Habitat characteristics, diatoms (Bacillariophyta), ceratopogonid flies (Insecta, Diptera) and ostracods (Crustacea) from freshwater rock pools at Kjugekull, southern Sweden

Burkhard Scharf[1], Peter Havelka[2], Małgorzata Bąk[3], Hans Berggren[4], Sven Björk[5] & Claude Meisch[6]

[1] Ellhornstr. 21, D-28195 Bremen, Germany (burkhard.w.scharf@t-online.de)

[2] Staatliches Museum für Naturkunde Karlsruhe, Erbprinzenstraße 13, D-76133 Karlsruhe, Germany (peter.havelka@smnk.de)

[3] Palaeoceanology Unit, Faculty of Geosciences, Natural Sciences Education and Research Centre, University of Szczecin, Mickiewicza 16a, 70-383 Szczecin, Poland (malgorzata.bak@usz.edu.pl)

[4] Laxvägen 11, S-295 35 Bromölla, Sweden (limnovision@telia.com)

[5] Skärvgöl, S-370 11 Backaryd, Sweden (sven.bjork@biol.lu.se)

[6] Musée national d'histoire naturelle, 25, rue Münster, L-2160 Luxembourg (claude.meisch@education.lu)

Scharf, B., P. Havelka, M. Bąk, H. Berggren, D. Björk & C. Meisch, 2019. Habitat characteristics, diatoms (Bacillariophyta), ceratopogonid flies (Insecta, Diptera) and ostracods (Crustacea) from freshwater rock pools at Kjugekull, southern Sweden. *Bulletin de la Société des naturalistes luxembourgeois* 121: 265–275.

Abstract. Morphometrical, physical and chemical characteristics of the freshwater rock pools on the rock ridge in the Natura 2000 protected area of Kjugekull in southern Sweden are described. The investigated rock pools are potholes that were carved during the Cretaceous in a granitic stream bed through the grinding action of stones and/or sand. The rock was polished through glacial activity and the potholes reappeared after the last ice age. During a survey carried out in the years 2016 to 2018, the biocoenoses of the rock pools were investigated: five species of diatoms (Bacillariophyta), one species of ceratopogonid flies (Ceratopogonidae, Diptera, Insecta) and one species of ostracod (Ostracoda, Crustacea) were collected. Of the five species of diatoms recorded, only *Eunotia bilunaris* (Ehrenberg) Schaarschmidt, 1881was found in abundant numbers. Details of the autecology of the ceratopogonid *Dasyhelea bilineata* Goetghebuer, 1920 and the ostracod *Heterocypris incongruens* (Ramdohr, 1808) are presented.

Keywords. Freshwater rock pools, potholes, Skåne county, Sweden, morphometry, electric conductivity, salinity, pH, Ceratopogonidae, Bacillariophyta, Ostracoda, biocoenosis.

1. Introduction

Kjugekull is a coastal landscape in the southernmost Swedish county of Skåne. The area is located immediately southwest of the Ivö Lake (Ivösjön in Swedish), c. 20 km east of Kristianstad. The area consists of a wooded grass land with scattered boulders and a hill dominated by a ridge of bare rocks. The boulders at Kjugekull, many of which are around 10 meters in height, are well known for the somewhat popular practice of bouldering, a form of rock climbing. In 2016 Kjugekull became part of the European Natura 2000 network of protected areas (SE0420107). The protected area, which includes the rock pools here investigated, covers a surface of 11.6 hectares (Länsstyrelsen Skåne 2016).

Most rock ridges in Sweden were polished during the glacial period and are still bare of vegetation. This is also the case at Kjugekull.

The rocks were polished during the Ice Age and it is therefore somewhat surprising at first sight to find pools on some of these rocks. Geological studies have shown that these rock pools are potholes carved in granitic rocks during the Cretaceous (Mag-

nusson & Lidmar-Bergström 1983, Lidmar-Bergström & Magnusson 1984, Magnusson 1985a, b, Lidmar-Bergström 1997). The 'fossil' Cretaceous potholes reappeared after the retreat of the glaciers at the end of the last ice age (Lidmar-Bergström 1997).

Potholes are pits that originate in the beds of streams, especially so in torrents and at the base of waterfalls. Stones, driven by hydraulic pressure and swirling in a circular fashion, cut vertically into the rock of the stream bed, gradually forming a cylindrical rock pool designated as pothole (Cole 1983). Potholes, in general, can have a diameter from less than one meter to the size of a lake (Cole 1983).

At Kjugekull, 30 small 'fossil' potholes were found on the rock ridge. They are mostly round in shape, mostly with a diameter of less than half a meter (Fig. 3).

We here present the results of a survey of the rock pools at Kjugekull carried out from 2016 to 2018. The physical and chemical characteristics as well as the biocoenoses of the pools were investigated. Diatoms, ceratopogonid flies (Insecta) and ostracods (Crustacea) found living in the pools were studied in some detail.

