Helgol Mar Res (2011) 65:103–109
DOI 10.1007/s10152-010-0206-3

ORIGINAL ARTICLE

On the occurrence of the thumbnail crab *Thia scutellata* in the inner German Bight

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Received: 22 December 2009 / Revised: 9 May 2010 / Accepted: 10 May 2010 / Published online: 30 May 2010

Abstract The thumbnail crab *Thia scutellata* occurs in the German Bight in at least two stable populations: at Borkum Riff and Loreley Bank. The western (Borkum Riff) population is larger than the eastern (Loreley Bank) one, probably because of the more frequent ingression of south-western warmer water along the Dutch coast. The sediments of these two localities are well-sorted middle sands with a very low amount of finer fractions.

Keywords *Thia* · German Bight · Population study · Morphometry · Sediment correlation

Introduction

The thumbnail crab *Thia scutellata* is an easily recognisable species with a wide distribution in the north-eastern Atlantic and the Mediterranean Sea. The northernmost record comes from Norway (Christiansen 1985). The species occurs throughout the North Sea and the north-eastern Atlantic down to Portugal (d'Udekem d'Acoz 1999). In the Mediterranean it is known from the Alboran Sea to the Levantine Basin (d'Udekem d'Acoz 1999). In spite of this broad distribution the occurrence is scattered. This is due to the fact that *Thia* has clear environmental preferences for coarse sediments in areas governed by strong currents and high wave energy. This is reflected by the known distribution in the North Sea. In such species distribution maps mirror the distribution of specific environments.

The thumbnail crab has been known only from very few records off the German North Sea coast. Intensive surveys during the last 40 years have revealed that at least two stable and reproducing populations exist in the area, one of which has been monitored since 2003. In this paper the results for this population are presented together with other basic data for this crab in the inner German Bight.

Materials and methods

Two regions (Fig. 1) within the research area revealed a regular and abundant occurrence of *Thia*. Borkum Riffgrund is an area with coarse sediment 18 nautical miles NW of the East Frisian Island of Borkum, where the species was previously collected in the 1970s by R.V. *Astarte*. Newer surveys with R.V. *Senckenberg*, mainly in 2005, confirmed the occurrence of a flourishing population. The second area, Loreley Bank, is the end part of a shallow sill connecting the North Frisian Eiderstedt-peninsula with Helgoland. The sandy sediments of Loreley Bank contain Pleistocene rubble material including coarse sand. These rougher grounds are patchily distributed on the bank and it is in these spots that *Thia scutellata* occurs in high abundance and stable populations. Besides these abundant samples, material from a few other locations in the outer German Bight has been included in the analyses. As these stations have not been sampled on a regular basis, only the occurrence of *T. scutellata* can be noted at those locations. The details of the stations and the material collected with reference to the catalogue numbers under which they are kept in the Senckenberg collection (SMF) are listed in Table 1.

Communicated by H.-D. Franke.

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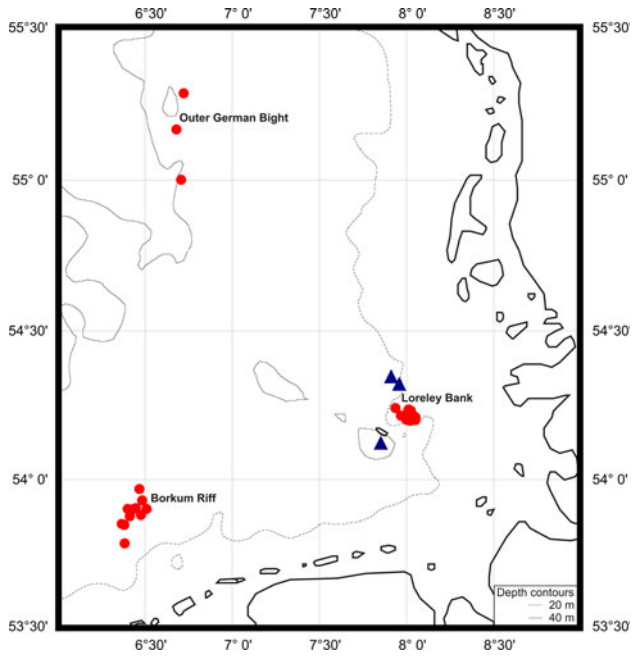

