

## Notes on growth and behaviour of the American razor clam *Ensis directus* in the Wadden Sea and the predation on it by birds

C. Swennen<sup>1</sup>, M. F. Leopold<sup>1</sup> & M. Stock<sup>2</sup>

<sup>1</sup>Netherlands Institute for Sea Research; P. O. Box 59, 1790 AB Den Burg (Texel),  
The Netherlands

<sup>2</sup>Fachbereich Biologie/Chemie der Universität Osnabrück; Postfach 44 69,  
D-4500 Osnabrück, Federal Republic of Germany

**ABSTRACT:** *Ensis directus* (Conrad), a bivalve found in Europe only in the past few years, has filled an empty niche and spread rapidly over the intertidal flats in the Wadden Sea. The growth of the animals was investigated using a few samples taken near Langeness in February 1984. The age of the animals could be determined by reading the clearly visible year marks on the shells. Notwithstanding the low density of *E. directus*, some oystercatchers appear to have already specialized in feeding on this new food source.

### INTRODUCTION

In 1979, the first occurrence in Europe of *Ensis directus* (Conrad) was established. Within a few years after its introduction, the species had extended its habitat along the coasts of the Federal Republic of Germany and Denmark (Von Cosel et al., 1982) as well as along the North Sea coast of the Netherlands (de Boer & de Bruyne, 1983; Essink, 1984; Swennen, 1984).

Live animals have been found in shallow marine waters down to a depth of 18 m in the North Sea in a number of places off the Frisian islands (Von Cosel et al., 1982; Mühlenhardt-Siegel et al., 1983) and on intertidal flats in the Wadden Sea (Essink, 1984; this paper).

Density, growth and mortality in the first year after settling were studied by Mühlenhardt-Siegel et al. (1983) in a subtidal population in the North Sea. These authors also gave data on growth and length-weight correlations in older age classes.

In the present paper, details are presented on (1) growth of shells of animals up to an age of 5 years in an intertidal population in the Wadden Sea and (2) some observations of the behaviour of *E. directus* and the predation on it by birds.

### METHODS

The study was carried out on the intertidal flats near the island of Langeness (Schleswig-Holstein, FRG) in late February 1984. The foraging behaviour of birds was

observed by means of a 50x magnifying mirror telescope. These observations were verified by studying foot prints, bill marks and remains of prey in the sediment.

*Ensis directus* was collected at four places (A, B, C, D) in the intertidal zone. In all places, the sediment consisted of fine sand with a small amount of silt, as often found on flats in the Wadden Sea.

(A) About 1 km NW of Mayenswarft. Mean exposure time of the flat 3.5 h. Oxidized layer 3 cm above black sand. Faunal composition (according to core samples): *Cerastoderma edule* (two- and three-year old individuals at a density of 50 to 200. m<sup>-2</sup>), *Macoma balthica*, *Mya arenaria*, *Hydrobia ulvae*, *Arenicola marina*, *Lanice conchilega*, *Nephtys hombergii*, *Anaitides maculata* and *Scolopes armiger*. A sample of 89 shells of *Ensis directus* was taken, which had just been eaten by oystercatchers *Haematopus ostralegus*, judging by the foot prints and pieces of flesh left in the shells.

(B) About 2 km west of A, at the same level according to the hydrographic map. Oxidized layer 8 to 10 cm on the top of grey sand. The faunal composition was the same as in A, but less dense. A sample of 26 shells of *E. directus* was collected, which had just been emptied by birds.

(C) About 1.5 km west of the harbour at the western end of the island. Sandy slope along a tidal creek. Mean exposure time 2.5 h. Oxidized layer more than 30 cm. Faunal composition: only a few *Nephtys hombergii* were found and castings of *Arenicola marina* were seen with a density of less than 1 per m<sup>2</sup>. A sample of 21 live *E. directus* was dug out.

(D) Scattered over the large flat west of the island, some fresh empty shells, without traces of flesh, were collected that were remarkably larger than the shells mentioned before. It was not certain whether they had indeed lived in the flat or had been washed out from a subtidal habitat e.g. the bottom of the main tidal channel.

