Scaup *Aythya marila* numbers and the Cockle *Cardium edule* fishery on the Solway Firth: are they related?

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This paper describes the changes in numbers of Scaup wintering on the Solway Firth, Scotland and offers an explanation for variation in their numbers and, in recent years, their distribution. Scaup occurred on the Solway in "thousands" in the 1950s, but from 1961 to 1986, numbers rarely exceeded 1,000. The initial decline coincided exactly with the sudden large increase in numbers on the Firth of Forth. Commercial cockling began on the Solway in 1987 and with it came a large increase in the numbers of Scaup. There was a significant correlation between the size of the Cockle harvest and Scaup numbers from 1986 to 1993. Changes in the distribution of Scaup within the Solway between 1991 and 1994 were related to the distribution of cockling effort. It is suggested that Scaup have taken advantage of the increased feeding opportunities provided by the large amounts of Cockles rejected (due to their small size or damage) by the cockling industry. When commercial cockling was banned on the Solway in June 1992, Scaup declined and many of those remaining moved to an area of Mussel beds which was considered, historically, to be their main feeding area on the Solway.

Keywords: Scaup, Cockling, Cockles, Solway, Trends

Although omnivorous, Scaup *Aythya marila* feed primarily on molluscs in winter. The Blue Mussel *Mytilus edulis* appears to be the primary food item in European waters (Cramp & Simmons 1977). In one part of the Caspian Sea, Scaup fed entirely on Cockles *Cardium edule* (Dementiev & Gladkov 1952). Seeds, insects, marine annelids, Periwinkles *Littorina*, Dogwhelks *Nassa reticulata* and Laver Shells *Hydrobia* have also been found in their diet (Madsen 1954; Nilsson 1969). Their versatility is well illustrated by Christmas's (1960) observation that Scaup in North America scavenged on dead fish; he also cites another case of large numbers feeding on discarded Shrimp heads. Originally from Europe, Zebra Mussels *Dreissena polymorpha* have recently invaded the great lakes of North America and now form an important part of the Scaup's diet there (Hamilton & Ankney 1994).

Scaup have had a chequered history in British and Irish waters where their numbers and distribution have changed greatly through this century (Kirby *et al.* 1993). Salmon (1988) estimated the British population at 6-7,500 and a further 3,000 winter in Ireland (Hutchinson 1989). Surveys on the Solway Firth from 1991-1993 (Quinn *et al.* 1993) suggested the British population alone was 11,000 (Kirby 1995) but there are even now signs that the population has fallen again. Conclusive evidence that winter numbers fluctuate regularly is provided from the Scaup's history at one site. Up to 30,000 Scaup have been counted around Leith on the Firth of Forth, Scotland in the mid-1960s (Milne & Campbell 1973). For many years, this was the most important wintering site in Britain but numbers crashed there in the mid-1970s.

These changes are widely believed to be linked to the Scaup's sensitivity to variations in food supply and in their ability to detect and exploit temporary food sources. The Scaup in the Firth of Forth were apparently attracted to a sewage outfall pipe which not only held grain from a local distillery but probably also held high densities of marine annelids resulting from eutrophication (Milne & Campbell 1973; Campbell 1984). When sewage treatment improved, Scaup numbers fell dramatically. Numbers at the Invergordon distillery in the Cromarty Firth also fell in a similar manner and apparently for the same reasons (Campbell 1986).

Numbers of Scaup on the Solway have increased substantially in recent years (Waters & Cranswick 1993) and it is now the main wintering site in Britain, although there are signs that, once again, numbers have fallen dramatically on the Solway (J. Quinn, pers obs). The aim of this paper is to examine the status of Scaup on the Solway since 1960 and to offer an explanation for changes in their status which, in recent years, appear to have been linked to commercial cockling.

Although Cockles have long been taken from the Solway in small amounts (W. Wright; N. Bailey, pers comm), commercial cockling first began in early 1987 when 33 tonnes were reported taken. This increased to a maximum of 4,519 tonnes in 1991 but fell to 120 in 1993 and 80 in 1994 (Howell *et al.* 1995). Steps were taken to control the fishery at a time when it was shown that the cockle stock was highly vulnerable because of the age structure of the population (Bailey *et al.* 1992); in May 1993, the biomass of Cockles of commercial size was 20% of that in 1990 (Chapman *et al.* 1994). Suction dredging was banned in June 1992 and land-based dredging in November 1994.