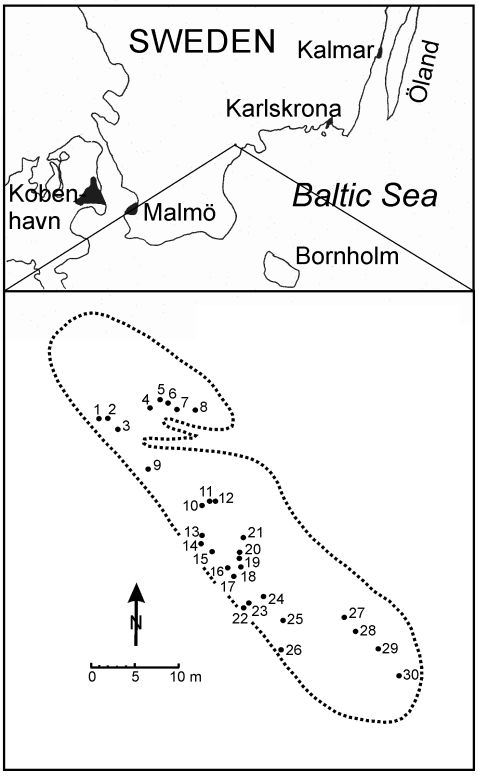


Fig. 1. A: Map of southern Sweden. B: Enlarged map. The rock ridge at Kjugekull is situated between the village Kjuge and lake Ivösjön. C: Location of the rock pools studied and their numbers as used herein.

2. Study site, material and methods

2.1. Study site

The investigated rock pools are situated in the county of Skåne, southern Sweden, on top of the rock ridge at Kjugekull, near the village Kjuge, located immediately southwest of Ivösjön (Ivö Lake). The small ridge of Precambrian gneissic granite protrudes through the Cretaceous sediments (Lidmar-Bergström 1997). The rock pools studied herein extend from 56°04'27.4"N to 56°04'28.8"N and 4°22'04.1" to 14°04'07.0"E, respectively (Fig. 1). The elevation of the rock pools is between 47 m asl at the sample site 1 and 41 m asl at the sample site 30 (elevations taken from Google Earth; accessed April 20, 2017) (Fig 1).

The rock surface with the 'fossil' potholes is glacially polished. In some of the potholes, those protected from erosion during the glacial period, Cretaceous sediment was found (Magnusson & Lidmar-Bergström 1983; Lidmar-Bergström & Magnusson 1984; Magnusson 1985 a, b). A round, polished stone was found in pothole no 26 (Fig. 3), but it is unclear if this stone was the one which was responsible for or took part in the carving of the pothole.

Fig. 2 schematically shows the length and depth as well as the filling with sediment of a typical pothole at Kjugekull. See Fig. 3 for photos of the rock summit with part of the rock pools. The morphological data of all the pools are presented in Table 1.

2.2. Methods

The 30 rock pools were each individually identified and numbered from 1 to 30. To obtain and present the precise localization of all the rock pools, the following procedure,

based on two spots taken as references, was applied. The first spot is the rock pool no 7 and has a latitude/longitude of 56°04'28.6" N / 14°22'05.1" E. The second spot is an easily recognizable pine tree at the lower, southern end of the rock ridge; it is positioned at 56°04'27.6" N / 14°22'06.7" E.

With these two spots taken as references the precise position of each pool and the distance between the pools were determined using an azimuth compass and a measuring tape (Fig. 1).

The rock pools at Kjugekull were visited on five days: on August 29, 2016; September 14, 2016; March 24, 2017, April 14, 2017, and July 11, 2018. On September 14, 2016, the aquatic vegetation was noted, and the animals were collected quantitatively from seven selected pools (Table 4).

Water samples for physical and chemical analyses (temperature, electric conductivity, pH) were taken from about 5 cm below the water surface. Water temperature and conductivity were measured with TESTR 35 (Co. EUTECH Instruments OAKTON), pH with the liquid pH-indicator RF1.09175 (pH 4-10, with 0.5 steps, Co. Merck), alkalinity was measured titrimetricly with Aquamerck 1.11103.0001 (Co. Merck), and water colour was determined visually.

On September 14, 2016, to avoid the destruction of the entire biocoenosis of the selected pools, the pools to be investigated were each subdivided in two equal compartments with a rigid, laterally compressed plastic bag made heavy with glass beads at the inner bottom. The water and the sediment of one of the two compartments were then entirely sampled and sieved through a net (200 µm mesh size). The unsieved material was used for the study of the diatoms.

All four samples of the collected diatoms were treated with 10% hydrochloric acid (HCl) to remove calcium carbonate and, after thorough washing, boiled in 37% hydrogen peroxide (H_2O_2) to eliminate any organic material. After four successive baths in distilled water, drops of the final suspension were deposited on microscope cover slips, left there for evaporation, and then mounted on glass slides using Naphrax® diatom mountant. The slides were examined under a Zeiss Axio Scope A1 light microscope. A total of 400 valves (thecae) were identified to the species level (Battarbee 1986; Bodén 1991).

