Consequences

Theunis Piersma & Kees Camphuysen, Netherlands Institute for Sea Research, Den Burg, Texel, NL
Theunis Piersma, University of Groningen, NL
Kees Camphuysen, CSR Consultancy, Oosterend, Texel, NL

What Can Peak Mortalities of Eiders Tell us about the State of the Dutch Wadden Sea Ecosystem?

Two mass mortality events of Common Eiders *Somateria mollissima*, which occurred in the Dutch Wadden Sea in the 1990s can be considered either trivial (if in proportion to the total breeding population size of eiders: c. 1% died in 1999/2000), or enormous (if in proportion to the size of the Dutch wintering population: c. 15%). What is most critical, however, is not the magnitude of the mortality events, but the ecological reasons behind the enhanced mortality. We put forward the hypothesis that gross overfishing in the early 1990s resulted in permanently reduced food resources, a reduced foraging area and an increased use of secondary prey such as *Spisula subtruncata* in the North Sea coastal zone, all of which led to increased interference competition among eiders. A further decrease in food quality in the winter of 1999/2000, coupled with the removal of major *Spisula* banks in late summer 1999, induced starvation and concomitant parasite problems that led to spectacularly increased mortality rates in an otherwise long-lived bird species. The eider story tells us that early warning signals of the continuing 'ecological erosion' of the Wadden Sea were largely ignored, thus leading to a loss of biodiversity and structural food shortages for molluscivorous birds. In any case, the limited additional conservation measures that were introduced shortly after the first increased eider mortalities in 1990/91 have proven inadequate.

Introduction

Unprecedented mass mortality of Common Eiders was observed in the winter 1999/2000 in the Dutch Wadden Sea (this issue). Between November 1999 and June 2000, at least 21,000 Common Eiders died representing c. 15% of the national wintering population. At least 7,500 individuals were adults. Dissected birds were all severely emaciated and 94% were infested with the acanthocephalan parasite *Profilicollis botulus*.

This mortality is worrying for conservationists, managers and government officers alike, as the Dutch Wadden Sea is designated a wetland of international importance (e.g. RAMSAR Site), where nature conservation is the first and foremost policy concern. Nevertheless, extensive human use of the area is allowed. Mussel cultures occur in subtidal areas while mechanical cockle fisheries are licensed annually after evaluation of the available resources. Of the intertidal areas, c. 31% is now used solely by fisheries, while the remaining 69% are open and potentially fished by mechanical cockle fisheries.

The official estimate of annual requirements of shellfish-consuming waders and ducks amounts to 12.6 million kg of flesh in high densities, of which 60% (7.56 million kg) may not be harvested in 'poor years'. However, the specific requirements of the predators in terms of profitability and availability of prey are not taken into account in this policy (Ens, 2000) and their energetic requirements are underestimated (Camphuysen et al., MS). The winter of 1999/2000 was the third mild winter in a row, leading to a series of summers with low recruitment and generally reduced shellfish condition ('quality'). Food shortage involving both the primary prey (mussels and cockles) and the secondary prey (*Spisula subtruncata*) may have been the principal cause of the observed starvation (Camphuysen et al., MS).

What does the limited hindsight that we now have tell us about the state of the Wadden Sea ecosystem? In this article, we outline a hypothesis of the coincidental human and environmental factors that may have lead to the mass mortality of eiders in the winter of 1999/2000 based on the recent assessment by Camphuysen et al., (MS). This may have also triggered other events that took place in the 1990s, such as widespread population declines of Oystercatchers *Haematopus ostralegus* (Smit et al., 2000), and perhaps also of molluscivorous long-distance migrants such as Red Knots *Calidris canutus* (Piersma & Baker, 2000).