Evidence is provided to support the suggestion that Scaup exploited Cockles rejected by fishermen and that this has influenced their status and distribution on the Solway since 1987.

Study Area and Methods

Study area

Although the Solway Firth normally refers to the finger of sea enclosed by the Mull of Galloway in Scotland and Workington in England, here it is used to refer only to the inner estuarine part, from Portling on the Dumfries & Galloway shore to Silloth in Cumbria (**Figure 1**). The majority of the estuary's 25,000 ha of intertidal substrates are on the Scottish side. On the inner part of the estuary, the substrates are very fine, muddy in places or stony, whereas on the

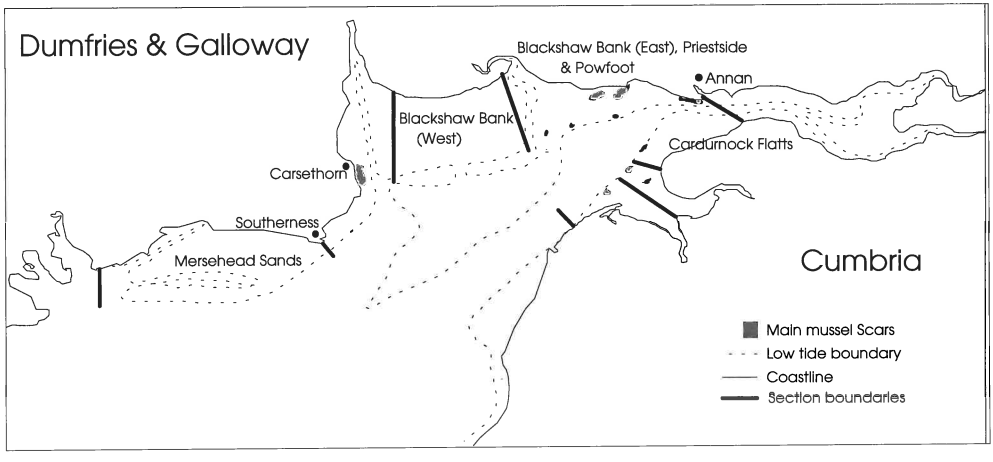


Figure 1. The Solway Firth showing places mentioned in the text, low tide count sections and the main mussel scars.

outer parts of the estuary they are more sandy. The main Cockle beds are found on Blackshaw Bank, Priestside, Powfoot, Mersehead Sands and on Cardurnock Flatts. Mussel beds are less extensive but found in a variety of locations around the estuary.

Population trends

The long-term trend in numbers of Scaup was examined using data from the Wetland Birds Survey (WeBS) from the 1960-61 winter season to 1993-94. Counts of the estuary have been undertaken traditionally at high tide once every month during the winter (September to March) by a team of about 20 volunteers. Coverage of the 20 count-sections has been comprehensive only in the last eight years. Trends were estimated using maximum numbers of Scaup counted per winter season.

Location of feeding areas

The low tide distribution was thought to reflect the location of important feeding areas for Scaup. This is because the low tide roosts were usually adjacent to the Cockle beds over which they were seen feeding in greatest numbers as the tide began to rise. They were never seen flying to other feeding areas as the tide began to rise. Scaup rarely fed at low tide and were largely out of sight at high tide. It is possible that they fed extensively at night as has been suggested by other studies (Nilsson 1969).

Waterbirds on the Solway Firth were counted at low tide every month from November 1991 to August 1993; further counts were undertaken in the most important areas until March 1994. It took 16-20 man-days, spread over a four day period, to cover the area completely. Adjacent areas were counted on the same day to reduce the likelihood of over- or under-counting caused by bird movement between days. For this analysis, the Solway was split into eight different sectors (**Figure 1**) which were surveyed in all months.