The larvae of the ceratopogonid flies collected in September 2016 were preserved in ethanol (70%) and identified by the second author (P.H.) down to the genus level: *Dasyhelea* sp. The larvae collected on March 29, 2017 were sent alive to P.H. to be reared in beakers in the laboratory, where the emerged adults were collected daily with an exhaustor. The first adults (imagines) emerged on April 6, 2017. They were first preserved in glass tubes in 70% ethanol to be later transferred to a phenol alcohol mixture. The flies were mounted on phenol balsam coated slides for further identification (Wirth & Marston 1968). The permanent slides are stored in the scientific collection of P.H.

The Ostracoda (Crustacea) were separated from the sediment as described by Scharf et al. (2014) and identified with the keys and descriptions presented in Meisch (2000). The ostracods are stored in the scientific collection of the first author (B.S.).

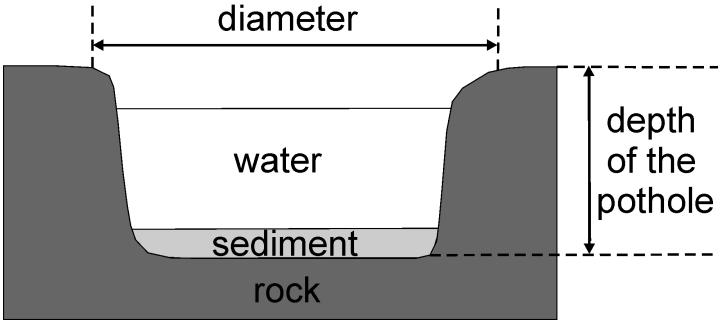


Fig. 2. Schematic illustration of a typical rock pool at Kjugekull.

3. Results

The rock pools on the granitic ridge at Kjugekull are typically round in shape and small, with a diameter of mostly less than 50 cm and a maximum depth of 38 cm. At the time of investigation, some pools were completely dry, others were filled with humid leaves, still others had either colourless or brownish transparent water, with water columns up to 21 cm deep (Table 1).

On March 24, 2017 the rock pools 1, 11-15, 21-23, 25, 27 and 30 were dry and filled with leaves and/or detritus from decaying leaves, no free water being present (Table 1). In July 11, 2018, after a drought period of several months, all the rock pools were completely dry. Only some humidity was noticed in the lower part of the deepest pools.

The forest around the rock ridge consisted of beeches, oaks and pines. The sediment