Fig. 1 Distribution of *Thia scutellata* in the inner German Bight. Locations from which material was examined are marked with *filled circles*, localities from the literature (Berberich 1989; Kühne and Rachor 1996) with *filled triangles*

The early sampling in the 1970s was made with a 0.2 m^2 Van Veen Grab by our late colleague Jürgen Dörjes. The sediment was sieved down to a mesh size of 0.63 mm (Dörjes 1977). The samples were preserved in 4% formalin in sea water and taken back to the laboratory. After sorting, the animals were finally stored in 70% ethanol. More recent collections since 1984 were performed with a ring dredge as described by Gustafson (1934). Our gear has a diameter of 100 cm and is made of iron with a thickness of 15 mm. The net has a mesh size of 1 cm between stretched meshes. The gear was lowered from the drifting ship. Upon the gear reaching the ground the vessel steamed up for about 10 min, reaching an end speed of about 0.5 knots and dragging the dredge through the ground. After heaving, the net was drawn through the surface water until the fine sediment was sieved through the meshes. The remaining material, consisting of rubble, stones and larger benthos (>1 cm), was sorted on board and the biological material preserved in part in 4% formalin–seawater and to a larger extent in 70% ethanol for subsequent analysis in the laboratory. Besides this biological sampling, sediment samples for grain-size analysis were collected with a 0.2 m^2 Van Veen Grab.

The preserved specimens were brought back to the laboratory. They were sexed and carapace length (CL) and carapace breadth (CB) were measured with Mituyoto electronic callipers, allowing a direct input into MS-Excel.

Results

A total of 323 specimens were collected in the areas of Borkum Riffgrund and Loreley Bank, not counting fragments. In the former 185 specimens were collected at 11 stations, contrasting with 138 specimens at 36 stations in the latter. This suggests that the species is more common in the western part of the German Bight than in the eastern. This conclusion is supported by the fact that in earlier years much less efficient gear like a Van Veen Grab was used and more recent collections with the ring dredge yielded many more specimens by effort than at Loreley Bank (e.g. ring-dredge sample BORRIF-050526-3 with 66 specimens in contrast to a maximum of 21 specimens at Loreley Bank: Station LB-070809-6/2).

As in total 150 males and 164 females were collected, the sex ratio seems to be even; this is also true if both main sampling areas are treated separately. As can be seen in Table 1, ovigerous females were only collected in late July and early August (thus only at Loreley Bank), none in May. In contrast, juvenile specimens were exclusively collected in May (thus only at Borkum Riffgrund).

The size distribution of carapace breadth (CB) versus carapace length (CL) does not show any allometry during growth, the regression curve is fully linear (Fig. 2). The best-fit line follows the function: $CL = 0.928CB + 0.368$, a robust correlation with a $R^2 = 0.991$. Also there is no significant size difference between sexes. The means and variances of the carapace breadth (for size distribution see Fig. 3) have been compared with a two-sample t test, which only yielded significant differences between ovigerous females and non-ovigerous ones ($p = 0.01$), also between the former and males ($p = 0.03$). Ovigerous females are the largest category in the population.

Sediment samples were taken from the collecting locations at Loreley Bank in order to compare the occurrence of *T. scutellata* with grain-size distribution. Table 2 gives the details of the sediment collected at the individual stations. The highest percentage of sediment grains is between Phi values of 1 and 2, corresponding to grain sizes between 0.250 and 0.500 mm. Therefore, the sediment of Loreley Bank is predominantly medium sand. There is only one exception: at station 080606-4VV the majority of the particles has a Phi value of 3 and it is therefore fine sand. This is more clearly shown in the totals contrasting particles with a Phi value of 2 or less and those with over 2. At this station the finer fraction totals double the coarser one (Fig. 4). When sediments are compared to the occurrence and abundance of *T. scutellata* (bottom row in Table 2) then 080606-4VV is the only one at which no specimens were collected. The most abundant catches are correlated with fine sand fractions of under 10%, but in samples with specimen numbers of 7 or less, this correlation is not

