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Increased abundance of floodwater mosquito species over three seasons in Forshaga municipality, western Sweden

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RESEARCH ARTICLE

Abstract

Floodwater mosquitoes are a main cause of mosquito nuisance in several European countries, including Sweden. Since 2002, a large-scale mosquito control programme around the river Dalälven in eastern Sweden targets floodwater mosquito species such as *Aedes sticticus*. The current study was initiated due to citizen complaints about nuisance mosquitoes around Deje village in Forshaga municipality, a region situated at the river Klarälven in western Sweden. Over three years, 2010-2012, mosquito collections with CDC-light traps and morphological species identification were performed to determine the nuisance causing mosquito species and to describe the seasonality, abundance and species composition of mosquitoes in the area. Over the three years of collections at eight trap sites, mosquito abundance increased with a mean of 282 mosquitoes collected per trap-night in 2010, 702 mosquitoes per trap-night in 2011, and 1,367 mosquitoes per trap-night in 2012. The increase in abundance was mainly due to an increase of floodwater mosquitoes, with *Ae. sticticus* as the main species. Single traps collected over 5,000 floodwater mosquitoes at several occasions in 2011 and 2012. A correlation between river discharge exceeding 300 m^3/s and an increase in floodwater mosquito abundance three weeks later when average air temperatures were around 15 °C could be seen. Interestingly, river discharge was the highest in 2010, however mosquito abundance was higher in both 2011 and 2012. Potentially, the increasing number of diapausing eggs available after each season has contributed to the amplification of the *Ae. sticticus* population in the region.

Keywords: Culicidae, *Aedes sticticus*, *Aedes vexans*, mosquito nuisance

1. Introduction

Floodwater mosquitoes are a main cause of mosquito nuisance in several European countries (Becker *et al.,* 2010; Berec *et al.,* 2014; Merdic and Lovakovic, 2001; Minar *et al.,* 2001; Schäfer *et al.,* 2008). In Sweden, a large-scale mosquito control program using *Bacillus thuringiensis israelensis* (Bti) to target primarily, but not exclusively, the floodwater species *Aedes (Ochlerotatus) sticticus* (Meigen, 1838), has been running since 2002 across several municipalities affected by flooding of the river Dalälven (Schäfer and Lundström, 2014). Several regions in Sweden, including Övertorneå, have also reported nuisance problems due to floodwater mosquito species (Blomgren *et al.,* 2018) but for most of them no mosquito control has been performed. This group of mosquitoes lay their eggs in soils prone to flooding, caused by alterations in river flow or rainfall. Since eggs can remain viable in the soil for many years, so called egg-banks may accumulate and mass hatching may occur during a flooding when circumstances (e.g. temperature) are right.

In the late fall of 2009, the authors were contacted by representatives of Forshaga municipality, describing serious mosquito nuisance problems in and around Deje village, situated at the River Klarälven in western Sweden. The municipality had received a massive amount of mosquito nuisance complaints by telephone, email and personal visits

to the municipality administrative building by the locals, who also expressed their frustration over the situation in local and national media. After instructions over telephone, the representatives of Forshaga sampled a few mosquitoes that were sent to the authors for identification. More than 60% of the mosquitoes were *Ae. sticticus*, indicating that the village may have a serious floodwater mosquito nuisance problem. This motivated an extensive study of the mosquito fauna species composition and the abundance patterns over several summer seasons.

This study aims to identify the cause of the mosquito nuisance problems in Deje, and to describe the seasonality, abundance and species composition of the mosquitoes in the area. These data provide abundance measurements that are useful in the evaluation of the potential need for mosquito control.

2. Material and methods

Study sites

Forshaga municipality is situated in the lower stretch of the River Klarälven with a catchment area that includes major parts of the Värmland County in Western Sweden, as well as regions across the border to Norway. Based on the available information on mosquito nuisance problems in 2009, sampling of blood-seeking female mosquitoes was initiated in 2010. Several study sites were selected in and around the village of Deje in the central portion of Forshaga municipality (Figure 1, Supplementary Table S1). These study sites were selected based on collections of floodwater mosquitoes made by Forshaga representatives in 2009. In addition, we included areas that we identified as potential floodwater mosquito production sites as well as urban areas where mosquito nuisance was experienced.

All study sites were characterised by vegetation composed by sedges (*Carex* spp.) and grasses (*Calamagrostis* spp.) interspersed with tufts of bushes (*Salix* spp.) in the open parts, and with mainly birch (*Betula* spp.) and some alder (*Alnus* spp.) in the more forested parts. The sampling effort each year is summarised in Table 1 and the characteristics of each study site is described below, following the river from north to south:

Korset is a forested area a few meters from the River Klarälven and contains several ditch-like structures that get flooded during periods of increased water levels in the river.

Sjöbottnen is a wet meadow located at the perimeter of Lake Sjöbottnen. The Lake is directly connected to the river