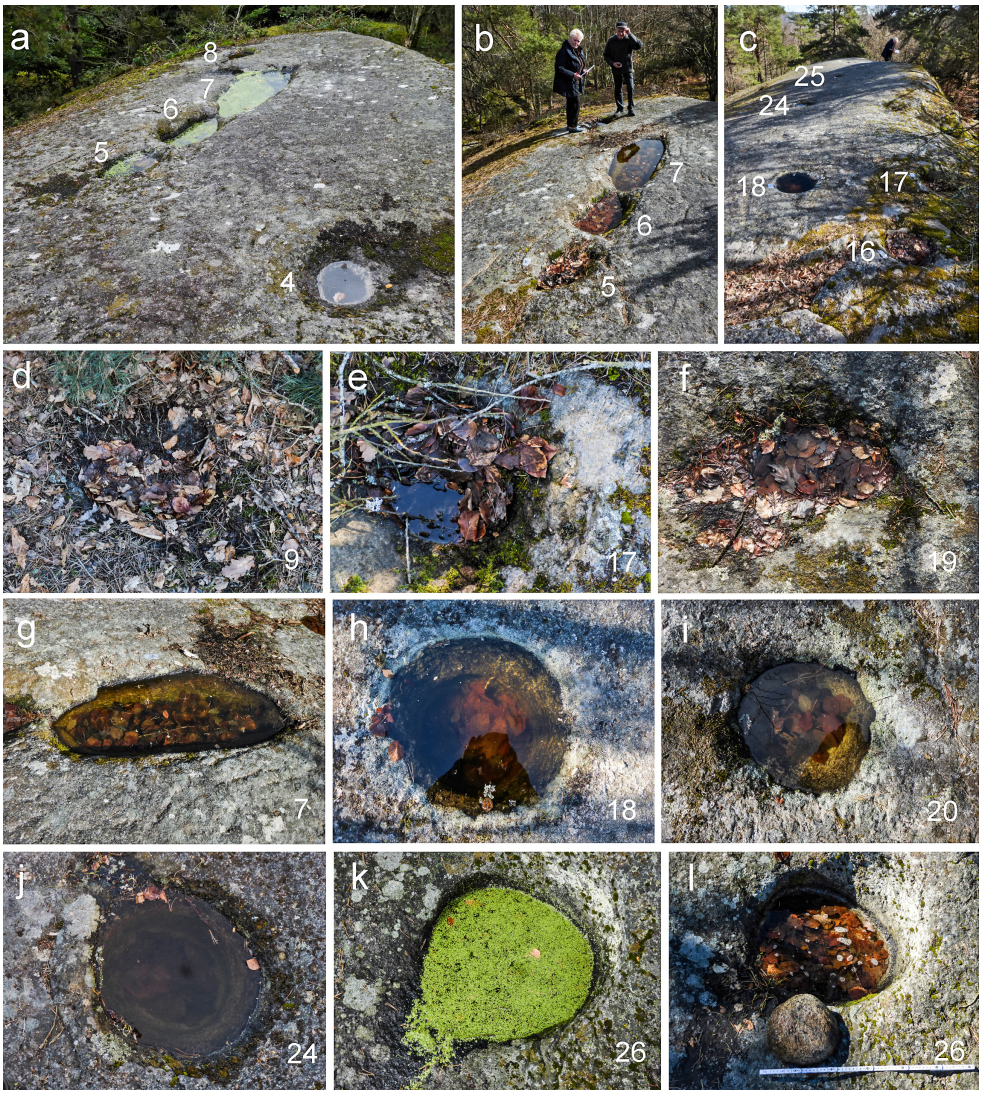


Fig. 3. Photographs of some of the rock pools studied at Kjugekull. The number of each rock pool is given in the lower right. a-c: overview of the rock with some rock pools; d-l: selected rock pools; a and k from August 16, 2016; b, c, e, f, g, h, and i from March 24, 2017; d and j from April 14, 2017. Photos by B. Scharf.

Table 1. Morphological data of the rock pools at Kjugekull, Sweden, measures taken on 14 April 2017. All lengths and depths in cm.

Pool number	Shape					Depth	Water depth	Water column and sediment
	round	oval		elongated				
	diameter	length	width	length	width			
1		45	27			8	0	4
2		60	45			16	2	4
3	45					16	3	5
4	40					28	2	6
5				45	35	15	1	7
6		75	45			23	2	18
7		140	63			29	12	26
8	48					21	3	13
9		40	25			12	0	7
10		60	47			19	3	17
11		40	32			18	0	16
12	20					5	0	4
13	33					10	0	8
14	42					35	0	33
15	42					22	0	15
16		41	38			23	0	21
17	33					17	10	14
18	46					29	19	28
19		41	24			10	1	10
20	33					15	9	14
21	34					12	0	10
22		42	39			30	0	28
23	21					9	0	7
24	39					27	17	22
25	23					12	0	4
26	62					38	5	29
27	25					10	0	6
28	15					8	1	5
29	40					24	21	22
30	30					20	0	6

in the rock pools was dominated by leaves and/or needles of the trees which grew in the neighbourhood of the corresponding pools. Leaves of beeches appear to be transported over somewhat greater distances than those of the other trees, because the pools in the middle of the rock predominantly contained leaves of beeches.

Two rock pools contained remains of recent human activities: some charcoal in pothole 4, and a date kernel was found in pool 18.

The water of most of the pools was colourless and transparent at each investigation (Table 2), except for the pools 2, 6, 10, and 24, where the water was transparent, but brownish, charged with humic acid. Water temperature varied in relation to the season but also with the relative location of the pools. Temperature was 2-4 °C higher in the pools which were (almost) constantly exposed to the sunshine, but elsewhere depended on the duration of the shading by the surrounding trees. On March 24 2017, water temperature varied between 6.9 and 11.2 °C, while electric conductivity varied between 13 and 149 µS cm^{-1}. The pH ranged between 5.0 and 6.0, the water thus being slightly acidic. The alkalinity was generally <0.4 meq l^{-1} with the exception of the pools 4 and 10, in which conductivity was significantly higher (Table 2).

The flora in the rock pools was poor in species. Filamentous algae were seen at the border of the rock pools 6 - 8. Moss (bryophytes) were only found in the pools 1, 2, 4,

Table 2. Physical and chemical characteristics of the water of the potholes at Kjugekull. 1 = clear water; 2 = brownish water; 3 = filled with leaves up to the surface of the water; 4 = dry or filled with leaves, without any visible water.

No	Colour of the water / filled with leaves			Temperature [°C]			Conductivity [µS/cm]			pH			Alkalinity [meq/l]		
	2016 29.8.	2016 14.9.	2017 24.3.	2016 29.8.	2016 14.9.	2017 24.3.	2016 29.8.	2016 14.9.	2017 24.3.	2016 29.8.	2016 14.9.	2017 24.3.	2016 29.8.	2016 14.9.	2017 24.3.
1			4												
2	1		1, 2	20.5		7.0	44		44	6.0		5.5	<0.4		<0.4
3	1			20.2		10.8	15		23	5.3		5.5	<0.4		<0.4
4	1		3	19.9		7.4	149		75	6.5		5.0	0.7		0,7
5			3			11.2			26			5.0			<0.4
6	1		1, 2	19.7		10.2	24		26	5.5		5.5	<0.4		<0.4
7	1	1	1	20.6	20.3	8.5	13	23	19	5.5	5.5	6.0	<0.4	<0.4	<0.4
8			1			9.4			27			5.5			<0.4
9			4												
10		1,2	2		20.2	8.0		110	39		6.0	5.5		0.7	<0.4
11			4												
12			4												
13			4												
14			3												
15			3												
16			3												
17			4												
18	1		1	20.4		6.9	47		25	5.0		6.0	<0.4		<0.4
19			3												
20			1			8.6			15			5.5			<0.4
21			3												
22			3												
23			3												
24		1,2	1		21.3	8.1		18	19		5.5	5.0		<0.4	<0.4
25			3												
26			1												
27			4												
28			3												
29			3												
30			4												

10, 17, 18 and 24 (see the pools 4, 17, and 24 in Fig. 3). The floating duckweed *Lemna minor* L., 1753 occurred in nearly all the pools filled with water in the summer, but with different percentages of surface coverage (August 29, 2016: pool 3 with 5 %, 5 with 30 %, 6 with 100 %, 7 with 80 %, 26 with 100 % of coverage, while in September 2016 the coverage was reduced (Fig. 3).