Table 1 Material examined for this study

Area	Station	Position	Depth (m)	Gear	Date	Vessel	Specimens examined	SMF
(a) *Various localities in the southern North Sea*								
Outer German Bight	D2007-21	55°0.076′N 6°42.414′E	38	RD	04.08.2007	F.K. Senckenberg	1 ♂; 1 ♀	31856
Outer German Bight	D2007-27	55°17.136′N 6°43.285′E	39.9	RD	07.08.2007	F.K. Senckenberg	1 ♀	31857
Outer German Bight	DEB(87)-7 RD1	55°10′N 6°40.8′E	39–43	RD	24.05.1987	F.K. Senckenberg	1 ♀	16450
Borkum Riffgrund	BORRIF-700623-8	53°52.801′N 6°28.571′E	(25)	VV	23.06.1970	F. K. Astarte	1 ♂	31110
Borkum Riffgrund	BORRIF-720802-3	53°55.773′N 6°28.998′E	(25)	VV	02.08.1972	F. K. Astarte	1 ♂; 1 juv ♂	31111
Borkum Riffgrund	BORRIF-720802-4	53°54.179′N 6°26.81′E	(24)	VV	02.08.1972	F. K. Astarte	1 ♂	31112
Borkum Riffgrund	BORRIF-720802-5	53°52.527′N 6°24.725′E	(25)	VV	02.08.1972	F. K. Astarte	1 ♀; 1 juv ♂	31113
Borkum Riffgrund	BORRIF-720802-6	53°50.795′N 6°22.813′E	(28)	VV	02.08.1972	F. K. Astarte	1 ♀; 1 ♀ Fr	31114
Borkum Riffgrund	BORRIF-050526-1	53°58.075′N 6°28.015′E	28.5	RD	26.05.2005	F.K. Senckenberg	6 ♂; 4 ♀; 2 juv; 2 Fr	30214
Borkum Riffgrund	BORRIF-050526-2	53°54.014′N 6°30.514′E	29.4	RD	26.05.2005	F.K. Senckenberg	6 ♂; 5 ♀; 1 Fr	30215
Borkum Riffgrund	BORRIF-050526-3	53°54.014′N 6°25.984′E	27.1	RD	26.05.2005	F.K. Senckenberg	25 ♂; 29 ♀; 3 juv ♂; 1 juv ♀; 4 juv; 1 ♂ Fr; 1 ♀ Fr; 2 Fr	30216
Borkum Riffgrund	BORRIF-050526-4	53°54.024′N 6°23.998′E	26.5–26.6	RD	26.05.2005	F.K. Senckenberg	17 ♂; 25 ♀; 1 juv ♂; 1 juv ♀; 2 juv; 1 ♂ Fr; 2 ♀ Fr; 1 Fr	30217
Borkum Riffgrund	BORRIF-050526-5	53°50.97′N 6°21.971′E	24.9	RD	26.05.2005	F.K. Senckenberg	10 ♂; 13 ♀; 1 juv ♂; 1 Fr	30218
Borkum Riffgrund	BORRIF-050526-6	53°47.007′N 6°22.957′E	21.9	RD	26.05.2005	F.K. Senckenberg	7 ♂; 9 ♀; 1 juv; 1 Fr	30219
(b) *Localities on Loreley Bank E of Helgoland*								
Loreley Bank	NR-2	54°12′N 8°1.6′E	17–18.8	RD	04.08.1984	F.K. Senckenberg	1 ♀	12793
Loreley Bank	NR-42 RD1	54°12.1′N 8°2.37′E	25–25.8	RD	13.08.1984	F.K. Senckenberg	1 ♀	12880
Loreley Bank	DOGK-LB03-1	54°12.761′N 8°0.557′E	14.7	RD	07.08.2003	F.K. Senckenberg	1 ♂; 2 ♀	32311
Loreley Bank	DOGK-LB03-2	54°12.036′N 8°0.44′E	13.3	RD	07.08.2003	F.K. Senckenberg	1 ♂	32312
Loreley Bank	DOGL-LB1	54°12.7′N 8°0.95′E	24.1	RD	09.08.2004	F.K. Senckenberg	1 ♂; 1 ♀	30200
Loreley Bank	DOGL-LB2	54°11.98′N 8°0.55′E	23.1	RD	09.08.2004	F.K. Senckenberg	3 ♂; 2 ♀; 1 ♀ Fr	30201
Loreley Bank	DOGL-LB3	54°11.89′N 8°1.3′E	23	RD	09.08.2004	F.K. Senckenberg	1 ♀	30202
Loreley Bank	DOGL-LB4	54°12.6′N 8°3.08′E	23.5	RD	10.08.2004	F.K. Senckenberg	2 ♂; 1 ♂ Fr; 6 ♀	30203
Loreley Bank	DOGL-LB6-1	54°13.8′N 8°1.28′E	14.4	RD	10.08.2004	F.K. Senckenberg	1 ♂; 1 ♀; 1 Fr	30204
Loreley Bank	DOGL-LB6-2	54°13.77′N 8°1.26′E	14.2	RD	10.08.2004	F.K. Senckenberg	3 ♂; 3 ♀; 1 ovig. ♀	30205
Loreley Bank	LB-041130-4	54°12.05′N 8°3.06′E	18.1–19.1	RD	30.11.2004	F.K. Senckenberg	2 ♂	30761
Loreley Bank	LB-041130-5	54°12.97′N 8°2.3′E	13.7–14.2	RD	30.11.2004	F.K. Senckenberg	4 ♂; 8 ♀	30762
Loreley Bank	LB-041130-5a	54°12.98′N 8°2.09′E	13.5	VV	30.11.2004	F.K. Senckenberg	1 ♂	30763
Loreley Bank	LB-060727-4/3	54°12.108′N 8°2.85′E	14.7	RD	27.07.2006	F.K. Senckenberg	1 ♀	31202
Loreley Bank	LB-060727-5	54°12.998′N 8°2.046′E	14.1	RD	27.07.2006	F.K. Senckenberg	1 ♂	31785
Loreley Bank	LB-060727-6	54°13.321′N 8°1.143′E	14.6	RD	27.07.2006	F.K. Senckenberg	1 ♂; 2 ♀	31203
Loreley Bank	LB-060727-6	54°13.321′N 8°1.143′E	14.6	RD	27.07.2006	F.K. Senckenberg	1 ♂; 1 ♀	31204
Loreley Bank	LB-060727-6	54°13.321′N 8°1.143′E	14.6	RD	27.07.2006	F.K. Senckenberg	1 ♂	31205

