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Herring gulls learn to feed on a recent invader in the Dutch Wadden Sea, the Pacific oyster *Crassostrea gigas*

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Herring gulls (*Larus argentatus*) learned to exploit a new food source in the Wadden Sea near Texel, the introduced Pacific oyster *Crassostrea gigas*. The first 'wild' specimens of this oyster were observed in 1983. Due to a series of warm summers in the 1990s, the invader successfully reproduced and rapidly spread over the Dutch Wadden Sea. Herring gulls break large bivalves by shell-dropping; they lift oysters (and adhering attached objects) of up to 93 grams in weight. They were less successful in breaking the shells of oysters than of mussels *Mytilus edulis*: only about one third of the oysters were broken by shell-dropping, in mussels this was nearly 100%. Experiments indicated mussels to break easier during shell dropping. Future research will indicate whether herring gulls will learn to improve their breaking technique.

Key words: Bivalvia, Ostreidae, *Crassostrea gigas*, oysters, predators, gulls, alien species, Wadden Sea, Netherlands.

INTRODUCTION

The Pacific oyster *Crassostrea gigas* (Thunberg, 1793) is now rapidly increasing in numbers in the Dutch Wadden Sea. The first 'wild' specimens were observed near the outlet of the cooling-water basin of the power plant near Oudeschild on Texel in 1983. They were introduced in this basin already in 1976 and had escaped (Bruins, 1983; Cadée, 2000a). For its reproduction *C. gigas* needs temperatures of above 19.5-20°C; the planktonic larvae thrive best at temperatures of >20°C (Korringa, 1976). In the long-term series of temperature measurements in the westernmost tidal inlet of the Wadden Sea the Marsdiep (since 1861), five of the ten warmest years occurred in the period 1989-1999 according to Van Aken (2000) and temperatures in 2000 were again relatively high (Van Aken, 2001). This might explain why the expansion of this species started in the 1990s. Also, in summer 2000 a new spatfall occurred (Cadée, 2001). The Pacific oyster occurs now all over the Dutch Wadden Sea (Tydeman, 1999; Essink, 2000; Cadée, 2000a). In 1986 Pacific oysters also escaped from cultures near Sylt in the northern part of the German Wadden Sea (Reise, 1998). In the Oosterschelde, in the southern part of the Netherlands, Pacific oysters were introduced in 1964; spat escaped there too (Drinkwaard, 1999). It is possibly from this stock that the first specimens were introduced into the cooling-water basin on Texel in 1976. Observations of oysters dropped by herring gulls were made earlier in the Oosterschelde area than in the Wadden Sea (P. Wolf, Middelburg, and P. de Wolf, Texel, pers. comm. 2000).

Herring gulls (*Larus argentatus*) are well-known omnivores (Glutz von Blotzheim & Bauer, 1982); molluscs form an important part of their diet in the Wadden Sea area