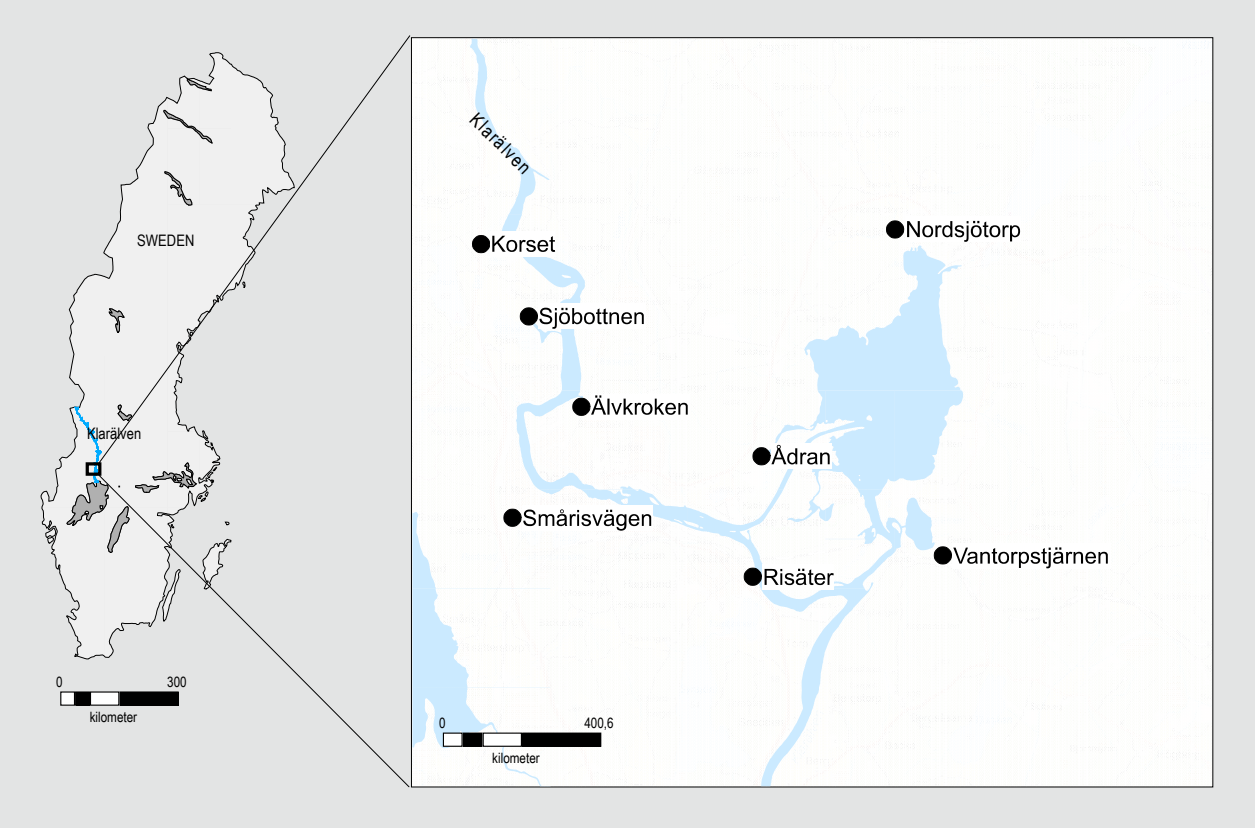

Figure 1. Collection sites (black dots) in and around the village Deje in Forshaga municipality, western Sweden.

Table 1. Sampling-sites and sampling effort expressed as total number of trap-nights per year for mosquito collections in Deje, Forshaga municipality, Sweden, during 2010, 2011 and 2012.[1,2]

Sampling site	Trap-nights and weeks in 2010	Trap-nights and weeks in 2011	Trap-nights and weeks in 2012
Korset	9 (w 21-37)	7 (w 25-37)	NS
Sjöbottnen	9 (w 21-37)	7 (w 25-37)	7 (w 25-37)
Älvkroken	9 (w 21-37)	7 (w 25-37)	NS
Smårisvägen	NS	5 (w 29-37)	7 (w 25-37)
Risätter	4 (w 31-37)	7 (w 25-37)	7 (w 25-37)
Ådran	9 (w 21-37)	7 (w 25-37)	7 (w 25-37)
Vantorpstjärnen	NS	NS	7 (w 25-37)
Nordsjötorp	NS	NS	7 (w 25-37)
Total number of trap-nights	40	40	42

[1] Total number of trap-nights at a specific site and year. In parenthesis are the first and last sampling weeks of the year, during that period trapping was performed every second week.
[2] NS = not sampled.

Klarälven by a short stream. It is surrounded by agricultural land and strong growth of reed indicate high nutrient load.

Älvkroken is located at the northern shore of the River Klarälven and just upstream from the village Deje. The area contains some low parts that could get flooded at increased water levels in the river, but the size of the potentially flooded areas is rather small.

Smårisvägen and Risätter are populated areas at the perimeter of the village Deje. Here, the traps were set in trees near these areas of single-family houses and facing nearby potentially flooded meadows.

Ådran is a peninsula with the River Klarälven on one side and a small lake on the other side. The area contains wet meadows dominated by grass and willow bush, and also has extensive areas with deciduous forest that could get partially flooded when water flow in the river is increased.

Vantorpstjärnen is a wet meadow shortly downstream of Lake Lusten, and it is indirectly connected to River Klarälven by groundwater. When the water level starts rising in Lake Lusten subterranen water flow will increase the water level in Lake Vantorpstjärnen and flood the wet meadow.

Nordsjötorp is a wet meadow at the perimeter of Lake Lusten, and it reacts directly on any change of water level in the Lake.

Mosquito sampling and identification

Mosquitoes were collected with Centers for Disease Control and Prevention miniature light traps (CDC-traps; Clarke, St Charles, IL, USA), baited with dry ice. The CDC-traps were hung out in the afternoon and retrieved the following morning. Collected mosquitoes were brought back alive to the field station where they were counted as described in Blomgren *et al.* (2018). Once mosquitoes were counted and separated from bycatch, they were frozen and stored at -25 °C until morphological identification. Identification of female mosquitoes was performed under a stereo microscope illuminated with a cold light lamp using the dichotomous key by Becker *et al.* (2010). In each catch, up to 1000 individual mosquitoes were identified, and catches with more than 1000 individuals were extrapolated to the estimated total number of mosquitoes in that catch.

