Published on paper: 2002. Published online: 2024-10-03.
ISSN 1502-4873 (paper). ISSN 1891-5396 (electronic).
doi: https://doi.org/10.5324/fn.v22i0.5987.

Forum

Mass occurrences of Sandeels (*Ammodytes* spp.) causing aggregations of diving ducks

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Frengen, O. & Thingstad, P.G. 2002. Mass occurrences of Sandeels (*Ammodytes* spp.) causing aggregations of diving ducks. – Fauna norvegica 22: 32-36.

In autumn 1999, large, compact flocks of foraging diving ducks, particularly Common Eiders *Somateria mollissima,* were observed within and at the mouth of Trondheimsfjord in Central Norway. Some of these aggregations were at places previously not known as particularly rich feeding grounds. This situation continued through the winter, and still existed in March 2000. Investigations on these feeding grounds showed that the only possible prey species occurring in significant quantities was Sandeel (only *Ammodytes tobianus* was verified). Although most of the fish were swallowed before the birds reached the surface, some ducks (including Velvet Scoter *Melanitta fusca* and Goldeneye *Bucephala clangula*) were observed eating Sandeels. Sandeel populations fluctuate in size annually and shoals are very patchily distributed. Consequently, the very variable occurrence in time and space of this food resource may occasionally bring about unusually dense and patchy aggregations of various species of diving ducks. Due to the specific habitat requirements of the Sandeel, these aggregations may also occur at localities that are not generally preferred feeding grounds for diving ducks, as was the case here. These findings may be relevant for some monitoring projects involving populations of diving ducks in marine environments.

Key words: Aggregations of diving ducks, Sandeels, effects on monitoring

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Large stocks of Sandeels (*Ammodytes* spp.) spawn in the North Sea and their larvae drift with the current over the northwest European shelf. This drift causes substantial interannual variations in the distributions of the 0-group and, later, the adults (Proctor et al. 1998). According to statistics from the Norwegian Directorate of Fisheries, the stock on many fishing banks off the Norwegian coast has tended to fluctuate, peaking every 6-8 years in 1960, 1966, 1974, 1980, 1987-89, partly also 1995, and 1997-98(99), with an increasing trend in the catch. Sandeels landed from the banks are mainly *Ammodytes marinus*, and the cyclic pattern in that species may differ somewhat from that in other Sandeel species living nearer the coast and in the fjords.

Being an important prey for many marine predators (mammals, birds and fish), Sandeels represent a resource that is patchily distributed in time and space. Consequently, seabirds that forage on these fish will occur in considerable aggregations when and where this resource is available (e.g. Boyd 1996, Mehlum et al. 1996). Bird species so far verified as predators on Sandeels are Shag *Phalacrocorax aristolis* (Harris & Wanless 1991), auks Alcidae (Lilliendahl & Solmundsson 1997, Wright & Begg 1997, Wanless et al. 1998), Arctic Tern *Sterna paradisaea* (Monaghan et al. 1992) and Kittiwake *Rissa tridactyla* (Harris & Wanless 1997, Lilliendahl & Solmundsson 1997, Suryan et al. 2000). These seabirds have mainly been observed feeding on pelagic Sandeels. Probably as a response to this great predation risk, Sandeels prefer to remain buried in the gravelly and sandy substrate of the sea floor most of the winter, and at night in summer (Høines & Bergstad 2001). *Ammodytes tobianus* is found from the intertidal zone down to a depth of approximately 30 metres, the other species sometimes also at greater depths (Gjøsæter 1992, pp. 206). Sandeels buried in the intertidal zone may, however, run the risk of being predated upon by such species as the Bald Eagle *Haliaeetus leucocephalus*, Crow *Corvus caurinus*, Raven *C. corax* and gulls *Larus* spp., all of which have been observed digging in or disturbing sand to cause concealed fish to emerge (Willson & Armstrong 1998).