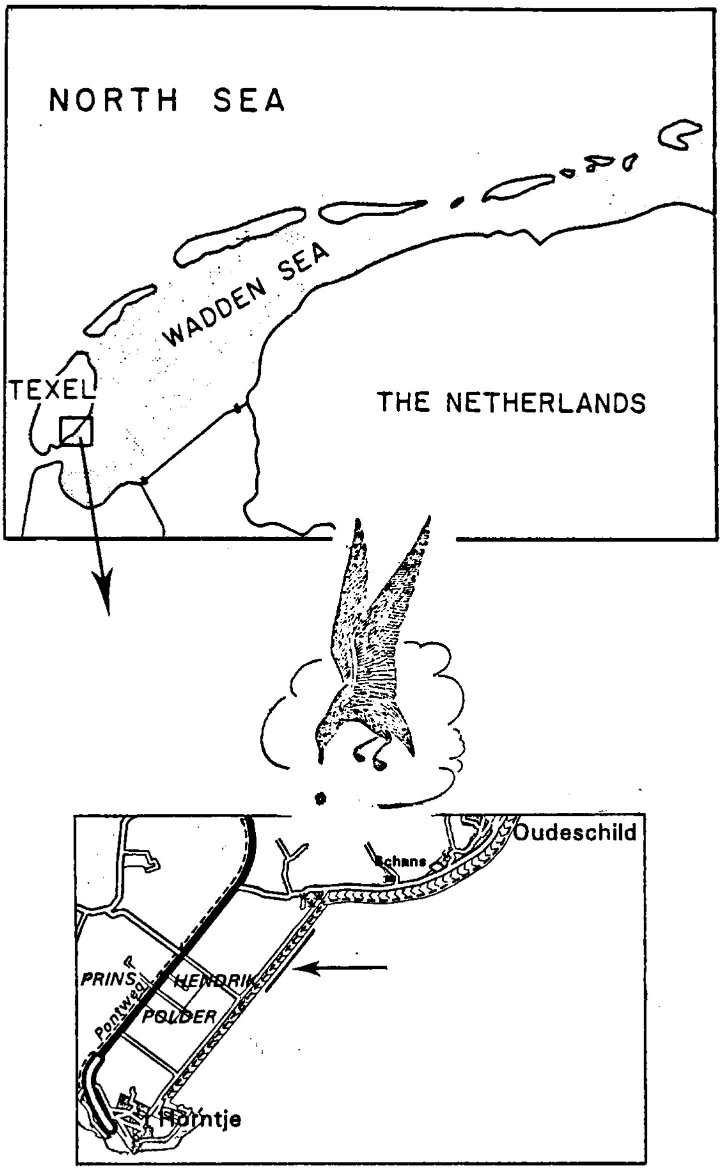

Fig. 1. Location of the sampling area on the island of Texel.

(Goethe, 1980; Vauk & Prüter, 1987; Noordhuis & Spaans, 1992; Spaans, 1998). They ingest small molluscs whole and break them in their gizzard. Larger shells are taken into the air and dropped from a certain height to break. This smashing method is already known for a long time (MacGillivray, 1817; Oldham, 1930; Tinbergen, 1953; Cadée, 1989, 1995). It occurs world-wide also in a number of other gull species (Maclaine, 1904; Maron, 1982; Siegfried, 1977), as well as in ospreys (Leshem, 1985; Mienis, 1993), and some crows (Zach, 1978; Mienis, 2000). Up to now, herring gulls used this method along the Wadden Sea coast of Texel mainly to break larger mussels *Mytilus edulis* L., 1758 (Cadée, 1989, 1993, 1995), sometimes for breaking *Ensis directus* (Conrad, 1843) (Cadée, 2000b); Goethe (1958) observed them dropping *Mya arenaria* L., 1758 in the German Wadden Sea.

Early 2000, on my daily bike-ride along the Wadden Sea dike to the Netherlands Institute of Sea Research, I observed the first Pacific oyster between the many mussels dropped on the pavement (Cadée, 2000a). At first this was only an occasional specimen, but since the middle of November 2000 they became more common. This offered a good opportunity to study the size distribution of the oysters collected by herring gulls. Moreover, I could evaluate their success of this shell-dropping method in breaking oysters and mussels.

MATERIAL AND METHODS

Between 23 and 30 November 2000, 131 freshly dropped Pacific oysters were collected on the pavements on both sides of the Wadden Sea dike of the Prins Hendrik Polder, southern part of Texel (fig. 1). In addition seven oysters were collected from the grass that covers the upper part of the dike; these were not used for estimates of breaking efficiency. An additional 101 oysters could be collected on the pavement of the dike in the next period of low tides during the daylight period (10 to 27 December 2000). Most oysters were collected on the road on the sea-side of the dike, but also some on the road on the land-side. Both roads are mainly used by bikers and, with so many broken mussels on the pavement, the road on the sea-side was hardly used at all, because the broken shells easily puncture bicycle tires. This, and the fact that I collected almost daily, ensures that broken shells were due to gull activity and not to traffic.