The identified mosquitoes were classified into functional groups (FG) as defined by Schäfer *et al.* (2004) and Lundström *et al.* (2013). Here we use the term 'floodwater mosquitoes' as synonym for FG 2b (i.e. *Ae. sticticus, Ae. (Aedes) cinereus* Meigen, 1818 */ geminus* Peus, 1970*, Ae. (Aed.) rossicus* Dolbeskin, Gorickaja & Mitrofanova, 1930*, Ae. (Aedimorphus) vexans* (Meigen 1830)), 'snow-pool mosquitoes' for FG 2a (i.e. *Ae. (Och.) annulipes* (Meigen 1830), *Ae. (Och.) cantans* (Meigen, 1818), *Ae. (Och.) cataphylla* Dyar, 1916, *Ae. (Och.) communis* (De Geer, 1776), *Ae. (Och.) diantaeus* Howard, Dyar & Knab, 1913, *Ae. (Och.) intrudens* Dyar 1919, *Ae. (Och.) punctor* (Kirby, 1837)), and 'Others' for all other groups (i.e. *Anopheles (Anopheles) claviger* s.s. (Meigen, 1804), *An. (Ano.) maculipennis* s.l. Meigen, 1818*, Coquillettidia (Coquillettidia) richiardii* (Ficalbi, 1889)*, Culex (Culex) pipiens* Linnaeus, 1758 */ torrentium* Martini, 1925*, Culiseta (Culiseta) alaskaensis* (Ludlow, 1906)*, Cs. (Cus.) annulata* (Schrank, 1776)*, Cs. (Cus.) bergrothi* (Edwards, 1921)*, Cs. (Culicella) morsitans* (Theobald, 1901)*, Cs. (Cuc.) ochroptera* (Peus, 1935)). When appropriate, abundances were calculated as average number of mosquitoes caught per trap and night (i.e. trap-night).

River discharge and air temperature

Information of the daily average water flow at Skymnäs hydrological station, situated approximately 20 km upstream of Deje, was kindly provided by Fortum, the major water power company of the River Klarälven catchment area. Air temperature measurements from Karlstad airport, approximately 15 km south of Deje, were downloaded from the Swedish Meteorological and Hydrological Institute (SMHI). The temperature data was measured hourly and recalculated to daily mean temperature and analysed along with daily maximum and minimum temperature as well as daily variation in temperature.

3. Results

Over the three years of collections, a total of 96,766 mosquitoes were collected over 122 trap-nights. Mosquito abundance increased over the years with a mean of 282 mosquitoes/trap-night in 2010 (11,289 in total), 702 mosquitoes/trap-night in 2011 (28,074 in total) and 1,367 mosquitoes/trap-night in 2012 (57,403 in total). The increase in abundance was mainly due to an increase of floodwater mosquitoes and was recorded at all sites (Figure 2).

For all three years, most mosquitoes were collected at site Ådran (Figure 3). In 2010, the largest catch of floodwater mosquitoes was 1,183 per trap-night in week 27 (i.e. early July), and in 2011 it was 8,341 per trap-night in week 27. In 2012, the largest catch was 10,510 floodwater mosquitoes per trap-night in week 31 (i.e. late July). The nuisance tolerance threshold used by Swedish authorities is 5,000 mosquitoes per trap-night. This threshold was not exceeded for any site in 2010, but was exceeded for Ådran in both 2011 and 2012, as well as for Risätter in 2012 (Table 2).

Mosquito abundance differed between trap-sites, with floodwater mosquitoes making up over 90% of the collections at four sites (Ådran, Risätter, Nordsjötorp and Vantorpstjärnen) (Figure 4, Supplementary Figure S1). Floodwater mosquitoes dominated at all the other sites as well, however these sites were characterised by a more mixed species composition with snow-pool mosquitoes occasionally making up to 39% of the catch (Supplementary Table S2).

Over the three years of collections, 20 species were identified in the area with 10 to 18 species detected per site (Table 3). Most species were collected at Ådran and Risätter and fewest species at Nordsjötorp. Floodwater mosquito species were collected at all sites during all years investigated with *Ae. sticticus* as the main floodwater species with 61,489 individuals in total, followed by *Ae. vexans* with less than half as many individuals. The least common floodwater species was *Ae. rossicus* with 1,530 individuals. The number of *Ae. sticticus* and *Ae. vexans* followed the same temporal pattern throughout the seasons, with one peak in 2010 and 2011 and two peaks in 2012 (Figure 5). Different snow-