Table 1 continued

Area	Station	Position	Depth (m)	Gear	Date	Vessel	Specimens examined	SMF
Loreley Bank	LB-060727-8/1	54°12.99′N 8°0.928′E	13.1	RD	27.07.2006	F.K. Senckenberg	1 ♀; 1 ovig.♀	31557
Loreley Bank	LB-060727-8/2	54°12.969′N 8°0.994′E	13.4	RD	27.07.2006	F.K. Senckenberg	1 ovig. ♀	31558
Loreley Bank	LB-060727-10	54°14.451′N 7°56.183′E	19.5	RD	27.07.2006	F.K. Senckenberg	1 ♀; 2 ovig ♀	31559
Loreley Bank	LB-070809-5	54°12.971′N 8°1.953′E	13.6	RD	09.08.2007	F.K. Senckenberg	1 ♀	31858
Loreley Bank	LB-070809-6/1	54°14.163′N 8°0.738′E	17.3	RD	09.08.2007	F.K. Senckenberg	1 ♀	31859
Loreley Bank	LB-070809-6/1	54°14.163′N 8°0.738′E	17.3	RD	09.08.2007	F.K. Senckenberg	1 ♂	31930
Loreley Bank	LB-070809-6/1	54°14.163′N 8°0.738′E	17.3	RD	09.08.2007	F.K. Senckenberg	1 ♀	31931
Loreley Bank	LB-070809-6/2	54°13.971′N 8°0.608′E	17.5	RD	09.08.2007	F.K. Senckenberg	16 ♂; 5 ♀	31860
Loreley Bank	LB-070809-8	54°13.131′N 8°0.943′E	14.5	RD	09.08.2007	F.K. Senckenberg	10 ♂; 5 ♀	31861
Loreley Bank	LB-080806-1	54°12.112′N 8°59.913′E	11.9	RD	06.08.2008	F.K. Senckenberg	3 ♂, 4 ♀	32779
Loreley Bank	LB-080806-5/2	54°12.853′N 8°1.976′E	12.4	RD	06.08.2008	F.K. Senckenberg	2 ♂, 2 ♀	32780
Loreley Bank	LB-080806-6/1	54°13.912′N 8°1.235′E	16.0	RD	06.08.2008	F.K. Senckenberg	2 ♀	32781
Loreley Bank	LB-080806-6/2	54°13.918′N 8°1.443′E	16.1	RD	06.08.2008	F.K. Senckenberg	6 ♂, 3 ♀	32782
Loreley Bank	LB-080806-7	54°11.981′N 8°0.985′E	10.9	RD	06.08.2008	F.K. Senckenberg	1 ♀	32783
Loreley Bank	LB-080806-8/1	54°13.029′N 8°1.317′E	14.8	RD	06.08.2008	F.K. Senckenberg	3 ♀	32784
Loreley Bank	LB-080806-8/2	54°13.094′N 8°1.382′E	14.4	RD	06.08.2008	F.K. Senckenberg	1 ♂, 1 ♀	32785
Loreley Bank	LB-080806-9/2	54°12.924′N 8°58.038′E	15.8	RD	06.08.2008	F.K. Senckenberg	1 ♂, 1 ♀	32786
Loreley Bank	LB-080806-10/1	54°14.467′N 8°56.171′E	21.4	RD	06.08.2008	F.K. Senckenberg	2 ♂, 3 ♀, 1 ovig. ♀	32787