The length of the dropped but still articulated oysters, not broken by the gulls, and usually closed with the animal still inside, was measured with vernier callipers to the nearest 0.1 mm. The weight of the fresh, still closed oysters was measured to the nearest 0.5 gram, using a simple letter-balance. Calibration with a modern electronic laboratory balance later showed differences of less than 0.5 gram. The length of the broken oysters was also measured, sometimes after carefully matching the broken parts. To compare breaking success of the gulls in oysters and mussels, 200 dropped mussels were collected at the same locality.

A few indoor experiments have been performed to study shell breaking by dropping oysters and mussels from a height of 6 m on a concrete floor.

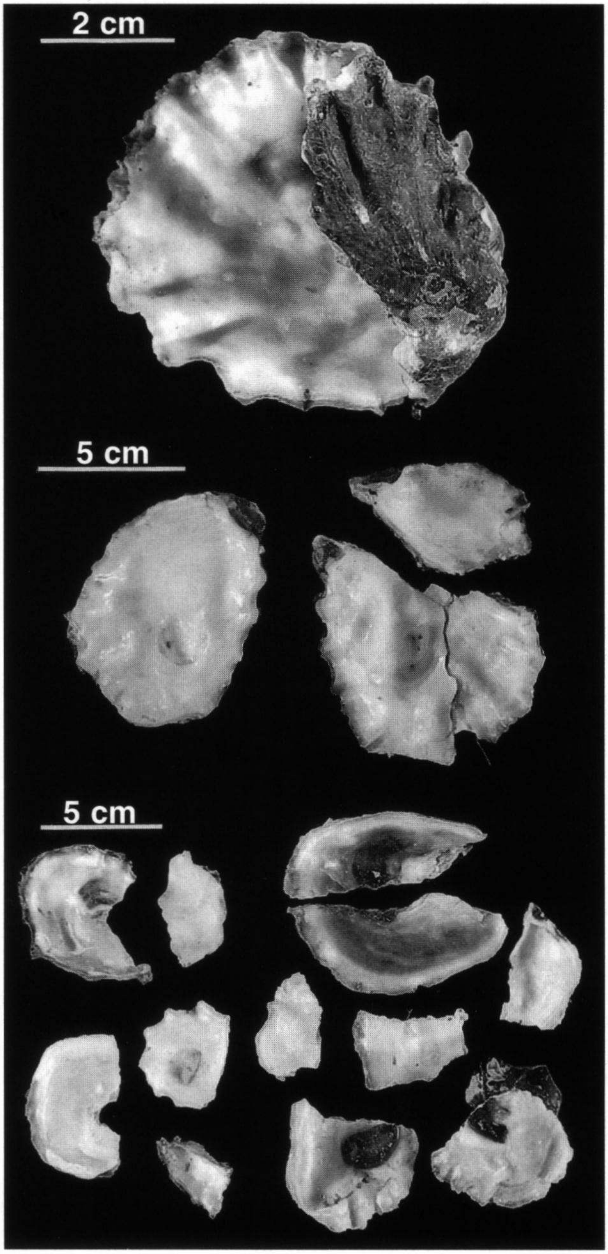

Fig. 2. Broken *Crassostrea gigas* shells. Top, one valve broken but still articulated; middle, one valve broken and disarticulated; bottom, disarticulated fragments.

RESULTS

Herring gulls cannot of course collect the oysters that are attached to the stones, which form the foot of the dike. They will collect only those attached to small objects, usually empty shells of mussels, cockles, periwinkles and razor clams, that are found on the tidal flat bordering the dike. In some cases the oysters collected by the gulls had settled on living mussels, that occur here in small mussel-banks.

Of the 232 oysters collected from the pavement, only 78 (33.6%) were broken and 154 were intact, most even still alive with the valves closed. Usually, only one valve was broken, resulting in a number of fragments partly still adhering by the ligament to the other valve (fig. 2). Of the 200 mussels 199 were broken and consumed, only one relatively small mussel (40 mm long) had escaped consumption; maybe because of its small size, it may have been overlooked after dropping by the gull. The average length of the dropped mussels was 67.8 mm. Fragments of both valves were usually still connected by the ligament as figured in Cadée (1995, pl. 1).