Food Abundance

During a series of three unusually mild winters (1989-91) there was no spatfall of cockles and mussels. This led to very low stocks in the Dutch Wadden Sea. These low stocks were then depleted further in 1990 by mechanical cockle dredging and mussel seed fishing (Van Berkel & Revier, 1991; Dankers, 1993). In addition, virtually all mature mussel beds were removed from the intertidal areas of the Dutch Wadden Sea (Van Berkel & Revier, 1991; Beukema, 1993; Beukema & Cadeé, 1996; Piersma & Koolhaas 1997; Piersma et al., in press). Mature mussel beds, removed in the early 1990s, have so far only marginally recovered (Van Berkel & Revier 1991; LNV 1998).

Prior to this, Swennen et al. (1989) concluded that eiders obtained c. 20% of their prey from mussel culture plots. Since then, the significance of mussel cultures for wintering eiders has increased (Baptist et al., 1997; Berrevoets et al., 2000). Based on Smit (1994) and Smaal et al. (2000), a reconstruction of the mussel stocks showed a structurally low level since the early 1990s.

In winter 1999/2000, both quality (body mass index; BMI) and stocks of cockles were on the low side, according to broad-scale inventories by in the Wadden Sea by the Dutch fisheries Institute (RIVO; Van Stralen & Kesteloo-Hendrikse, 1998) and previously unreported data (Camphuysen et al., MS). The autumn 1999 mussel census indicated a stock of 5 million kg fresh flesh mass of cockles in subtidal areas, 60 million kg cockles in the intertidal zone, 17.5 million kg mussels in the subtidal zone (no data for mussels in the intertidal zone). If these prey were all suitable, accessible and profitable for eiders as exclusive consumers, this would amount to six times the winter requirements of c. 97,000 birds (Camphuysen et al., MS). However, as the greater part of cockle resources were in the intertidal areas of the eastern Wadden Sea (utilized largely by species such as Oystercatchers), and as between autumn 1999 and spring 2000, the mussel stock was reduced by 63% as a result of mussel harvesting and mortality, while 70% of the remaining mussels were 'seed mussels' of sizes too small for eiders (Nehls, 1995), we may safely conclude that the mussel resource was also on the low side.

A final potential prey is *Spisula*, which was utilized during the last decade of the 20th century in response to low shellfish resources after the overfishing of the early 1990s. *Spisula* banks north of the Wadden Sea islands were intensively fished in late summer 1999 by a large fleet (c. 20) of modified cockle vessels, followed by two vessels from small-scale fisheries throughout most of the following winter. Dedicated inventories of shellfish stocks prior to and following the fishery indicated that 85% of the stock in an area with >250 *Spisula* m^{-2} were removed (Camphuysen et al., MS). Some 1-year old molluscs remained but these small *Spisula* are unsuitable for eiders due to their low profitability. Also, the remaining *Spisula* occurred in far too low densities to allow successful exploitation.

Could Eiders Cope?

Eiders (for two consecutive years, autumn 1989 to spring 1991, c. 3x background levels; Camphuysen, 1995) as well as Oystercatchers (winter 1990/91; Camphuysen et al., 1996) experienced peak mortality levels following the depletion of shellfish stocks in 1988-1990. Wintering numbers of Oystercatchers have declined ever since and breeding stocks of Oystercatchers utilizing the Wadden Sea have also declined (Smit et al., 2000). The wintering population of eiders in 1990/91 (103,000 individuals) was c. 20% lower than the average for the 1970s and 1980s (132,000). Of more significance that this possible decline was the food-induced shift in the wintering distribution since the early 1990s as compared to the 1970s and 1980s (Baptist et al., 1997). Camphuysen et al. (MS) found a significant negative relationship between mussel stock and the proportion of eiders utilizing North Sea coastal waters.

Since 1990, the use of *Spisula* in the North Sea coastal waters has become a permanent feature. Considering that North Sea coastal waters only provide foraging opportunities in the form of banks of *Spisula* (a secondary prey, which can be considered difficult to obtain), the shift must be indicative of a structural reduction in the carrying capacity of the Wadden Sea area since 1990.