Depths in brackets have been taken from chart

Fr fragments, *RD* ring dredge, *VV* Van Veen Grab

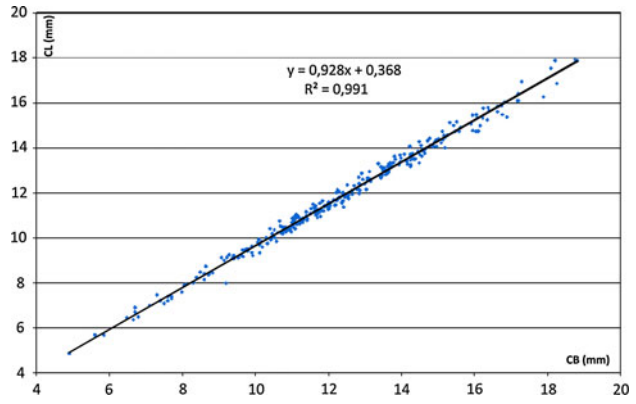

Fig. 2 Correlation of carapace length (*CL*) to carapace breadth in the material examined for this study

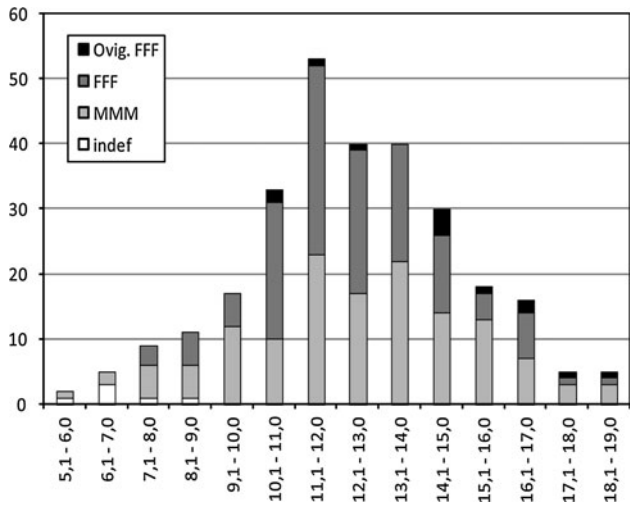

Fig. 3 Size distribution in the examined material from the two main locations with reference to sex: numbers of specimens (*vertical axis*) versus size classes (in mm) (*horizontal axis*). *indef* sex not defined, predominantly juveniles; *MMM* males; *FFF* non-ovigerous females; *Ovig. FFF* ovigerous females

deterministic. For the Borkumriff area no sediment analysis was conducted, but all stations are in the area where Figge (1981) mapped medium sand without any finer sediment.