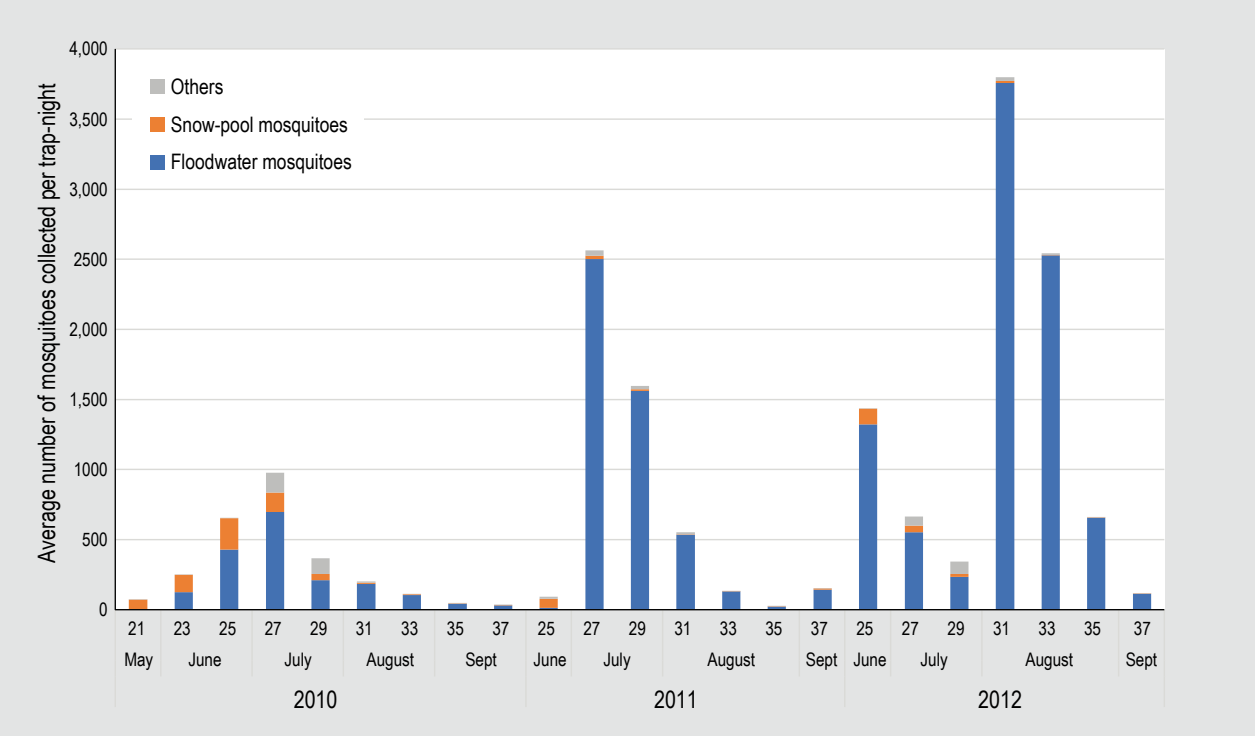

Figure 2. Average number of mosquitoes collected per trap-night in CDC-light traps baited with dry ice every second week over three seasons at Deje, Forshaga municipality, Sweden, and classified into functional groups defined by Schäfer *et al.* (2004).

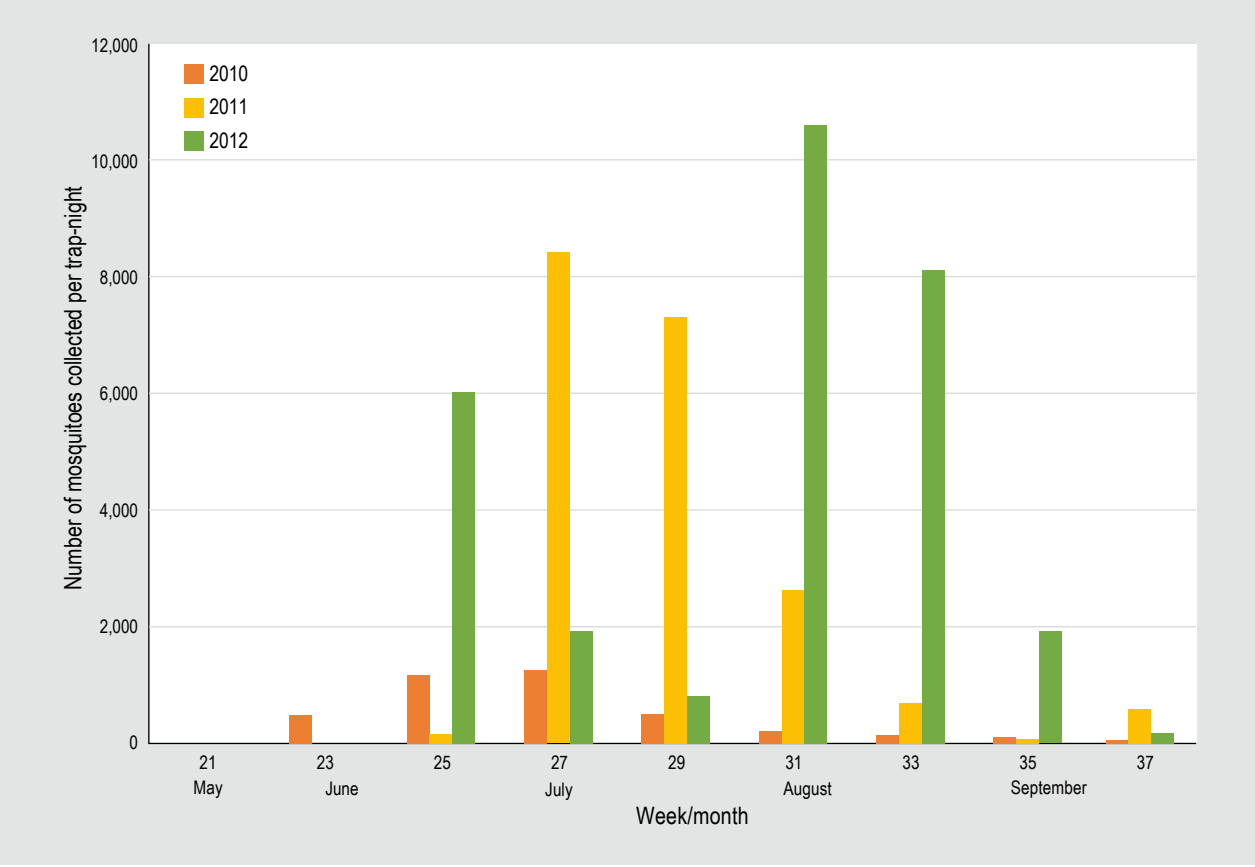

Figure 3. Number of mosquitoes collected per trap-night at site Ådran (Deje, Forshaga municipality, Sweden) throughout the summer season in 2010, 2011 and 2012.

Table 2. Sites and occasions where the nuisance threshold of >5,000 mosquitoes was exceeded in Deje, Forshaga municipality, Sweden.