The Possible Role of the Commercial Fisheries

Eiders and fisheries overlap in their requirements. Diving eiders experience threshold values with respect to a required minimum density (catch per unit effort; De Leeuw, 1997; 1999), a factor that is of equal significance for economically viable fisheries. Size selection studies confirm that eiders select considerable quantities of potentially marketable shellfish (Leopold et al., 2000), while the reverse is obviously also true: fisheries harvest suitable prey for eiders.

Mussel fisheries harvest mussel seed in most of the Wadden Sea to translocate this to mussel culture plots for further growth under largely controlled conditions. Seed mussels are too small to be profitable for eiders (Nehls, 1995). Culture plots of more mature mussels are excellent feeding sites for eiders and may even favorable because of better growing conditions for mussels. The same fisheries have depleted the wild mussel stocks in the Wadden Sea, automatically leading to a reduction of wintering eiders on mussel cultures (interpreted by fishermen as an 'increased population'). Systematic chases of eiders, to scare them away from plots, became routine in the 1990s (M.R. van Stralen, pers. comm.).

The removal of permanent natural mussel beds in the early 1990s may have been the most damaging measure taken by this industry in the Wadden Sea. To date, these mussel beds have not yet recovered. Mechanical cockle fisheries remove suitable prey occurring in high densities. This starts (<1993) mainly in the intertidal parts of the Wadden Sea but recently has also occurred in subtidal areas. These fisheries actively harvest (potential) eider feeding areas and are therefore, at least potentially causing conflict. Recent stock assessments from the fisheries institute combined with blackbox data of the fisheries sector indicated clearly how efficient cockle fisheries remove the subtidal cockle banks with the highest densities (i.e. the most profitable areas for eiders; Van Stralen & Kesteloo-Hendrikse, 1998; 1999).

Spisula fisheries are a recent development in the Wadden Sea area that has rapidly grown into a full-blown fishing industry. Fishing pressure on the limited and patchy resources of *Spisula* is large. Several documented cases of considerable to near-complete (local) stock depletion exist. In February 1993, the first mass-fishery (7-8 ships) was noted off Terschelling, the preferred *Spisula* feeding ground of eiders in that year. Before and after fishery surveys showed that 55% of the stock had been fished (Den Hollander, 1993). Similarly, the largest, concentrated fleet ever recorded, 20 ships working off Texel in May 1999, removed 85% of the fishable *Spisula* within one month.

In conclusion, combined fishery activities in the Wadden Sea seem to have resulted in a reduction of the foraging range of eiders by the removal of old mussel banks, the partial removal of high density cockle and *Spisula* banks and a shift towards mussel cultures. This would then have led to increased levels of interference and a reduction in the carrying capacity of the Dutch Wadden Sea.

Fisheries Management and the State of the Wadden Sea Ecosystem

The current food reservation policy 'guarantees' the availability of only 60% of the energetic requirements of *all* molluscivorous birds in so called 'poor' years. This deliberately risks mass 'die-offs' of birds. It is doubtful whether calculations and assumptions used in this policy were correct. In a recent analysis of the procedures and negotiations underlying this policy, a long list of scientific uncertainties was identified (Ens, 2000). While underestimating the energetic requirements of wintering birds, the reserved quantities are almost certainly too low and the proposed buffer of preserving four times the needs of birds to be at least on the safe side, was applied for some regions, but not for the Wadden Sea. These observations strongly suggest that prey resources are now too small, despite an apparent 'surplus' of five times the energetic requirements of eiders alone.

The evidence so far suggests that the overfishing in 1990, particularly the removal of mature mussel beds, has been a fatal management error. Several bird species were apparently able compensate this for this irreversible loss of prey by seeking alternative foraging areas. In the case of the eider, offshore *Spisula* banks have been a refuge, but only until the late 1990s, when it was the turn of these banks to be overfished. To make the situation much worse, there is now evidence that seafloor disturbance through cockle dredging and other forms of mechanical fisheries have strong long-term negative effects on the recruitment of the bivalves on which eiders and other waterbirds rely (Piersma et al., in press).