Diving ducks inhabiting marine environments are normally known to have a strong preference for shallow areas, where they feed on the epifauna. Various species of mussel are particularly favoured food items for Eiders and Scoters (Soot-Ryen 1941,

Madsen 1954, Pethon 1967, Player 1971, Nilsson 1972, Bustnes & Erikstad 1988, Durinck et al. 1993, Guillemette et al. 1993, Meire 1993). The Common Eider *Somateria mollissima* may even have a quite narrow size preference for its favourite mussel, *Mytilus edulis* (Bustnes & Erikstad 1990). Nevertheless, Eiders sometimes show a quite diverse and individualistic, selective foraging pattern causing other taxonomical groups to become significant food resources. Even fish eggs have occasionally been reported as an important food item (Bustnes & Erikstad 1988, Thingstad et al. 2000). However, so far, fish have been thought to be of insignificant importance as a food resource for most species of diving ducks (but see Nilsson 1972, Stempniewicz 1995, Thingstad et al. 2000).

From October 1999 to March 2000, large flocks of diving ducks were recorded at many localities in the Trondheimsfjord area, including some not known to be particularly favoured foraging grounds. Unfortunately, we had no opportunity just then to undertake a systematic investigation that could reveal the cause of these unfamiliar aggregations. However, we made some observations that indicated that these flocks were not exploiting their usual food resources, different species of Mollusc, but rather a previously unrecognised resource, Sandeels. To verify our Sandeel foraging hypothesis, we gathered occational field observations (our own and other reliable personal communications) of flocks of diving ducks located on unusual feeding grounds. We also collected some grab samples from the sea floor at one duck aggregation, but no ducks were collected to analyse their stomach contents. We intend to do that during the next mass occurrence of Sandeels in the Trondheimsfjord area. Nevertheless, the existing more or less arbitrary observations summarised here are sufficiently unambiguous to provide strong support for our Sandeel foraging hypothesis.

Wintering diving ducks aggregated in unusual places

Trondheimsfjord is situated in Central Norway, at approximately 63°30´N. Its total length is 126 km, making it the third longest fjord in Norway. Even though its mean depth is as much as 165 metres, many shallow sills with strong currents occur within the basin (Bakken 2000). In addition, extensive areas of shallow water occur just beyond the outlet of the fjord, for instance around the Ørlandet peninsula and the islands of Storfosna and Tarva. Many of these localities are known to be excellent feeding grounds for seabirds and shorebirds (Husby & Lorentsen 2000). However, during the autumn of 1999 and the winter of 1999-2000 many large flocks of diving ducks were observed at localities