Cockle harvest

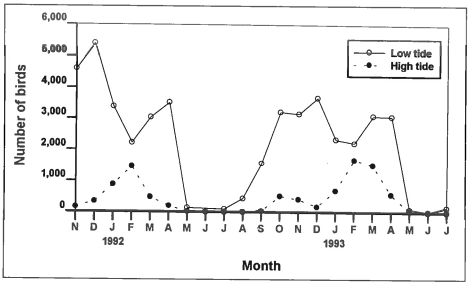
The data used on the amount of Cockles taken commercially is from published Scottish Office, Agriculture and Fisheries Department (SOAFD) accounts (Howell *et al.* 1995). Three extraction methods have been employed: by hand using rakes, by tractor drawn dredges and by boat-borne suction dredges. All involve selecting suitably sized and rejecting the smaller, usually one-year-old Cockles. Data from the suction-dredge boats were collected by fisheries officers on board the vessels. The information from the tractor dredges is believed to be less accurate and likely to be under estimated (N. Bailey, pers comm). The method of cockling and the distribution of cockling effort within the Solway has not been monitored scientifically but semi-quantitative, sometimes anecdotal, information on the distribution of cockling effort was provided by Scottish Natural Heritage, SOAFD and the fishermen themselves.

Results

Low and high tide counts

A comparison of low and high tide counts undertaken between November 1991 and July 1993 showed that Scaup were consistently undercounted at high tide (**Figure 2**). Five times as many Scaup were counted at low tide over the whole period and there was very poor, only just significant, correlation between the two (r_s=0.485, P=0.05, n =21). In both winters, peak numbers were in December, although nationally Scaup normally peak in late-winter (Owen *et al.* 1986).

Figure 2. Numbers of Scaup counted at low and high tide on the Solway Firth from November 1991 to July 1993.

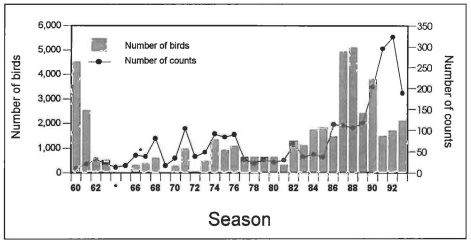


Long-term trend

Maximum numbers of Scaup exceeded 4,000 and 2,500 in 1960-61 and 1961-62 respectively (**Figure 3**). Numbers dropped dramatically in 1962-63 when the maximum counted was less than 500, and this coincided with an increase in numbers on the Firth of Forth (see Milne & Campbell 1973). Maxima rarely exceeded 1,000 over the next 25 years and it was not until 1987-88 that over 4,000 Scaup were recorded again.

Yearly estimates of Scaup numbers may not be very accurate since the amount of coverage achieved varied considerably (**Figure 3**). After 1985-86, more counts covering a greater area were undertaken than had been the case since the early 1970s (where one section covered in one month is one count). If the likelihood of detecting flocks increases as more counts are made, this could explain why the maximum jumped from 1,438 in 1986-87 to 4,926 in the following season. This, however, is unlikely because even when high tide coverage more than doubled after 1989-90, numbers of Scaup counted at high tide decreased, even though low tide counts showed that larger numbers were actually present. An alternative explanation for the increased numbers of Scaup is provided by the commencement of commercial cockling in 1987.

Figure 3. Long-term trend in Scaup numbers on the Solway Firth as shown by seasonal maxima. Numbers of WeBS section-counts made are also shown. * = no counts were made. 60= 1960-61 season.



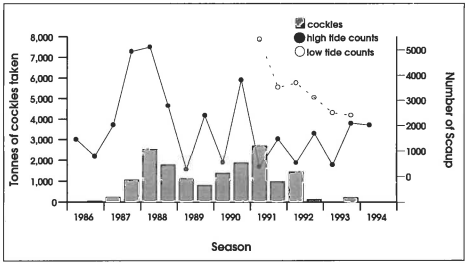
Scaup numbers and cockling

The timing of the return of large numbers of Scaup to the Solway coincided exactly with the start of cockling in 1987 (**Figure 4**). In the second half of the 1987-88 season, intensive Cockle harvesting resulted in a catch of 1,033 tonnes and Scaup numbers increased to a Solway record of 4,926 birds. The highest count from 1962 to 1986 was just 1,438 Scaup.