In summary, we belief that in an ecosystem under severe and prolonged stress from fisheries and aquaculture (mussel cultures), the wintering eider population collapsed as a consequence of what would otherwise have been a minor dip in prey availability. Damaged intertidal habitats take a long time to recover if they should manage to recover at all (Piersma et al., in press), whereas fished stocks that are currently being overfished have a low likelihood of showing any recovery (Hutchings, 2000). We therefore predict that the Wadden Sea ecosystem as we knew it in the early 1980s, will need a long time to recover especially if immediate stringent protection measures are not taken. Events similar to the mass mortality of eiders may well continue in the near future, eventually inducing structural declines in the populations of molluscivorous and other migrating waterbirds that have made this ecosystem so famous (Van de Kam et al., 1999).

References

Berkel, B.M. van & J..M. Revier, 1991. Mussel fishery in the international Wadden Sea, consistent with "wise use"? Landscape Urban Planning 20, pp 27-32.

Berrevoets, C., H. Baptist & R. Witte, 2000. Analyse Eidereenden Waddenzee/ Waddenkust/ Hollandse Kust. Werkdocument RIKZ/ IT/2000.841, Rijksinstituut voor Kust en Zee, Middelburg. 25 pp

Beukema, J.J., 1993. Increased mortality in alternative bivalve prey during a period when the tidal flats of the Dutch Wadden Sea were devoid of mussels. Netherlands Journal for Sea Research 31, pp 395-406.

Beukema, J.J. & G.C. Cadeé, 1996. Consequences of the sudden removal of nearly all mussels and cockles from the Dutch Wadden Sea. Publ. Staz. zool. Napoli. I: Marine Ecology 17, pp 279-289.

Camphuysen, C.J., 1995. Olieslachtoffers langs de Nederlandse kust als indicatoren van de vervuiling van de zee met olie. Sula 9 (special issue), pp 1-90, pp I-XX.

Camphuysen, C.J., C..M.Berrevoets, H.J.W..M. Cremers, A. Dekinga, R. Dekker, B.J. Ens, T. .M. van der Have, R.K.H. Kats, T. Kuiken, M.F. Leopold, J. van der Meer, & T. Piersma, MS. .Mass mortality of Common Eiders *Somateria mollissima* in relation to commercial fisheries and fisheries management in the Dutch Wadden Sea. Journal of Applied Ecology.

Camphuysen, C.J., B.J. Ens, D. Heg, J.B. Hulscher, J. van der Meer & C.J. Smit, 1996. Oystercatcher *Haematopus ostralegus* winter mortality in The Netherlands: the effect of severe weather and food supply. Ardea 84A, pp 469-492.

Dankers, N., 1993. Integrated estuarine management – obtaining a sustainable yield of bivalve resources while maintaining environmental quality. In: R.F. Dame (ed.), Bivalve Filter Feeders in Estuarine and Coastal Ecosystems. NATO ASI Series, Vol. G33. Springer-Verlag, Berlin, Heidelberg.

Ens, B.J., 2000 Berekeningsmethodiek voedselreservering Waddenzee. Alterra-rapport 136, Alterra, Wageningen.

Hollander, N. den, 1993. Zwarte Zeeëenden (*Melanitta nigra*) en schelpdiervisserij. Student Report, Netherlands Institute for Sea Research and DLO-Institute for Forestry and Nature Research, Texel.

Hutchings, J.A., 2000. Collapse and recovery of marine fishes. Nature 406, pp 882-885.

Kam, J. van de, B.J. Ens, Piersma, T. & L. Zwarts, 1999. Ecologische Atlas van de Nederlandse Wadvogels. Schuyt & Co., Haarlem. 368 pp.