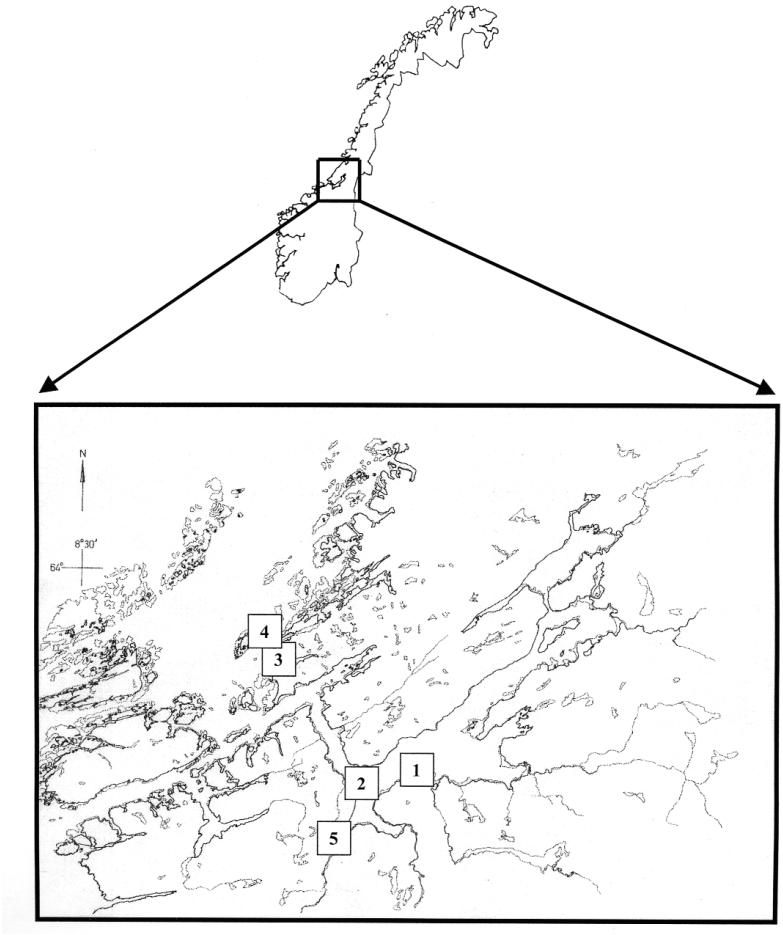

Figure 1
The five locations with diving duck aggregations in 1999-2000 discussed here: 1. Trolla on the outskirts of Trondheim, 2. Orkanger, 3. Ervika, Bjugn, 4. Tarva, Bjugn, and 5. Orkanger, at the mouth of the River Orkla.

known not to be particularly favoured foraging grounds (see Fig. 1), and the reason for this was sought. We therefore started to collect existing observations of duck aggregations at such unexpected foraging locations, emphasising in particular the feeding behaviour of the ducks. In addition, five sea-floor samples were collected from one of the locations (in Orkdalsfjord, a branch of Trondheimsfjord) using a Van Veen grab mounted on a boat (Høines & Bergstad 2001); the samples were taken at the exact positions where the Eiders had just previously been observed foraging. Each sample measured 0.18 m^2, and all were taken from a depth of 5-10 metres on 7th January 2000.

What caused the aggregations?

During autumn 1999 and early winter 1999-2000, many large, compact flocks of diving ducks composed particularly of Common Eider, but also Common Scoter *Melanitta nigra*, Velvet Scoter *M. fusca,* Long-tailed Duck *Clangula hyemalis* and Goldeneye *Bucephala clangula*, were observed in and at the mouth of the Trondheimsfjord. The discrepancy between the spatial distribution of known localities of the preferred macrozoobenthos food resource, blue mussels and other seated epifauna, and the occurrence of these flocks was surprising at first. A typical example was an aggregation of Common Eider off Trolla (see Table 1), on the outskirts of Trondheim, from October to December 1999 (location 1 on Fig. 1). The fjord is approximately 6-8 metres deep there, has a sandy floor, and is therefore a typical habitat for Sandeels. The Eiders were very co-ordinated and dived eagerly, but apparently without bringing any food items to the surface in their beaks. Usually, when they feed on mussel beds, some birds will not swallow their prey before surfacing. Now, all the birds were just smacking their beaks, a behaviour commonly seen immediately after they have swallowed some food item. On 6th November, some gulls were observed close to the Eiders, and some of them were seen eating Sandeels from the surface of the sea. This observation provided the first hint of the reason for the extraordinarily large aggregation of Eiders.

The next, more direct indication of the correctness of this Sandeel foraging hypothesis came from an aggregation of diving ducks off Orkanger in Orkdalsfjord (location 2 on Fig. 1). Early in January 2000, this flock was diving synchronously only 25-50 metres off the beach (Table 1). Five grab samples (total coverage 0.9 m^2) were obtained from the sea floor there. These contained 52 Sandeels (only *Ammodytes tobianus*) spread through all the samples, implying a density of about 60 fish per m^2. No other potential food items except one large mussel *Modiolus modiolus* were found in the samples. This clearly suggests that only the Sandeels could represent a food resource for the diving ducks at this particular site.