Only four species of diatoms were found, of which one species, *Eunotia bilunaris* (Ehrenberg) Schaarschmidt, 1881, was abundant (Table 3). *Hantzschia calcifuga* E.Reichardt & Lange-Bertalot, 2004 was represented with one single specimen (Table 3).

Only a few animal groups were present in the rock pools (Table 4). Crustaceans were represented with the single ostracod species *Heterocypris incongruens* (Ramdohr, 1808) and Cladocera of the families Daphnidae and Chydoridae (Cladocerans were not identified to the species level). Among

Table 3. Diatoms collected on September 14, 2016 from four rock pools at Kjugekull, Sweden.

Sample sites	6	7	10	18
Eunotia bilunaris (Ehrenberg) Schaarschmidt, 1881	394	397	397	398
Gomphonema exilissimum (Grunow) Lange-Bertalot & E. Reichardt, 1996	4	2	-	-
Hantzschia abundans Lange-Bertalot, 1993	1	1	4	1
Hantzschia calcifuga E.Reichardt & Lange-Bertalot, 2004	-	-	1	-
Pinnularia borealis Ehrenberg, 1843	1	-	2	1

the Insecta only two larvae of Ephemeroptera (no 10 in Table 4) and one exuvia of a Heteroptera (pool 6) and larvae of Diptera were found. Chironomidae were the most frequent family among the Diptera and they were present in all the pools. The number of flies of the Ceratopogonidae (biting midges) was slightly inferior to that of the Chironomidae (the latter unstudied herein), but they were found only in four of the nine rock pools investigated (Table 4). All ceratopogonids belonged to *Dasyhelea bilineata* Goetghebuer, 1920. The number of Culicidae larvae was less than 10 % of the Ceratopogonidae and present in only four of the seven pools studied (Table 4).

4. Discussion

The 'fossil' potholes on top of the rock ridge at Kjugekull, southern Sweden, are extreme aquatic habitats because of their smallness, exposition and chemical characteristics.

Some of the pools are partly in the shadow of trees growing at the border of the rock during the day; the pools in the middle of the rock are exposed to the sun, without any shading during the whole day. Water temperature therefore varies significantly from pool to pool at any given time. In the winter, the ice certainly reaches the bottom of the pools. In the extremely dry summer of 2018 all the pools were found dry in September.

The rock pools at Kjugekull are not connected to the groundwater, due to the impermeable granitic underground. They are exclusively fed by rainwater and therefore the electric conductivity as well as the alkalinity are generally low, in particular so as the pools have a very small catchment area (Table 2). The conductivity of 13 meq l^{-1}, e.g. in the pool 7, was so low that it is surprising that life is possible there. The animals must have an extreme capacity to regulate the osmosis. Ostracoda, Cladocera, and Diptera were found living in that rock pool (Table 4). In the pools where conductivity and alkalinity are increased, this is due to external, mainly human causes. For example, rock pool 4 contained an amount of charcoal, most certainly the remain of barbecuing. In September 2016, faeces of a sheep or deer were found in pool 7, with the consequence that conductivity was slightly increased. A date kernel was found in pool 18.

In the summer, the duckweed *Lemna minor* progressively and finally completely covered the surface of at least some of the pools (Fig. 3). This means that darkness reigns in the water column. Probably there are no algae and the animals feed on the leaves and their biofilm, though this needs further investigation.

Many animal groups are absent from the rock pools at Kjugekull: in particular, there were no Hydrozoa, Bryozoa, Turbellaria, Oligochaeta, Hirudinea, Hydracaria, Euphyllopoda, Copepoda, Isopoda, Amphipoda, Decapoda, Plecoptera, Odonata, Megaloptera, Trichoptera, Coleoptera, Mollusca. Also, the pools are obviously too small to support the lives of any amphibians and fish, this because of the lack of sufficient numbers of prey animals and probably also the freezing of the entire water column in the winter.

The absence of molluscs, e.g. gastropods, may be explained by the low calcium content of the water: the granitic underground does not contain calcium and rainwater is not a supply for it. Possibly, the presence of Copepoda was overlooked. If present, they certainly occurred in very small numbers.

Table 4. Invertebrates collected in 2016 from selected rock pools at Kjugekull, Sweden.