All shells were cleaned, dried, weighed and the lengths were measured from the anterior edge to the various winter-rings in the posterior part. The flesh of the live animals was removed from the shells and dried in a stove at 60 °C, weighed, ashed in a furnace at 600 °C and weighed again to obtain the ash-free dry weight (ADW) of the flesh.

All individuals found in the area clearly belonged to *Ensis directus* as defined by Van Urk (1964). Part of our material has been deposited in the collection of the Rijksmuseum van Natuurlijke Historie, Leiden.

## RESULTS

### Observations on predators of *Ensis directus*

Oystercatchers on the flat off the eastern half of the island were seen to take mainly worms as food; those on the flats in the western half ate mainly molluscs. The main prey of the mollusc feeders on the sand flats was *Cerastoderma edule*, but some birds regularly caught *Ensis directus*.

While foraging, *Ensis* feeders walked faster and in a more upright posture than those feeding on *Cerastoderma*. They were obviously searching for *Ensis* by sight. A bird would suddenly run sideward or forward to drive its bill into the sediment and then pull out an *Ensis* shell up to half its length. Catching and emptying an *Ensis* appeared to take

much less time than handling a *Cerastoderma*. Scattered *Ensis* shells with small pieces of the adductor muscles still attached, together with the foot-prints and bill marks around the shells proved that our observations were correct. However, sieving of a number of core samples in the area brought no *Ensis* to light. Therefore, some larger areas of sediment, together about 6 m<sup>2</sup>, were dug out with a fork. It appeared that *Ensis* was present at a density of only a few individuals per square meter. The upper parts of the animals were never found less than 25 cm below the surface. The low density and great depth explained the absence of *Ensis* in the core samples. The burrowing depth of *Ensis* is much deeper than the length of any oystercatcher's bill, which in the Wadden Sea population is less than 10 cm (Glutz von Blotzheim et al., 1975; Swennen et al., 1983).

It was found, however, that live *Ensis* sometimes protrude above the surface of the sandflat. When attempts were made to pick up such an animal by hand, it always retreated immediately. After disturbance, it burrowed so rapidly that its upper end was more than 20 cm deep before the animal could be dug out. Even if the protruding end of the shells could be grasped, it proved impossible to extract the mollusc from the substratum, for, as long as the anterior end with the muscular foot was in the sediment, the animal could anchor itself very strongly.

From the traces found it could be concluded that oystercatchers were successful in taking *Ensis* by surprise. This was different in the curlew *Numenius arquata*, which according to their traces had unsuccessfully pecked into the holes in which live intact *Ensis* were found deeper down. From only one such hole did we dig out an *Ensis* of which the posterior part of the body (siphons and gills) had been eaten while the anterior part including the foot, which represents the largest piece of meat in *Ensis*, was still intact. Apparently the mollusc had dug deeper until far out of the reach of the bill of the curlew after part of its body had been lost by the attack of the bird.

We observed *Ensis* (shell length about 8 cm) in a glass tank now and then generating a jet of water through the pedal opening in the mantle. When that happened the animal shot backwards like a rocket for some decimeters. This swimming behaviour may be induced by the unnatural environment but it can be concluded that the power of inducing such a strong current will be of great help to the muscular foot when the animal moves rapidly into the sediment or back to the surface again and when it accidentally emerges from the sediment when escaping slowly moving predators.

### Age and growth

According to the year marks on their shells, the *Ensis* collected alive or freshly eaten were in their second winter (samples A, B, and C). Only among the *Ensis* collected as empty shells (sample D) were first year as well as older individuals found; the latter were up to an age of 5 years. The general growth pattern of the shells (Fig. 1) follows the von Bertalanffy equation (Beverton & Holt, 1957) with the parameters

$$L_t = 142.2 [1 - e^{0.58(t-0.623)}]$$

In the samples originating without doubt from the intertidal zone, the mean shell growth in the first year as well as in the second year appeared to be smallest in sample A and largest in sample C (Table 1). The differences in shell growth are statistically significant (t-test,  $P < 0.05$ ), except those between B and C in the first year.