Observations from Ervika in Bjugn (location 3 on Fig. 1, Table 1) in the same period are also interesting. Following a northwesterly gale in late January 2000, huge numbers of dead Sandeels were washed up in the lower intertidal zone at low tides. Many gulls and other seabirds foraged eagerly on this wealth of fish, estimated to amount to about 10 litres of Sandeels per 10 metres of shoreline (Birger Skutberg, pers. comm.). For many weeks prior to this gale, a large, compact flock of diving ducks had been observed foraging off this shore (Table 2). The only logical explanation for this flocking behaviour was now quite evident, particularly since both Common Eider and Velvet Scoter had sometimes been observed with Sandeels in their beaks (Hans E. Ring, pers. comm.); they must have been selec-

Table 1. Some observations of duck aggregations from the last peak occurrence of Sandeels in the Trondheimfjord area that support the Sandeel foraging hypothesis (see the text for further details).

Locality	Period	Duck species involved	Numbers	Observations at the site
1. Trolla	Oct. – Dec. 1999	*Somateria mollissima*	~1000	Diving eagerly, no food seen
2. Orkanger	Early Jan. 2000	*Somateria mollissima*	~1000	As loc. 1, numerous Sandeels in grab samples on 7th January
3. Bjugn	Dec. 1999- Feb. 2000	*Somateria mollissima* *Melanitta nigra* *M. fusca* *Clangula hyemalis* *Bucehpala clangula*	> 7000 (see also Table 2)	*Somateria mollissima* and *Melanitta fusca* seen with Sandeels in their beaks after diving
4. Tarva	20th Feb. 2000	*Bucephala clangula* *Mergus serrator*	108 and 168	Both species brought Sandeels to the surface after diving
5. Mouth of River Orkla	Oct. 1999 – March 2000	*Mergus merganser* *Bucephala clangula*	78 and 300	Diving eagerly; no food seen, but Sea Trout caught in the estuary were filled with Sandeels

tively foraging on the same Sandeel population that the other seabirds were now collecting from the intertidal zone. The following winter there was no indication of Sandeels in this area, and only one Eider and no other diving ducks were present in the entire Bjugnfjord area, which had been so heavily populated with Sandeels and seabirds the previous winter (Hans E. Ring, pers. comm.).

A compact flock of Goldeneye and Red-breasted Merganser *Mergus serrator* was observed foraging on 20th February 2000 off the island of Tarva, just outside Trondheimsfjord (location 4 on Fig. 1), at a site with a shallow, sandy bottom (Table 1). Both species were seen surfacing with Sandeels in their beaks. No other, normally equally preferable, localities around Tarva (based upon a 30-year survey), had flocks of Goldeneye that day. In fact, only one other Goldeneye was seen.

Finally, interesting observations of aggregations were made at the mouth of the River Orkla (location 5 on Fig. 1) between October 1999 and March 2000 (Table 1). Many Goosander *Mergus merganser* were observed up to 500 metres up the river, but still in a significantly marine-influenced environment (Georg Bangjord, pers. comm.). Moreover, we saw more than 300 Goldeneye eagerly foraging at the same locality on 16th January; usually, only 0-10 Goosander and Goldeneye forage here (Hans Høiby, pers. comm.). Local anglers gave us a good indication of the food item these birds had been foraging on. During February to April, extraordinarily large numbers of Sea Trout *Salmo trutta* were caught in the estuary and their stomachs were filled with Sandeels (Asbjørn Grimsmo, pers. comm.).

Should diving ducks prefer sandeels?

Various seabird monitoring projects in recent decades have recorded diving duck aggregations at localities not previously known to be favoured feeding grounds. No connection has been suggested between these aggregations and the more or less cyclic occurrence of Sandeels, since most diving ducks normally forage on mussel beds in shallow waters. However, during this last mass occurrence of Sandeels in the Trondheimsfjord area in 1999-2000 some diving ducks were actually seen foraging on Sandeels. These observations clearly indicate that when Sandeels are buried or half-buried in sand in shallow water, diving ducks can easily pick them up. The species observed in these aggregations included the relatively poor diver, the Goldeneye, and the relatively able diver, the Long-tailed Duck.