Site	Year	Week	Number of mosquitoes/trap-night	Number of floodwater mosquitoes/trap-night
Ådran	2011	27	8,400	8,341
Ådran	2011	29	7,300	7,269
Ådran	2012	25	6,000	5,638
Ådran	2012	31	10,600	10,510
Ådran	2012	33	8,100	8,085
Risätter	2012	31	5,000	5,000

pool species also followed a temporal pattern and peaked around week 25-27 (i.e. late June to early July) during all the three years (Supplementary Figure S2). Too few individuals belonging to the group 'Other species' of mosquitoes were collected to distinguish seasonal patterns in occurrence, except for *Cq. richiardii* that peaked around week 27-29 (i.e. early to mid-July) during all three years investigated, and *Cx. pipiens/torrentium* that peaked with 46 individuals collected in week 31 (i.e. late July) in 2012. This can be compared to other years and weeks when only 0-4 *Cx. pipiens/torrentium* were collected (Table 3).

The daily water discharge measured at Skymnäs hydrological station varied between 75 and 620 m^3/s during April to September for the three years investigated. Every occasion of river discharge above 300 m^3/s in May, June or July was followed by an increase in floodwater mosquito abundance, albeit with notably varying increase for the different years (Figure 6). With the exception of May 2012, the river discharge exceeded 300 m^3/s for 8-17 consecutive days and the increase in floodwater mosquito abundance was noted approximately three weeks after. Average daily

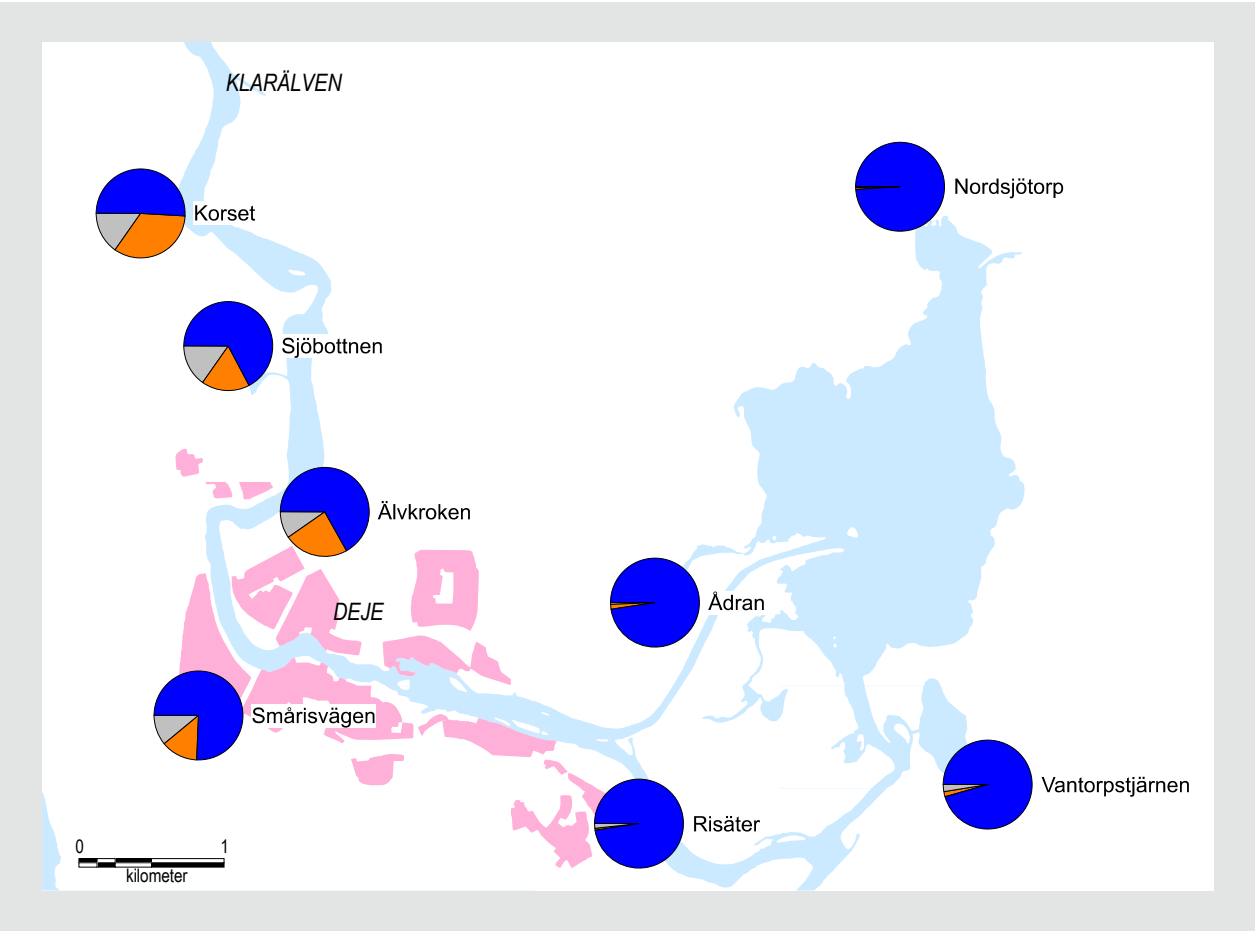

Figure 4. Percentage of floodwater mosquitoes (blue), snow-pool mosquitoes (orange) and mosquitoes of other functional groups (grey) collected on average over the three years 2010-2012 at the different collection sites in Deje, Forshaga municipality, Sweden.

air temperature for all of these three-week periods was around 15 °C (data not shown).