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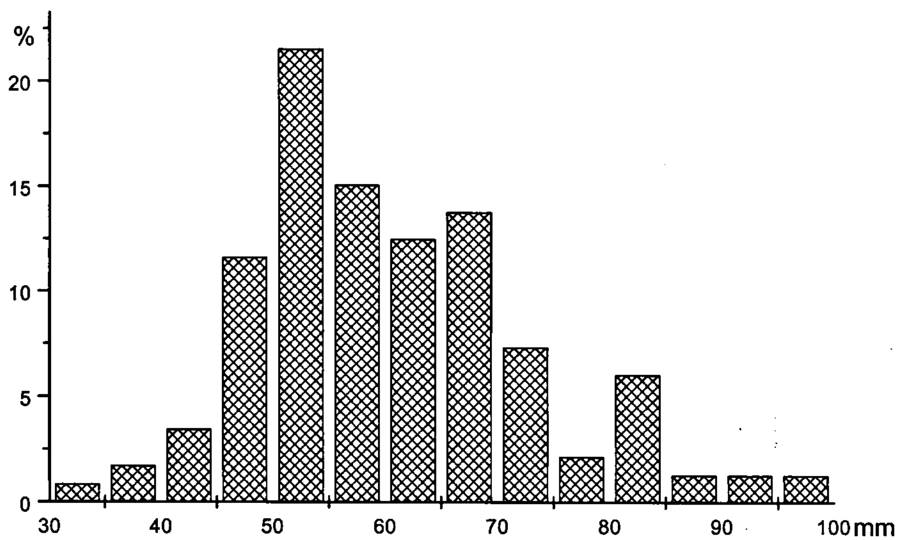

Fig. 3. Size frequency distribution of *Crassostrea gigas* shells dropped by herring gulls, Texel, November-December 2000 [n=232].

Dropped oysters ranged in length from 36.2 to 97.4 mm. The average length was 60.8 mm and there was no difference between average length of broken (60.9 mm) and intact oysters (60.7 mm). This indicates that the breaking success is independent of size. The size distribution (fig. 3) of the dropped oysters (broken and intact together) indicates scatter around this average, but also that the gulls select the medium sized oysters from the population for smashing. The oysters living here range in size from a few mm (spatfall of 2000) to 140 mm in length (Cadée, 2000a, 2001).

The high percentage of articulate and still living oysters made it possible to measure the weight of the prey the herring gulls take into the air to drop. The weight ranged from

6.5 to 93 grams (fig. 4). The positive relation between shell length and weight is somewhat obscured by the fact that the oysters settle on different objects: the gulls have to lift oyster plus these objects. Moreover, shell shape and shell thickness of the oysters show variation.

In the November period, seven oysters were dropped on the grass on top of the dike against 131 on the pavement, although the area occupied by grass equals the pavement in surface area. This indicates that herring gulls preferred to drop the oysters on a hard surface. Of these seven specimens collected from the grass, only one was broken; soft surfaces are inadequate for shell smashing.

The indoor experiments showed that oysters found entire on the dike could be broken after 2 to 6 (average 4) times dropping from a height of 6 m on a concrete floor. So if the herring gulls had persevered they might finally have broken the oysters. The oysters usually arrived flat on the floor, on one of their valves. One valve became finally fractured, the other remained intact, as was observed also in the oysters dropped by herring gulls. Of nine fresh mussels dropped in the same way, two were broken after the first dropping, the others after the second dropping. These experiments indicate that mussels break more easily than oysters, and that herring gulls could break oysters in the field if they had persevered, just as they persevere in dropping mussels repeatedly.

