorsalis*, *Oc. caspius* and *Oc. rusticus* were recorded only on Baltrum (Tab. 1, 2, 4).

Tab. 4: Mosqito species and mosquito phenology on Baltrum according to light trap catches between July and November 2008.

species resp. species complex \ month	Jul	Aug	Sep	Oct	Nov
Anopheles maculipennis complex					
Anopheles claviger complex					
Ochlerotatus caspius	■	■	■	■	■
Ochlerotatus detritus	■	■	■	■	■
Ochlerotatus dorsalis					
Ochlerotatus rusticus					
Culex pipiens					
Culex torrentium					
Culex pipiens / torrentium	■	■	■	■	■
Culiseta annulata					
number of genera	2	2	2	2	2
number of species / species complexes	3	3	3	3	3

Tab. 5: Mosquito species on Mellum. Data from pools and ditches without tidal influence (black) and data concerning adult mosquitoes accidentally landing on human bait (grey) sampled in August 2008.

species resp. species complex \ month	Aug
Anopheles maculipennis complex	
Anopheles claviger complex	
Ochlerotatus caspius	
Ochlerotatus detritus	▒
Ochlerotatus dorsalis	
Ochlerotatus rusticus	
Culex pipiens	■
Culex torrentium	
Culex pipiens / torrentium	
Culiseta annulata	
number of genera	2
number of species / species complexes	2

The genus *Culex* was represented by two species: *Culex pipiens* and *Culex torrentium*. *Culex pipiens* was recorded for the islands of Baltrum and Langeoog (Tab. 1–5), whereas the species *Culex torrentium* was found only on the island of Baltrum.

The number of species recorded for Baltrum was higher in water samples [nine species (Tab. 2)] than in the light trap samples [three species or species complexes (Tab. 4)]. In September 2008, only two species were caught in larval stage on Langeoog (Tab. 4) and two species were found on the Island of Mellum (Tab. 5).

Discussion

A total of 195 Nematocera species have been described for the East Frisian Islands (NIEDRINGHAUS 2008). Although the earliest, profound publications on the Nematocera fauna date back to SCHNEIDER (1898), no comparable inventories have been carried out since the middle of the 20th century. In particular, the mosquito fauna on the Island of Baltrum had never been studied before and only outdated inventories exist for the Island of Langeoog (NIEDRINGHAUS 2008). Previous studies found

a total of 70 Nematocera species on the Island of Mellum [inventories reviewed by NIEDRINGHAUS (2008)], however, these studies excluded the family Culicidae.

According to our results, at least two species complexes and seven mosquito species [out of 45 species which occur in Germany; MOHRIG (1969), BECKER & KAISER (1995)] are present on the islands we studied. Except for *Culex torrentium,* all new records for the East Frisian Islands belonged to the genus *Ochlerotatus*: *Ochlerotatus caspius, Oc. detritus*, *Oc. dorsalis,* and *Oc. rusticus*. Due to the fact that there were no previous studies for the islands of Baltrum and Mellum, all genera and species as well as species complexes were new records here. Finally, for Langeoog, the *Anopheles maculipennis* complex was confirmed and *Culex pipiens* was recorded for the first time [cf. NIEDRINGHAUS (2008), Tab. 1]. On the other hand, we did not confirm previous records of *Ochlerotatus annulipes* (MEIGEN, 1830) (cf. NIEDRINGHAUS 2008), a species which is most abundant in central parts of the continent (BECKER et al. 2003). *Ochlerotatus annulipes* prefers outskirts of forests and deciduous woods (BECKER et al. 2003), thus it might be underestimated in our study, since we focussed on biotops in salt marshes.

Specimens of *Oc. detritus* were found throughout the entire time of the study on Baltrum. Larvae already occurred early in April (Tab. 1), suggesting an overwintering strategy. According to results in England, eggs of *Oc. detritus* can hatch at any time of the year and larvae may be present even during the winter months (e. g. MARSHALL 1938, SERVICE 1968). This possibly also applies to the situation in Germany, at least in coastal areas.

Another aspect we ought to discuss here is the discrepancy between the number of species we caught with light traps and the number of species we caught as larvae in their breeding sites. The latter number was always higher (Tab. 2, 4), which might be due to low abundances or dispersal ability of some mosquito species or simply to the fact that some mosquito species are not attracted by light (BENTLEY et al. 2009) or human perspiration odour.

The comparatively low number of species recorded for these islands might also be influenced by our specific focus of analysis. We predominantly sampled pools and ditches of salt marshes, which are seasonally flooded by water with high salinities (LÜHKEN, unpublished data). Since only 5 % of all mosquito species may survive and develop in brackish or saline water [as reviewed by SILBERBUSH et al. (2005)], the fauna of our study sites should be restricted to an assortment of these well adapted species. More culicid species have to be expected, if more light traps at different sites would be operated, and if further habitat types (e. g. rain barrels, containers or tree-holes) will be studied. KÜPPER et al. (2006) revealed that a combination of various methods has to be used, if an extensive description of the mosquito fauna is intended. Furthermore, if we would have differentiated sibling species by PCR-methods – e. g. would have separated the *An. maculipennis* complex [as described by PROFT et al. (1999)] – even more species are to be expected.

Nevertheless, considering the vector competences of *Oc. caspius* or *Culex pipiens* for West-Nile virus (e. g. VINOGRAD & OBUKHOVA 1975, AKHTER et al. 1982, BALENGHIEN et al. 2006) and the severe nuisance that *Oc. detritus* or *Oc. caspius* may cause (e. g. MARSHALL 1938, ROBERTS 1995), our study indicates the importance of further and more intensive studies on the culicid fauna of the German coastal area.

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Authors' addresses

Renke LÜHKEN
Prof Dr Ellen KIEL
Aquatic Ecology and Nature Conservation Group
Institute of Biology and Environmental Sciences
University of Oldenburg
26129 Oldenburg
Germany
E-mail: renke.luehken@uni-oldenburg.de
ellen.kiel@uni-oldenburg.de

Tammo LIECKWEG
Dr Rolf NIEDRINGHAUS
Landscape Ecology Group
Institute of Biology and Environmental Sciences
University of Oldenburg
26129 Oldenburg
Germany
E-mail: tammo.lieckweg@gmx.de
rolf.niedringhaus@uni-oldenburg.de

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