When foraging on mussels, ducks need to consume daily a food mass equal to 2-3 times their body weight (DeLeeuw 1999) because of the large water and shell content, and hence low nutritional value, of this food resource. If they can replace mussels with a lipid-rich fish resource such as Sandeel or Herring, their gain, taking into account the energy they need to expend on foraging, would be very significant (cf. Hilton et al. 1998). Hence, even the very variable occurrence in time and space of Sandeels occasionally brings about unusual aggregations of many species of seabirds, including diving ducks. Due to the specific habitat requirements of the Sandeel, these aggregations will also arise at localities that are not normally preferable feeding grounds for diving ducks. The observations at Ervika in Bjugn are an excellent example of this. During the Sandeel peak in the winter of 1999-2000, at least 7000 diving ducks were foraging there; the next winter hardly any were seen.

An important consequence of these findings is that traditional feeding areas for diving ducks may have no birds during years with a superabundance of Sandeels, as these seem to represent an important and preferred food resource for ducks, even though they only occur locally and occasionally. This may also have serious implications for seabird monitoring projects. Such projects must be designed so as to ensure that data come from a sufficiently large area to cover unpredictable distributions caused by irregular occurrences of food resources, like the patchy and fluctuating quantities of Sandeels in the Trondheimsfjord area.

Acknowledgements

We are indebted to Elin B. Hopland at the Directorate of Fisheries for sending us the statistics of landed Sandeels, Georg Bangjord, Trond Haugskott, Hans E. Ring and Birger Skutberg for giving us access to their field observations, two anonymous referees for constructive remarks, and Richard Binns who has improved the English.

Table 2. Counts of diving ducks from Ervika in Bjugn during the winter of 1999-2000 (data from Hans E. Ring and Trond Haugskott).

Species/dates	11.12.99	27.12.99	09.01.00	23.01.00	02.02.00	13.02.00	18.02.00
Somateria mollissima	1500	>1500	2000	> 1200	> 2000	> 2500	1500
Melanitta nigra	180	500	900	> 200	> 150	?	200
M. fusca	1800	> 1800	1500	> 1500	> 2000	> 2500	1200
Clangula hyemalis	500	> 1000	2500	> 2000	> 500	> 2000	2000
Bucephala clangula	145	120	100	0	0	0	0

Sammendrag

Masseopptreden av sil (Ammodytes spp.) fører til opphopinger av dykkender

Høsten 1999 ble store, kompakte beiteflokker med dykkender, spesielt ærfugl *Somateria mollissima,* observert i og ved munningen av Trondheimsfjorden. Noen av disse opphopingene ble oppdaget på steder som tidligere ikke var kjent som spesielt gode beitelokaliteter. Denne situasjonen fortsatte gjennom vinteren og fram til mars 2000. Undersøkelser innen disse beiteområdene avdekket at det eneste mulige byttedyret som forekom her i vesentlig mengder var sil (bare *Ammodytes tobianus* verifisert). Selv om de fleste fiskene ble svelget før fuglene nådde overflata, ble noen dykkender (deriblant sjøorre og kvinand) observert med sil i nebbet etter dykk, og disse fiskene ble først fortært etter at fuglene var kommet opp. Det er kjent at det er store årlige fluktuasjoner i forekomstene av sil, og at disse silkonsentrasjonene forekommer sterkt flekkvis. Ettersom silstimene foretrekker sandbotn der de kan grave seg ned, vil denne meget variable næringsressursen i tid og rom tidvis kunne forårsake masseforekomster av dykkender innen andre lokaliteter enn det som er deres tradisjonelle næringshabitatene (som er knyttet til hardbotn). Denne oppdagelsen bør være relevant når en skal planlegge og utføre monitoringsprosjekter som involverer populasjoner av dykkender i marine miljø.

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