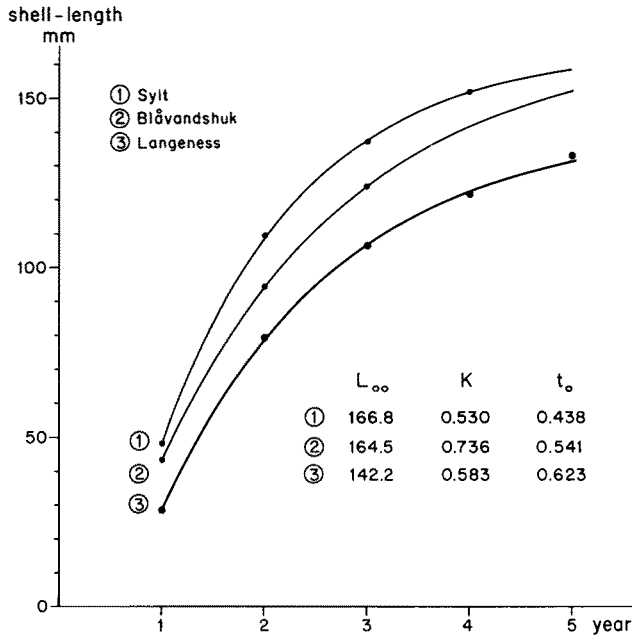


Fig. 1. Mean shell length of *Ensis directus* collected on tidal flats in the Wadden Sea near Langeness (F.R.G.), in February 1984 (all samples together). For comparison the Von Bertalanffy growth curves are also drawn for shells from the North Sea, off Sylt (1) and off Blåvandshuk (2) (Mühlenhardt-Siegel et al., 1983)

The small differences can be related to differences in distance to the main tidal channel and in exposure time, as the slower growing shells lived progressively further away from this channel. The growth pattern, with a rapid increase in shell length in the second year, conforms closely to that of other bivalves in the Wadden Sea (Kristensen, 1957; Lammens, 1967).

Within each of the three samples, the increase in shell length in the individuals in the second year (difference in shell length between first- and second-winter ring) was negatively correlated with the length achieved in the first year (slope in A: -0.53, B: -0.30, in C: -0.34). This correlation is significantly negative only in the large sample A

Table 1. Mean length gain (mm) of shells in *Ensis directus* during their first two years of age at 3 stations on intertidal sand flats near Langeness; s.d. = standard deviation

Sample site	A (n = 89)		B (n = 26)		C (n = 21)	
	growth	s.d.	growth	s.d.	growth	s.d.
First year (1982)	27.2	3.8	28.6	2.5	29.6	3.0
Second year (1983)	50.9	3.7	51.8	1.7	53.9	1.6
Total length	78.1	3.6	80.4	3.8	83.5	4.1

(95 %; confidence limits  $-0.71$  and  $-0.34$ ). The negative correlation between shell growth in the first year and in the second year indicates that retarded growth in the first year is somewhat compensated for by faster growth in the second year, inducing the uniformity in total sizes observed in the 2<sup>nd</sup> winter (Table 1). Such a catching-up phenomenon in shell growth in the first two years of life has also been reported in *Cerastoderma edule* (Kreger, 1940; Kristensen, 1957) and in *Macoma balthica* (Lammens, 1967).

In the two-year old animals (mean shell length 82.8 mm), the mean weight of the shell was 1.64 g, varying between 1.25 g in an animal with a shell length of 74 mm, and 2.10 g in an animal with a shell length of 88 mm. Mean ADW of the soft parts of the same animals was 0.331 g, s.d. 0.06 g ( $n=21$ ), varying between 0.296 g and 0.349 g in 74 mm and 88 mm long animals, respectively.

In 25.5 % of the fresh shells ( $n=136$ ) studied from the tidal flat population, besides year rings also disturbance rings were found. These rings occurred only on the former posterior shell edges and were situated at different lengths in the individuals. Therefore, they cannot represent spawning rings as found in some bivalve species (Coe, 1947; Davis, 1923; Gutsell, 1931), or disturbances caused by extreme temperatures or storms (Coe, 1947; Kreger, 1940) for then these rings would have occurred at about the same part of the shells and over the whole growth line. It is more likely that the disturbances on the posterior edges represent the slight damage caused by attacks of birds or other predators.

#### DISCUSSION

According to Van Urk (1964, 1972) the proper name of the species should be *Ensis americanus* (Binney, 1870) instead of *Ensis directus* (Conrad, 1843). The latter is a fossil from the Miocene. Some distinguishing marks used by Van Urk (1972) for the recent form proved to be more variable than was thought by this author (Von Cosel et al., 1982). Therefore, there is some doubt as to whether *E. americanus* and *E. directus* are really distinct. For this reason and in conformity with common practice in North America, the name *Ensis directus* has been used in the present paper.