Rock pool	Date	Fauna
2	29.8.	*Heterocypris incongruens* (9 ♀♀, 37 juv.) Chironomidae (c. 200 larvae)
3	29.8.	*Heterocypris incongruens* (49 ♀♀, 13 juv.) Daphniidae (>200) Chironomidae (c. 50 larvae)
4	29.8.	*Heterocypris incongruens* (5 ♀♀, 17 juv.) Chironomidae (c. 100 larvae) Culicidae (20 larvae)
6	14.9.	*Heterocypris incongruens* (7 ♀♀, 56 juv.) Heteroptera (1 exuvia) Chironomidae (38 larvae) Culicidae (1 pupae) Ceratopogonidae: *Dasyhelea bilineata* (170 larvae)
7	29.8.	*Heterocypris incongruens* (20 ♀♀) Daphniidae (c. 50) Chydoridae (c. 50) Chironomidae (>100 larvae)
7	14.9.	*Heterocypris incongruens* (34 ♀♀) Chironomidae (12 larvae) Ceratopogonidae: *Dasyhelea bilineata* (7 larvae)
10	14.9.	*Heterocypris incongruens* (7 ♀♀, 56 juv.) Daphniidae (>200) Ephemeroptera (2 larvae) Chironomidae (60 larvae) Ceratopogonidae: *Dasyhelea bilineata* (130 larvae)
18	29.8.	*Heterocypris incongruens* (8 ♀♀, 13 juv.) Daphniidae (50) Chydoridae (>100) Chironomidae (20 larvae) Culicidae (20 larvae)
18	14.9.	*Heterocypris incongruens* (5 ♀♀) Chironomidae (2 larvae) Culicidae (1 larva) Ceratopogonidae: *Dasyhelea bilineata* (180 larvae)

The finding of two larvae of Ephemeroptera and one exuvia of a Heteroptera is interpreted here as an unsuccessful attempt to colonize the rock pools at Kjugekull. Most certainly, the freezing down to the bottom in the winter and the lack of water in extremely dry summers limit the presence of the members of these animal groups.

The catchment area of the rock pools is nude rock, and therefore no colonization by aquatic animals can occur *via* surface water supply. We hypothesize that colonization occurs through rain, wind, flying insects and birds. Large water birds can probably be excluded because the water surface is too small for the landing of, for instance, ducks. The flying imagines of Chironomidae, Culicidae and Ceratopogonidae lay their eggs on or below the surface of the water. The rock pools might be favoured habitats for these insects because there are no large predators, such as amphibians and fish. *Heterocypris incongruens* was the only ostracod found in the rock pools. Eggs, juveniles and adults of this species are known to be resistant to desiccation and freezing (Tétart 1971), and thus excellent candidates for both wind-borne and phoretic dispersal (Meisch 2000).

Table 5. Habitat, ecology, and distribution of the diatoms collected from rock pools at Kjugekull (after Cantonati et al. 2017).

Species	Habitat and ecology	Distribution
Eunotia bilunaris (Ehrenberg) Schaarschmidt, 1881	oligo- to dystrophic, but oligosaprobic freshwater habitats	Central Europe: Distributed in a wide range of conditions, from acidic (due to humic acids) to well-buffered alkaline waters
Gomphonema exilissimum (Grunow) Lange-Bertalot et Reichardt 1996	characteristic species of electrolyte-poor, usually weakly acidic, nutrient-poor freshwater habitats on siliceous substrata	
Hantzschia abundans Lange-Bertalot, 1993	the most frequently encountered species in prolongedly dry and only temporarily wetted (aerial) biotopes, such as soils and rock crevices	
Hantzschia calcifuga Reichardt & Lange-Bertalot, 2004	found in electrolyte-poor, weakly acid to circumneutral habitats (e.g., reed meadows, springs in the siliceous central highlands of Germany), associated with acidophilous diatoms	
Pinnularia borealis Ehrenberg 1843	pseudaerial. Soils, bryophyte carpets, rock walls; also in different running waters and springs, rarer in lakes	all freshwater habitat types but scattered records of small numbers. Particularly in standing waters of the siliceous central highlands and in running waters of the coastal marshes

Of the five species of diatoms collected, only *Eunotia bilunaris* was abundantly found, the other three species being very rare in the pools investigated. *Gomphonema exilissimum* and *Hantzschia calcifuga* prefer waters which are poor in electrolytes and weakly acidic, while *Hantzschia abundans* E.Reichardt & Lange-Bertalot, 2004 and *Pinnularia borealis* Ehrenberg, 1843 prefer humid semi-terrestrial habitats. Both habitats are present in the rock pools at Kjugekull.

Larvae of the Ceratopogonidae found in the years 2016 and 2017 in the pools all belong to the species *Dasyhelea bilineata* Goetghebuer, 1920. This species is distributed all over Europe: from Norway, Sweden, Finland to Russia and Estonia (Strandberg & Johanson 2015), from Great Britain, Ireland, Belgium, Germany, France, Switzerland, Austria, Poland, the Czech Republic, Slovakia, Hungary, Romania, Bulgaria, Ukraine to the circum-Mediterranean regions (Italy, Croatia, Turkey, Spain, Gibraltar, Algeria) (Dominiak & Szadziewski 2010).