Discussion

The known distribution of the thumbnail crab in the North Sea is very patchy and reflects the special habitat type in which this species is found. Generally the distribution tends to a warm-water oceanic type so that it is relatively regularly found in the Southern Bight, from where it has been recorded quite consistently since earlier years, and increasingly so since 1996 (Adema 1991; Degraer et al. 2006; Clark 1986; Raven 1978; Severijns 2004; Vanhaelen 2005; Wolff and Sandee 1971). Also the records from

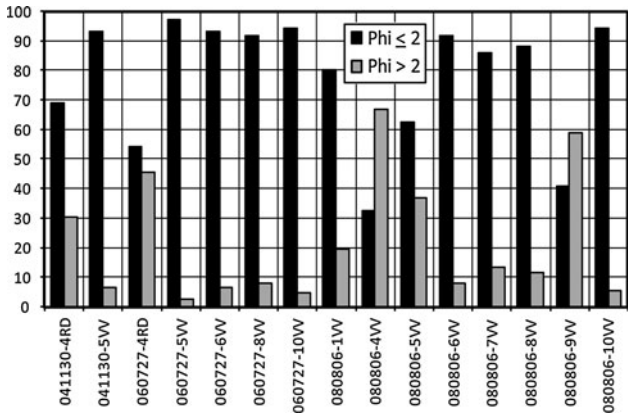

Fig. 4 Sediment grain-size composition at Loreley Bank in % with reference to the sampling stations

southern Norway (Christiansen 1985) and southern Sweden (Wahrberg 1930; Christiansen 1969) are in regions governed by oceanic (Atlantic) water influx along the Norwegian Trench. This is why many species that are absent from the central southern North Sea still reach similar latitudes in the Skagerrak. The occurrences in the German Bight correspond with this distribution pattern in that the species is, and has always been, more numerous at the Borkum Riffgrund area, which is closer to the channel-water influx along the Dutch coast, than at Loreley Bank in the extreme east of the German Bight. From the western area there are also old records by Metzger (1871) (repeated by Metzger 1875 and Blohm 1915), who found *Thia* regularly in the stomach of haddock taken off Norderney. It seems that the species, though probably always present there, may have increased abundance in recent years like other species of southern (oceanic) origin that are now found more regularly in the inner German Bight than before. Besides the two localities treated in detail in this paper Harms (1993) has listed records from the Helgoland Trench (Helgoländer Tiefe Rinne) and Steingrund NE of Helgoland. The first record is attributed to a diploma thesis (Berberich 1989), and indeed, one specimen was collected during that study SW of Helgoland (stat. VH 508, 54°07.25′N 07°50.50′E, 37.6 m depth, 2 August, 1988, R.V. *Victor Hensen*). Contrary to the statement of Harms (1993) this locality is clearly outside the Helgoland Trench. It confirms also an earlier single record by A. Hagmeier from at about 5 nautical miles SW of Helgoland on 9 July 1933. This record was published by Caspers (1938) where he also states that the locality is outside the trench on sandy bottom. He also mentions that Hagmeier had collected this species at other points in the German Bight, without giving details. Unfortunately there is no more information on these early records. Also Schellenberg (1928), referring to a letter of Hagmeier, states that this species reached the German coast without giving further details. The record

Table 2 Sediment composition (in % of total) and numbers of collected specimens at sampled stations at Loreley Bank (German Bight, North Sea)

Fraction	Phi value	041130-4RD	041130-5VV	060727-4RD	060727-5VV	060727-6VV	060727-8VV	060727-10VV	080806-1VV	080806-4VV	080806-5VV	080806-6VV	080806-7VV	080806-8VV	080806-9VV	080806-10VV
>8.000 mm	> −3	0.00	3.65	0.00	3.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>4.000 mm	> −2	0.00	7.13	0.00	12.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>2.000 mm	> −1	0.00	9.56	0.04	16.92	0.14	0.32	0.90	0.11	0.00	0.52	0.69	0.00	0.19	0.00	0.30
>1.000 mm	⩾0	0.16	13.89	0.28	15.81	2.54	1.56	1.70	0.70	0.20	1.06	6.95	0.16	1.46	0.04	2.06
>0.500 mm	>1	2.28	25.89	6.12	31.50	40.96	40.69	31.58	8.20	1.26	4.62	36.51	7.79	37.71	0.33	28.30
>0.250 mm	>2	66.66	32.95	47.67	16.73	49.76	49.31	60.02	71.19	31.16	56.47	47.63	77.90	48.84	40.60	63.59
>0.125 mm	>3	30.06	6.68	45.41	2.55	6.37	8.07	4.78	19.62	66.23	36.47	7.82	13.55	11.47	58.10	5.55
<0.125 mm	⩾4	0.49	0.05	0.34	0.14	0.02	0.05	0.15	0.07	0.70	0.33	0.05	0.02	0.07	0.68	0.09
Sum Phi ≤2		69.11	93.08	54.11	97.19	93.40	91.87	94.20	80.19	32.63	62.67	91.78	85.85	88.20	40.96	94.25
Sum Phi >2		30.55	6.73	45.75	2.69	6.39	8.12	4.93	19.68	66.93	36.79	7.87	13.57	11.53	58.78	5.64
Specimens		2	12	1	1	6	2	3	7	0	4	9	1	2	2	6