*E. directus* originates from the western Atlantic where it occurs from southern Labrador to South Carolina (Bousfield, 1960). Von Cosel et al. (1982) assume that larvae were transported by ship in ballast water from the American coast to the German Bight in the spring of 1978. Here the first animal was caught in a grab sample taken off the Elbe mouth in June 1979. As appears from the year rings, some of the fresh shells in our samples must have been born in 1979 (Fig. 1). Mühlenhardt-Siegel et al. (1983) mentioned the occurrence near Blåvandshuk (Denmark) of shells, which also must have been born in 1979. This means that already a year after the supposed first introduction a mass settlement of larvae must have taken place over a stretch of at least 175 km. Although Mühlenhardt-Siegel et al. (1983) suggest that some individuals may spawn at the end of their first year, we doubt that this can happen in the slowly growing animals from the mouth of the Elbe (see below) or Langeness. Therefore, it may be assumed that the introduction of *E. directus* took place before 1978 or that in 1979 a second large introduction occurred in the German Bight, this time off the North Frisian islands.

After its recent and accidental introduction, the species found an empty niche in the North Sea area. Of the other filter feeders, only *Mya arenaria* lives as deeply burrowed in

the sediment as *Ensis directus*. Adult *M. arenaria* are nearly immobile and feed via a long siphon. Adult *E. directus*, on the other hand, are very rapid burrowers with short siphons and usually live near the surface but are able to disappear rapidly to great depths when disturbed. Accordingly, *M. arenaria* inhabits stable sediments, usually with a high admixture of mud, whereas *E. directus* can live in unstable sands. Near Lange-ness, its density and shell growth were highest in the sandy banks of a tidal channel where hardly any other macrobenthic animals were present due to the instability of the sand. *Ensis minor* (Chenu, 1843), a European species that also lives in shallow water up into the lower intertidal zone, seems to prefer less estuarine conditions and somewhat coarser sediments (C. Swennen, personal observations in France).

In North America, *E. directus* lives in the low intertidal and subtidal zone in sand and sandy mud in bays and estuaries, where it is most abundant in areas swept by moderately strong currents such as tidal channel margins and tidal flats exposed to wave action (Drew, 1907; Bousfield, 1960; Gibbons, 1964; Stanley, 1970). Thus, in the Wadden Sea, *E. directus* was found to live in a similar habitat. McDermott (1976) found shell lengths after the first growing season of about 30 mm in America, which is also similar to our data. A much faster growth of *E. directus* is reported by Mühlenhardt-Siegel et al. (1983) in shells from Blåvandshuk (Denmark) and Sylt. A comparison of the growth parameters calculated in the von Bertalanffy model of shells from the different sites (Fig. 1) indicates that the expected maximum size ( $L_{\infty}$ ) of the molluscs of the Langeness area (Wadden Sea) is considerably smaller than that of the North Sea populations off Sylt and Blåvandshuk. Also the relative growth ( $K$ ) of *Ensis* in the Wadden Sea is slower. However, in both studies the data must be considered provisional because only 3, 4 and 5 age-classes have been studied from Sylt, Blåvandshuk and Langeness respectively, and also the number of shells in these older age classes was small.

In North America, ring-billed gulls *Larus delawarensis* eat *E. directus*, but are only able to do so when the clams leave the sand to escape attack by slowly moving predatory invertebrates (Schneider, 1982). In Europe, up to the present, the oystercatcher seems to be the only bird that substantially uses the new food source in the intertidal flats. We found *Ensis* to have similar flesh content to that of *Cerastoderma* from the same flats (*Ensis* 0.33 g ADW, *Cerastoderma* 0.28 g ADW). *Cerastoderma*, however, occurs at a density of about 100 times that of *Ensis*, and the majority of the oystercatchers on the flat feed on *Cerastoderma*. Despite the low density of *Ensis*, and its great burrowing capacity, some individual oystercatchers have already successfully specialized in catching them, which illustrates again the flexibility of the oystercatcher in changing its feeding habits (cf. Swennen et al., 1983).

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