In 2010, maximum discharge at Skymnäs was 465 m^3/s in June and the maximum average number of mosquitoes per trap-night reached 698 individuals of which 71% were floodwater mosquitoes. In the beginning of June 2011, maximum water discharge at Skymnäs reached 378 m^3/s but mosquito number were much higher than in 2010 with a maximum average number of 2,564 mosquitoes per trap-night of which 98% were floodwater mosquitoes. During 2012, there were several peaks in water discharge. In May 2012, discharge exceeding 300 m^3/s was first measured for three days at one occasion, and for one more day at a later occasion (Figure 6). Potentially, the first occasion triggered larval hatching, and the second contributed to a prolonged flooding of the larval habitat, i.e. allowing more time for larval development to complete. For this period, the daily mean temperature was around 12 °C, indicating that larval developmental time took approximately five weeks (data not shown). A new peak of almost 400 m^3/s occurred in July 2012 and the average number of mosquitoes per trap night increased to 3,798 individuals, of which 99% were floodwater mosquitoes.

Notably, despite that river discharge exceeded 300 m^3/s for ten consecutive days in 2010, the increase in floodwater mosquito abundance three weeks later was very moderate, compared to 2011 and 2012 when river discharge was less pronounced. River discharge above 300 m^3/s that occurred in April, August or September was not associated to any increase in mosquito abundance during any of the years investigated.

4. Discussion

This three-year study was initiated due to citizen complaints of nuisance mosquitoes mainly in the Deje area of Forshaga municipality. Mosquito abundance varied between the years studied and reached levels indicating a severe mosquito nuisance situation during two of the three years investigated. During the three years of mosquito collections, an increase in floodwater mosquito abundance was measured, which did not correspond to the variation in river discharge. River discharge between May and August was the highest in

Table 3. Total number of individual mosquito species collected in and around Deje, Forshaga municipality, Sweden, per week and year in 2010 (40 trap-nights), 2011 (40 trap-nights) and 2012 (42 trap-nights).

Species	Year	Week									Total
		21	23	25	27	29	31	33	35	37	
Ae. annulipes	2010	0	1	4	0	0	2	1	0	0	8
	2011	0	0	0	0	4	0	0	0	0	4
	2012	0	0	0	0	0	0	0	0	0	0
Ae. cantans	2010	0	40	63	26	14	19	9	4	0	175
	2011	0	0	9	7	16	11	7	2	4	56
	2012	0	0	352	49	55	30	12	9	2	509
Ae. cataphylla	2010	0	1	0	0	0	0	0	0	0	1
	2011	0	0	0	0	0	0	0	0	0	0
	2012	0	0	0	0	0	0	0	0	0	0
Ae. cinereus/geminus	2010	1	126	496	234	184	132	52	123	81	1,429
	2011	0	0	56	131	190	81	39	17	219	733
	2012	0	0	145	182	225	185	286	177	56	1,256
Ae. communis	2010	290	365	540	259	30	17	0	0	0	1,501
	2011	0	0	241	64	15	4	0	1	17	342
	2012	0	0	134	120	46	32	7	7	2	348
Ae. diantaeus	2010	0	34	207	248	121	11	2	0	0	623
	2011	0	0	50	41	33	6	0	0	0	129
	2012	0	0	155	88	32	9	3	0	0	287
Ae. intrudens	2010	1	27	62	16	3	0	0	0	0	109
	2011	0	0	25	0	5	1	0	0	0	31
	2012	0	0	27	10	1	15	0	0	0	53
Ae. punctor	2010	0	30	20	7	1	1	12	8	11	90
	2011	0	0	6	18	2	3	3	2	29	63
	2012	0	0	3	0	2	5	4	10	7	31
Ae. rossicus	2010	0	23	191	83	102	63	19	4	0	485
	2011	0	0	10	147	297	53	30	12	14	563
	2012	0	0	109	16	75	0	231	47	4	482
Ae. sticticus	2010	0	326	923	2,341	383	463	160	58	58	4,712
	2011	0	0	1	9,355	5 542	1,818	172	24	579	17,491
	2012	0	0	5,487	1,609	544	16,711	11,709	2,891	335	39,286
Ae. vexans	2010	0	26	105	133	183	264	301	31	20	1,063
	2011	0	0	1	2,871	3 345	1,267	552	95	49	8,180
	2012	0	0	2,203	1,524	564	5,650	2,941	822	302	14,006
An. claviger	2010	0	0	1	0	0	0	1	0	1	3
	2011	0	0	0	0	0	0	0	1	0	1
	2012	0	0	0	0	0	0	0	0	0	0
An. maculipennis sl	2010	0	2	3	1	0	1	0	1	0	8
	2011	0	0	14	1	1	0	2	0	0	18
	2012	0	0	10	12	4	0	0	0	0	26
Cq. richiardii	2010	0	0	0	557	450	42	2	1	0	1,052
	2011	0	0	61	176	119	76	5	1	0	438
	2012	0	0	0	377	500	106	56	4	0	1,043
Cx. pipiens/torrentium	2010	0	0	0	0	4	0	3	0	0	7
	2011	0	0	0	0	0	4	2	1	4	11
	2012	0	0	2	3	3	46	2	2	0	58
Cs. alaskaensis	2010	1	0	1	0	0	0	0	0	0	2
	2011	0	0	0	0	0	0	0	0	0	0
	2012	0	0	0	0	0	0	0	0	0	0
Cs. annulata	2010	1	1	0	0	0	1	1	0	0	4
	2011	0	0	0	0	0	0	0	0	0	0
	2012	0	0	0	0	1	0	0	0	0	1
Cs. bergrothi	2010	0	1	5	0	0	0	1	0	0	7
	2011	0	0	2	0	0	0	0	0	0	2
	2012	0	0	0	0	0	0	0	0	0	0
Cs. morsitans	2010	0	0	0	1	1	0	2	0	1	5
	2011	0	0	0	0	1	2	0	1	0	4
	2012	0	0	0	0	0	0	5	1	2	8
Cs. ochroptera	2010	1	1	0	2	1	0	0	0	0	5
	2011	0	0	0	2	6	0	0	0	0	8
	2012	0	0	0	1	8	0	0	0	0	9
Total		295	1,004	11,724	20,712	13,112	27,131	16,634	4,357	1,797	96,766