from Steingrund comes from an unpublished diploma thesis (Kühne 1992), the results of which were later summarised and published (Kühne and Rachor 1996). The diploma thesis was not available to me and the later publication does not give exact locality data. However, it is stated that the species was collected in "station group 1", which refers to two stations NE of Helgoland at the positions stat I: 54°20′N 07°56′E and stat. II: 54°19′N 07°58′E (both extrapolated from published map). Steingrund is part of a glacial end moraine of Saalian age (Stocks 1955; Schulz and Kiel 1983) with large boulders overgrown with abundant sessile fauna and very scarce sediment cover, very atypical for *Thia*. In fact, if the stations of Kühne are plotted on the sediment map of Figge (1981) both are situated not on Steingrund proper, but in a nearby area covered with coarse sand.

Besides the general distribution pattern the occurrence of *T. scutellata* is controlled by a specific sediment type that is very patchily distributed and thus the occurrence of the crab is patchy. Rees (2001) gives specific information concerning the sediments in which the species has been found on Welsh coasts: "On visual appearance alone, that with crabs had slightly coarser and better sorted sand with fewer shell fragments. It had a median Phi diameter of 1.1, the others having 1.7–1.9. Although all would be classed medium sand, that with crabs had few particles over 1 mm and less in the very fine sand and silty clay fractions." Furthermore, he observed for other locations that crabs were situated "where tidal currents are likely to produce mobile sand features". Wolff and Sandee (1971) state that their specimens were taken in medium sand beyond the 30 m contour with low turbidity. This agrees with the statement of Berberich (1989) that the sediment from station VH 508 (SW of Helgoland, for details see above), at which one specimen of *T. scutellata* was collected, was composed of medium sand. Our sampling confirms that the thumbnail crab prefers well-sorted medium sands (Phi values between 1 and 2), with a certain amount of shells and gravel without any discernible correlation to crab occurrence. The present data indicate that the proportion of finer sediment determines the presence of the crabs more than the coarser fraction. This seems logical under the assumption that *Thia* has a "mole" life type as stated by Rees (2001). Respiration while burrowed in the sediment depends on permeability of the sediment, i.e. easy penetration and circulation of seawater through the sediment. Permeability in consolidated and non-cemented sediments is positively correlated to grain size (mm), and negatively correlated to Phi values. The weak correlation of abundance to lower but still significant ratios of sediment with Phi values of more than 2 can only be explained by patchiness of the sediment distribution. As the sediment samples were taken at the same station, but with a different

gear and therefore at slightly different times and locations, such patchiness is very probable and would result in slightly different sediment characteristics.

In conclusion, the thumbnail crab *Thia scutellata* can be considered a precise indicator for grounds with well-sorted middle sand in the North Sea that are exposed to strong currents and/or wave action. In addition there is a preference for more stable oceanic conditions with warmer minimum temperatures. Thus, well-monitored stable populations, like the ones of Borkum Riff and Loreley Bank, can be used for detecting environmental change in average water temperatures and sediment properties.

Acknowledgments I have to thank my technical assistant Kristin Pietratus for careful sample processing and taking measurements as well as for continuous hard work at sea, alone and in my company, also numerous students who have helped us in the field work. Captains and crews of R.V. *Senckenberg* are gratefully acknowledged for skilful operation of the ship and sampling gear also in rough weather conditions. My colleague Dr. Achim Wehrmann (Senckenberg-Institute at Wilhelmshaven) organised the sediment analysis and helped with the interpretation of the results, for which I am grateful. Dr B. Ferebee from the Department of Mathematics of the Frankfurt University is gratefully acknowledged for his help in statistical analyses. I thank Dr. Richard Hartnoll (Isle of Man, UK) for streamlining my English making helpful comments on an earlier version of this manuscript. The distribution map was prepared using the software "Panmap" of the PANGAEA-Network (http://www.pangaea.de).

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