Whereas ceratopogonid larvae grow up to 15 mm, the adults rarely exceed two mm in length. Until c. 1950 entire adults were mounted on minutia needles. The introduction of genital preparation slides in the 1950s has improved the taxonomic identifications, which, for instance, resulted in the synonymization of at least eight nominal species with *D. bilineata* (Borkent & Wirth 1997, Havelka 2016).

The larvae of *D. bilineata* are known to inhabit small water bodies of water with varying depths, e.g. phytothelmes, cavities in tree trunks, roadside ditches, ponds, flower vases, tire tracks, and swimming pools. The rock pools at Kjugekull in southern Sweden belong to this group of water bodies.

The ostracod *Heterocypris incongruens* prefers shallow seasonal pools, like wheel ruts on clayey ground, tree cavities, (coastal) rock pools, water butts, fountains, and watering basins in graveyards (Tétart 1971, Meisch 2000, Fuhrmann 2010). The species tolerates rainwater as well as slightly brackish water,

and low O_2-contents. It is omnivorous and cosmopolitan (Meisch 2000). It is known to survive the drying out of the habitat. On July 2, 1995, B. S. collected dry sediment from a puddle with a loamy bottom in Braunschweig (Brunswick), Germany. Under the stereomicroscope he could see that specimens of *H. incongruens* were fixed with the posterior part of their carapaces within the sediment, while the anterior part was up in the air. After introducing the sediment into a petri dish filled with water, most of the animals emerged rapidly from the sediment and started to swim. This observation confirms that *H. incongruence* is able to survive at least some time in dry sediments. As resting eggs can survive dry periods of up to 40 months (Rossi et al. 2012, 2015), this species is perfectly apt to support the drying out of the rock pools at Kjugekull during summer months without any rain. Therefore, we believe that *H. incongruens* survived the months long drought in 2018 and that this species is a permanent inhabitant of at least part of the pools at Kjugekull.

H. incongruens was previously reported from coastal rock pools on the Swedish isle of Vrångskär in the Baltic Sea (Ganning 1971). These rock pools are located within the splashing zone of sea water and *H. incongruens* colonizes these pools together with two other ostracods, *Heterocypris salina* (Brady, 1868) and *Sarscypridopsis aculeata* (Costa, 1847). The latter two species are considered non-marine ostracods (Meisch et al. 2019) with a clear preference for slightly brackish waters (up to 10 ‰ and 17 ‰ under natural conditions, respectively) (Meisch 2000).

Ganning (1971) described as follows one of his Swedish pools as being a 'typical habitat' of *H. incongruens*: 'the water is mainly dark brown, thus suggesting high concentrations of humus, salinity is between 0.5 and 3 ‰, the pool often dries up completely'. From this description it follows that the occurrence of *H. incongruens* in the freshwater pools at Kjugekull is no surprise.

For a review of the zoocoenoses of freshwater rock pools, see Jocqué et al. (2010).

5. Conclusion

The freshwater rock pools at Kjugekull in southern Sweden are 'fossil' Cretaceous potholes created in a stream flowing over granitic rocks. The potholes reappeared on the polished rock ridge after the end of the last glaciation. The present-day rock pools are rounded, small pools with extreme physical, chemical and climatic conditions: being exclusively fed by rainwater, they are poor in electrolytes and subject to drying out. Of the five diatom species recorded from the rock pools at Kjugekull, only one species, *Dasyhelea bilineata*, was found in abundant numbers.

The pools harbour an impoverished zoocoenosis consisting of macroinvertebrates belonging to the insects, mainly larvae of the chironomids, and ceratopogonid dipterans. The Ceratopogonidae belong to one species, *D. bilineata*. The meiofauna consisted of specifically unidentified cladocerans of the families Daphnidae and Chydoridae, and the ostracod *Heterocypris incongruens*, the latter being a typical inhabitant of temporary pools. Because of their small size, the pools are probably too poor in prey to support the colonization by vertebrates such as amphibians and fish.

The present report confirms the second basic biocoenotic principle: The less a body of water contains ecological niches, the smaller the number of species supported by the habitat, though the number of individuals of each species may be high (Thienemann 1920; Bick 1993).

Acknowledgments

We thank Ursula Beddig, Bremen, for her assistance in the field work, Heidi Pintschovius and Anthony Slater, London, for proof-reading the English draft, and Dr Dietmar Keyser, University of Hamburg, for the review of the manuscript.

References

Battarbee, R. W., 1986. Diatom analysis. In Berglund, B.E., ed.: Handbook of Holocene Palaeoecology and Palaeohydrology. Wiley & Sons, Chichester, UK: 527-570.

Bick, H., 1993. Ökologie. 2 ed. Gustav Fischer, Stuttgart, Jena, New York, 335 pp.

Bodén, P., 1991: Reproducibility in the random setting method for quantitative diatom analysis. *Micropaleontology* 37: 313–319.

Borkent, A. & W.W. Wirth, 1997. World Species of Biting Midges (Diptera: Ceratopogonidae). *Bulletin of the American Museum of the Natural History* 233, 1-257.