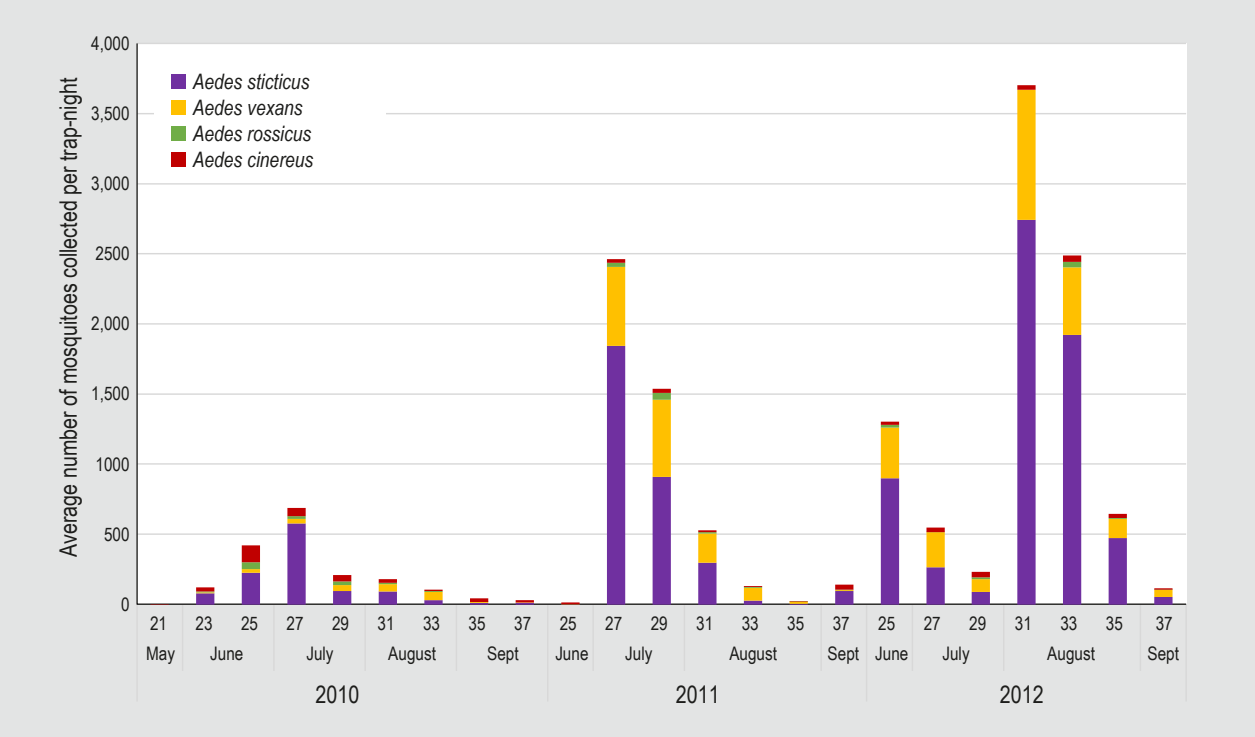

Figure 5. Average number of floodwater mosquitoes collected in Deje, Forshaga municipality, Sweden, per trap-night over all sites and the entire study period.

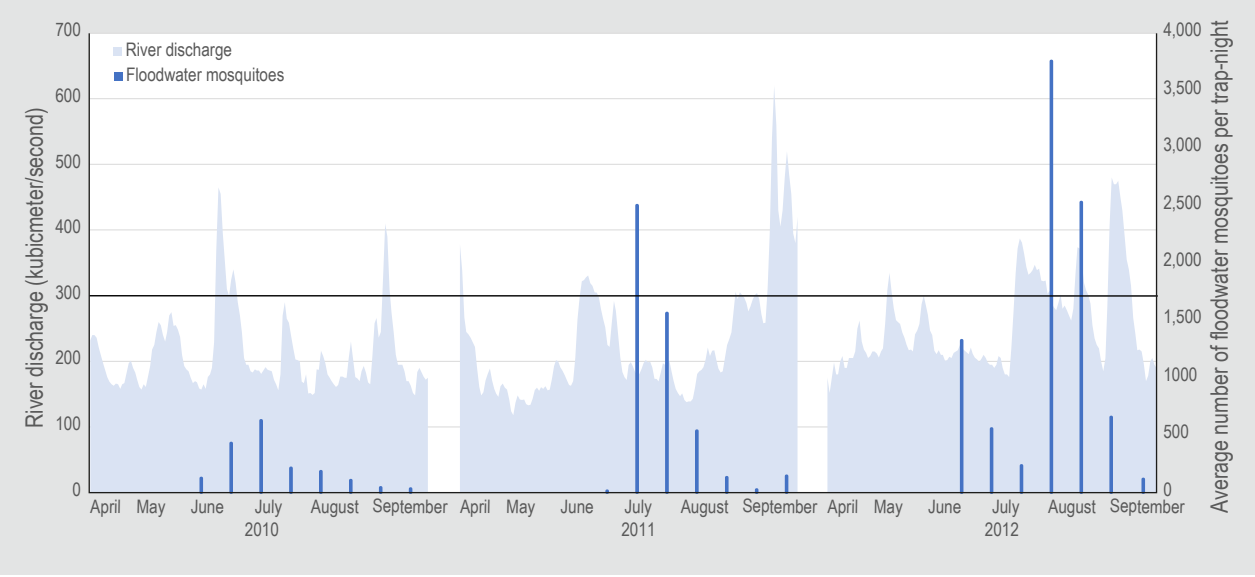

Figure 6. River discharge measured at Skymnäs hydrological station, situated approximately 20 km upstream from mosquito collection sites in Deje village (Forshaga municipality, Sweden), and the average number of floodwater species collected per trap-night in 2010, 2011 and 2012. River discharge of 300 m^3/s is highlighted with a bold line.