Leeuw, J.J. de, 1997. Demanding divers. PhD thesis, University of Groningen. 178 pp.

Leeuw, J.J. de, 1999. Food intake rates and habitat segregation of Tufted Duck *Aythya fuligula* and Scaup *Aythya marila* exploiting Zebra Mussels *Dreissena polymorpha*. Ardea 87, pp 15-31.

LNV, 1998. Structuurnota zee- en kustvisserij. Evaluatie van maatregelen in de kustvisserij gedurende de eerste fase (1993-1997). Ministry of Agriculture, Nature Management and Fisheries, Den Haag.

Leopold, M.F., R.K..H. Kats & B.J. Ens, 2000. Aanvullend onderzoek voedselbeschikbaarheid Eidereend *Somateria mollissima*: literatuuroverzicht voedselecologie. Unpublished working report, Alterra, Texel.

Piersma, T. & A.J. Baker, 2000. Life history characteristics and the conservation of migratory shorebirds. In: L.M. Gosling & W.J. Sutherland (eds), Behaviour and conservation. Conservation Biology Series 2, Cambridge University Press, Cambridge, pp 105-124.

Piersma, T. & A. Koolhaas, 1997. Shorebirds, shellfish(eries) and sediments around Griend, Western Wadden Sea, 1988-1996. NIOZ Rapport 1997-7, Netherlands Institute for Sea Research, Den Burg, Texel. pp 118.

Piersma, T., A. Koolhaas, A. Dekinga, J.J. Beukema, R. Dekker & K. Essink, in press. Long-term indirect effects of cockle-dredging on intertidal bivalve stocks: is mechanical shellfishing in the Wadden Sea sustainable? Journal of Applied Ecology.

Smaal, A.C., J.A. Craeymeersch, P. Kamermans, J.J. Kesteloo & E. Schuiling, 2000. Schelpdieren en krabben in het Waddengebied in de periode 1994-2000 als mogelijk voedsel voor Eidereenden. RIVO-Rapport C029/00, Netherlands Fisheries Research Institute, Yerseke.

Smit, C., 1994. Alternatieve voedselbronnen voor schelpdieretende vogels in Nederlandse getijdewateren. IBN rapport 1994/ 77, Institute for Forestry and Nature Research, Wageningen.

Smit, C., B. Ens & B. Koks, 2000. Afnemende aantallen Scholeksters in de Waddenzee. SOVON Nieuws 13(3), pp 16-17.

Stralen, M. van & J.J. Kesteloo-Hendrikse, 1998. Het kokkelbestand in de Oosterschelde, de Westerschelde, de Waddenzee en de Voordelta in het voorjaar van 1998. RIVO-report C020/98, Netherlands Fisheries Research Institute, Yerseke.

Stralen, M. van, J.J. Kesteloo-Hendrikse, 1999. Het kokkelbestand in de Oosterschelde, de Westerschelde, de Waddenzee en de Voordelta in het voorjaar van 1999. RIVO-report C045/99, Netherlands Fisheries Research Institute, Yerseke.

Swennen, C., G. Nehls & K. Laursen, 1989. Numbers and distribution of eiders *Somateria mollissima* in the Wadden Sea. Netherlands Journal of Sea Research 24, pp 83-92.

Theunis Piersma & Kees (C.J.) Camphuysen
Netherlands Institute for Sea Research (NIOZ)
P.O. Box 59
NL 1790 AB Den Burg, Texel
theunis@nioz.nl
camphuys@nioz.nl

Theunis Piersma
Centre for Ecological and Evolutionary Studies, Zoological Laboratory, University of Groningen
P.O. Box 14
NL 9750 AA Haren

Kees Camphuysen
CSR Consultancy
Ankerstraat 20
NL 1794 BJ Oosterend, Texel
kees.camphuysen@wxs.nl