Cantonati, M., Kelly, M. G. & H. Lange-Bertalot (eds), 2017. Freshwater benthic diatoms of Central Europe: Over 800 common species used in ecological assessment. Koeltz Botanical Books, Königstein, 942 pp.

Cole, G. A., 1983. Textbook of Limnology. 3 ed. Waveland Press Inc., Illinois, 401 pp.

Dominiak, P. & R. Szadziewski, 2010. Distribution and new synonymy in European biting midges of the genus *Dasyhelea* Kieffer (Diptera: Ceratopogonidae). *Zootaxa* 2437: 1–37.

Fuhrmann, R., 2010. Die Ostrakodenfauna der Gießwasserbehälter ausgewählter Friedhöfe Mitteldeutschlands mit Beschreibung von *Potamocypris altenburgensis* sp. nov. (Crustacea: Ostracoda). *Mauritiana* (Altenburg) 21: 95-107.

Ganning, B. 1971. On the ecology of *Heterocypris salinus*, *H. incongruens* and *Cypridopsis aculeata* (Crustacea: Ostracoda) from Baltic brackish-water rock pools. *Marine Biology* 8: 271-279.

Havelka, P., 2016. Rote Liste und Gesamtartenliste der Gnitzen (Diptera: Ceratopogonidae) Deutschlands. In: Rote Liste gefährdeter Tiere, Pflanzen und Pilze Deutschlands, Band 4: Wirbellose Tiere (Teil 2). (Gruttke, H., Binot-Hafke, M., Balzer, S., Haupt, H., Hofbauer, N., Ludwig, G., Matzke-Hajek, G. & M. Ries, eds). Landwirtschaftsverlag, Münster. *Naturschutz und Biologische Vielfalt* 70: 33-66.

Jocqué, M., B. Vanschoenwinkel & L. Brendonck, 2010. Freshwater rock pools: a review of habitat characteristics, faunal diversity and conservation value. *Freshwater Biology* 55: 1587-1602.

Länsstyrelsen Skåne, 2016. Bevarandeplan för Natura 2000-område Kjugekull SE0420107, 22 pp. https://www.lansstyrelsen.se/download/18.2e0f9f621636c844027f63f/1527519191275/Kjugekull_bevarandeplan.pdf

Lidmar-Bergström, K., 1997. A long-term perspective on glacial erosion. *Earth Surface Processes and Landforms* 22: 297–306.

Lidmar-Bergström, K. & S.-E. Magnusson, 1984. Krittidslandskapet i nordöstra Skåne. *Svensk geografisk* årsbok 60: 165-186.

Magnusson, S.-E., 1985a. Geologiska upptäckter på Kjugekull. *Villands härads hembygdsförenings hembygdsbok* 1985: 47-62.

Magnusson, S.-E., 1985b. Jättegrytor från krittiden vid Araslöv och Hallabacken in nordöstra Skåne. *Natur i Göinge* 16: 19-35.

Magnusson, S.-E. & K. Lidmar-Bergström, 1983. Fossila vittringsformer från krittiden på Kjugekull. *Svensk geografisk* årsbok 59: 124-137.

Meisch, C., 2000. Freshwater Ostracoda of Western and Central Europe. Spektrum Akademischer Verlag, Heidelberg, Berlin, 522 pp.

Meisch, C., R.J. Smith & K. Martens, 2019. A subjective global checklist of the extant non-marine Ostracoda (Crustacea). *European Journal of Taxonomy* 492: 1-35. https://doi.org/10.5852/ejt.2019.492

Rossi, V., D. Albini, G. Benassi & P. Menozzi, 2012. To rest in hydration: hatching phenology of resting eggs of *Heterocypris incongruens* (Crustacea: Ostracoda). *Fundamental and Applied Limnology* 181: 49-58.

Rossi, V., D. Albini, V. Pellegri & P. Menozzi, 2015. Early and late maternal effects on hatching phenology of *Heterocypris incongruens* (Crustacea: Ostracoda). *Journal of Experimental Zoology* 323A: 382-391.

Scharf, B., Adler, A. & F. A. Viehberg, 2014. New methods for collecting Ostracoda (Crustacea) in stony sediments with methodical remarks on the separation of ostracods from sediment. *Crustaceana* 87: 1136-1147.

Strandberg, J. & K. A. Johanson, 2015. New records of Dasyhelea Kieffer, 1911 from Sweden, with descriptions of two new species (Diptera: Ceratopogonidae). *European Journal of Taxonomy* 131: 1–22

Tétart, J., 1971. Etude de quelques populations d'Ostracodes dans les milieux astatiques de la vallée de l'Isère. *Travaux de Laboratoire d'Hydrobiologie et de Pisciculture de Grenoble* 62: 75-150.

Thienemann, A., 1920. Die Grundlagen der Biocoenotik und Monards faunistische Prinzipien. *Festschrift für Zschokke* (Basel) 4: 1-14.

Wirth, W. & N. Marston, 1968. A method for mounting small insects on microscope slides in Canada Balsam. *Annals of the Entomological Society of America* 61: 783-784.