2010, however mosquito abundance was higher in both 2011 and 2012.

This study thus shows that a high river discharge and flooding are not in themselves indicative of a high abundance of floodwater mosquitoes. A key factor is the number of floodwater mosquito eggs available for hatching in areas with shallow water during each specific flooding. During June to October females of *Ae. sticticus* oviposit on the soil in areas that may be subject to flooding at some time in the future (Berec *et al.,* 2014; Schäfer *et al.,* 2008; Sebesta *et al.,* 2013). The eggs can remain viable for at least

five years, but the vitality of the eggs is reduced over time (Gjullin *et al.,* 1950). The accumulation of eggs function as an egg-bank, and withdrawal occurs if eggs have been exposed to air before they get covered with water for a couple of days when the temperature is above 8-10 °C (Becker *et al.,* 2010; Horsfall and Trpiš, 1967). The larvae usually need one to three weeks of flooding, depending on temperature, to reach pupation and emergence as adults, and the number of larvae hatching from the egg-bank determines the size of the adult mosquito population. Thus, it is possible for even a relatively small flooding to produce very large numbers of blood-seeking *Ae. sticticus* females if the available flooded egg-bank is large. This may create variations in mosquito abundance and other nuisance patterns than what could be expected from flood size only. In addition, in the current study we use upstream river discharge to estimate flood size. The peaks in discharge that we report will be followed by a flooding which lasts for the time it takes for the land to dry out. If new peaks in discharge occurs within this time, the additional water will extend the flooding as in May 2012. A higher peak in discharge will also lead to new areas bring flooded, as seen in early summer 2010. Likely, the mosquitoes produced in early summer in 2010 hatched due to different flooding events and in different areas (with more areas flooded in June than in May).

The observed increases in adult floodwater mosquito abundance in this study followed roughly three weeks after river discharge 20 km upstream exceeded 300 m^3/s, and when average air temperatures were around 15 °C. When river discharge was less pronounced and average air temperatures were around 12 °C, as they were in May/June 2012, this period was potentially extended to roughly five weeks. Larval developmental time for *Ae. sticticus* can be affected by a number of different factors, but has been estimated to be 18-19 days at water temperatures of 15 °C and 37 days at water temperatures of 10 °C (Becker *et al.,* 2010). Trpiš and Horsfall (1969) found that *Ae. sticticus* larvae hatched from eggs collected in Illinois, USA, will fail to mature at a constant temperature of 15 °C. They postulate that diurnal temperature fluctuation above 15 °C may be important for completing larval development. In Europe, hatching of *Ae. sticticus* is known to occur at water temperatures below 8 °C, however, less is known about their development at such low temperatures (Becker *et al.*, 2010). In the current study there were no measurements of water temperature, but likely the average daily water temperatures have not significantly exceeded the average daily air temperatures. Our data suggests that successful hatching and development of *Ae. sticticus* could happen already in April, should there be a combination of flooding and unusually high temperatures (>15 °C). A flooding in August or September, when temperatures are more commonly above 15 °C, seems to be less likely to be followed by high mosquito trap-catches.

The Swedish Environmental Protection Agency (Swedish EPA) has decided that a measurement of at least 5,000 mosquitoes per trap-night is a prerequisite to grant permit for Bti-based mosquito control in a Natura 2000 protected area, and to allow helicopter application of the Bti-containing larvicide VectoBac G® (Valent BioSciences, Libertyville, IL, USA). During the first year of collections in Deje, all traps collected less than 5,000 mosquitoes per night, and thus the nuisance tolerance threshold set by Swedish EPA was not exceeded. However, during the second and third year of collections this threshold was exceeded on two and four occasions, respectively, with up to 10,600 mosquitoes per trap-night in 2012. Thus, mosquito abundance greatly exceeded high nuisance levels in this area. In addition, at least two generations of floodwater mosquitoes were produced in 2012 and contributed to prolonged nuisance.

The main floodwater mosquito species detected in the region, *Ae. sticticus,* is a species that is well established in the Nedre Dalälven region in eastern Sweden, and has been predicted to expand its distribution over the years (Schäfer and Lundström, 2009). There are previous records of the species also in western Sweden, including collections of over 12,000 mosquitoes per trap-night in Sunne, situated approximately 50 km north of Forshaga (Lundström *et al.,* 2013; Schäfer and Lundström, 2009). There is no previous abundance data available from Forshaga that indicates establishment or nuisance problems. The underlying cause of the observed increase in *Ae. sticticus* abundance in Forshaga municipality remains to be elucidated, however, the cumulative number of diapausing eggs available after each season may have contributed to the amplification of the *Ae. sticticus* population over the years investigated.

Supplementary material

Supplementary material can be found online at https://doi.org/10.52004/JEMCA2022.0009.

Table S1. Coordinates of study areas in WGS 84.

Table S2. Percentage of collected mosquitoes in Deje, Forshaga municipality, Sweden, belonging to either of the three groups floodwater mosquitoes, others and snow-pool mosquitoes.

Figure S1. Total number of mosquitoes collected at the different trap sites in Deje, Forshaga municipality, Sweden, in 2010, 2011 and 2012.

Figure S2. Number of individuals of snow-pool mosquitoes collected per trap-night over all sites in Deje, Forshaga municipality, Sweden, and the entire study period.

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Data availability

Sampling data is available at: https://doi.org/10.6084/m9.figshare.21916023.

Conflict of interest

The authors declare no conflict of interest.

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