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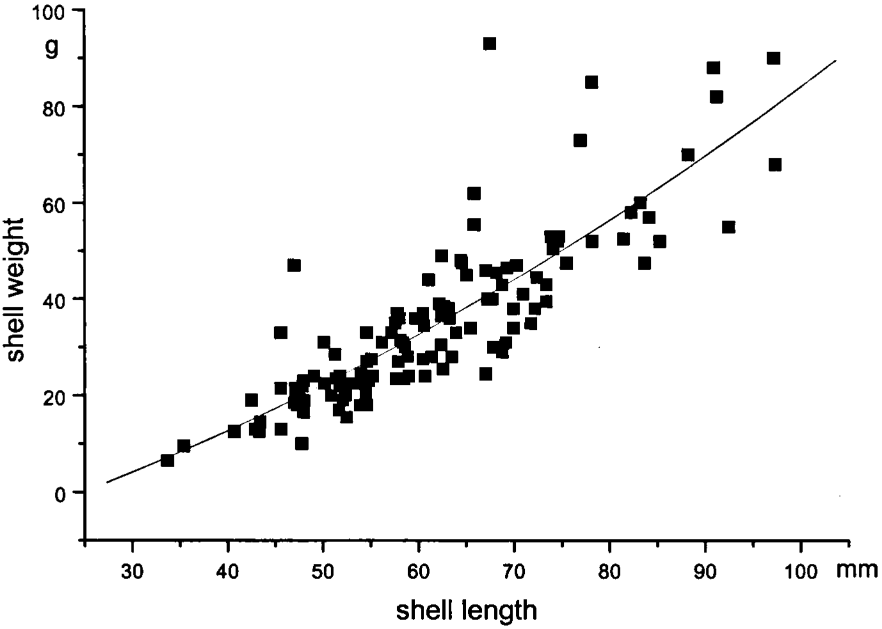

Fig. 4. Shell weight of dropped shells of *Crassostrea gigas* plotted against shell length [n=128, R-square= 0.817, p<0.0001].

DISCUSSION

In the past, it has been discussed whether herring gulls select hard substrates for shell-dropping or not. In my study they certainly did prefer the hard pavement above the grass. Tinbergen (1953), working along the North Sea beaches of the coast of the mainland of the Netherlands, observed that they did not select the few hard areas present here. In the absence of hard substrates herring gulls successfully dropped hard-shelled prey on soft sediments (MacGillivray, 1817; Kent, 1981). It takes more successive drops to break a shell on soft sediment than on hard substrate, but herring gulls may be quite persistent in dropping shells. Tinbergen (1953) observed one immature herring gull dropping the same prey 39 times (in shallow water); dropping the same shell ten times was not uncommon. Rarely shells are broken after the first attempt. Repeated droppings of mussels I also observed very regularly on Texel. This makes it difficult to understand why the gulls did not persevere with oysters: my own indoor experiments indicated four trials to be sufficient on average.

Teichert & Serventy (1947) mention that in Australia the Pacific gull (*Larus pacificus*) smashed gastropods of the species *Turbo stamineus* Martyn, 1845 weighing "8 to 10 oz" (1 ounce = 28.35 gram). Maron (1982) presented preys of different weight to the western gull (*Larus occidentalis*) and observed they could lift preys up to 268 grams. These values are much higher that the heaviest oyster herring gulls dropped in my study (93 grams). Herring gulls are of about the same size as Pacific and western gulls (Harrison, 1983), but apart from weight also the size and shape of the oysters might pose limits to their lifting capacity, i.e. they may not fit their bill.

An interesting question is: how did herring gulls discover this new food source? At the locality studied herring gulls have been breaking mussels already for a long period (Cadée, 1989, 1993, 1995). Mussels have decreased in numbers considerably since overfishing in the late 1980s (Van der Kam et al., 1999: 333), but a small population of mussels persisted at the study locality. Pacific oysters now occur along most of the Wadden Sea coast of Texel; this locality seems to be the first where herring gulls learned to prey on oysters in the Duth Wadden Sea area. Herring gulls started shell-dropping Pacific oysters earlier in the Oosterschelde area, so herring gulls in the Wadden Sea might have learned to tackle the new prey there; the question than still remains how they discovered oysters as food. In some cases, I collected a broken oyster attached to an also broken mussel. This could indicate that herring gulls learned by accident to prey on oysters: they started with those attached to (living) mussels.

Herring gulls breeding in the Wadden Sea area are partly sedentary but also show dispersion from N. Denmark to S. Spain (Goethe, 1980; Glutz von Blotzheim & Bauer, 1982). Herring gulls from Scandinavia migrate during winter to e.g. the Wadden Sea area. This suggests that herring gulls might have learned to use oysters as a food resource elsewhere in their distribution area, e.g. in SW. Netherlands, France, Spain or near Sylt, where Reise (1998) also observed herring gulls feeding on Japanese oysters.

Nothing is known of former predation by herring gulls on the so-called flat oyster *Ostrea edulis* L., 1758, which occurred in the Wadden Sea, but disappeared due to overfishing already in the first half of the 20th century (Nehring & Leuchs, 1999). Herring gulls are not mentioned among the 'enemies' of *Ostrea edulis* by Yonge (1960). For the Netherlands it should be kept in mind that herring gulls in the early part of the 20th century were far less common (Spaans, 1998); so predation might have occurred, but then only at a low level. Because of the disappearance of *Ostrea edulis* long ago, it is impossible that herring gulls recognized oysters as food from possible earlier experience with the flat oyster.

In recent years, herring gulls have learned to deal with another recent invader in the Wadden Sea, *Ensis directus* (Cadée & Cadée-Coenen, 1994; Cadée, 2000b). They now start to learn to prey on *C. gigas*, introduced in about the same period, but reaching higher densities much later. Herring gulls feed only on *Ensis directus* during mass mortalities of this species. It seems that herring gulls feeding on *E. directus* changed from the shell dropping method in the early 1990s to simply shaking the *Ensis* shells in the later 1990s, a method they also use in consuming crabs (Cadée, 2000b).

Herring gulls on Texel are still far less successful in breaking Pacific oysters than mussels. It will be interesting to repeat this kind of study after some years. With time, herring gulls might become more experienced in breaking oysters. It was observed repeatedly that herring gulls can learn to deal with their prey, they improve their foraging methods in the first years of their life before they become mature and start breeding (Verbeek, 1977; Creig et al., 1983; McLean, 1986). Barash et al. (1975) suggested that clam-dropping is a learned breaking behaviour in herring gulls. They conclude that trial and error learning is presumably involved in the improvement in shell-breaking efficiency. Herring gulls on Texel might prove this.

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Samenvatting

De in Europa geïntroduceerde Japanse oester *Crassostrea gigas* leeft sinds 1983 verwilderd in de westelijke Waddenzee bij Texel. Een serie warme zomers in de negentiger jaren heeft een goede reproductie tot gevolg gehad met als resultaat dat de Japanse oester thans over de hele Nederlandse Waddenzee voorkomt, zowel op de stenen van dijken als vastgehecht aan losse schelpen op het wad. Zilvermeeuwen hebben eind 2000 deze voedselbron bij Texel ontdekt (reeds eerder fourageerden ze op Japanse oesters in de Oosterschelde). Tot bijna 10 cm lange oesters nemen zij mee in de lucht om ze van enige hoogte op het asfalt van de dijkvoet of op de weg achter de dijk te laten vallen. Dezelfde methode gebruiken zij op deze plaats op zuid Texel al langer voor het breken van grote mossels. Zij blijken succesvoller te zijn in het breken van mossels dan van oesters: slechts 1/3 van de oesters gaat kapot tegenover bijna 100% van de mossels. Experimenten toonden aan dat mossels makkelijker breken dan oesters, maar na 2 tot 6 maal laten vallen gaan ook oesters kapot. Zilvermeeuwen moeten dit kennelijk nog leren; het zal interessant zijn na te gaan of ze succesvoller worden in de toekomst.