High numbers of Scaup were maintained until 1993 but in late 1992, suction-dredging was banned. This had a marked effect on the Cockle harvest in the second half of the 1992 season and consequently Scaup maxima also dropped to just over 3,000. In 1994, cockling with tractor-dredges was also banned and the Scaup maximum for the 1993-94 season fell to 2,500 birds. No Cockles were harvested in 1994-95 and maximum numbers of Scaup seen fell further to 2,007.

Despite the patterns in six-monthly Cockle-harvests and maximum Scaup high tide counts being broadly similar (**Figure 4**), there was no significant correlation between the two (r_s = 0.023, *n.s.*, n = 16). This was largely because of poor correlation after 1991. However, substituting the last six high tide maxima with low tide counts, which have already been shown to be a more accurate reflection of Scaup numbers present, resulted in a significant relationship between the two variables (r_s = 0.55, P = 0.05, n = 16).

Figure 4. The size of the Cockle harvest (tonnes) and Scaup maxima (low and high tide counts) on the Solway in the first (September to December) and second (January to May) halves of each season from 1986-87 to 1993-94.



Scaup distribution and cockling

The low tide distribution of Scaup on the Solway between November 1991 and March 1994 is summarised in **Figure 5**

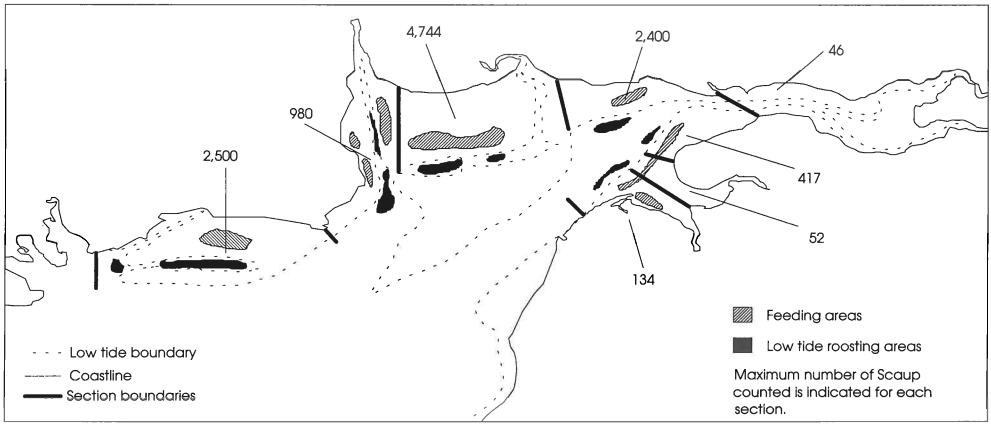


Figure 5. The main areas used by Scaup on the Solway at low tide from November 1991 to March 1994. Both maximum counts and location of areas used are indicated.

(see also Quinn *et al.* 1993). The principal areas used were Blackshaw Bank (West), Mersehead Sands and Powfoot, Priestside and Blackshaw Bank (East). Birds spent most of their time on or near the tideline, sometimes resting on sandbanks. At high tide, the distribution was similar but flocks tended to shift further into the estuary and closer to shore.

Further evidence that Scaup were affected by cockling was found when changes in occurrence were examined in the three main areas over three winter seasons (**Figure 6**). Throughout 1991-92, Scaup occurred predominantly on Blackshaw Bank (West) where most of the cockling boats were operating, although the boats also worked over Mersehead Sands and in the area due east of Southerness.

The following season, suction dredging was banned (June 1992) and only tractor dredging took place, mainly at Mersehead Sands but also near Powfoot. Large numbers of Scaup still occurred at Blackshaw Bank although they were much less numerous than in the previous year. At the same time, more than 1,000 Scaup were seen in two consecutive months between the River Lochar and Priestside, an area where tractor dredging was still taking place (C. Henderson, pers. comm.).

In the first half of the 1993-94 season, tractor dredging was largely restricted to Mersehead Sands which, for the first time since November 1991, then became the most important area for Scaup on the Solway. In January 1994, however, cockling had ceased largely everywhere on the Solway and most of the Scaup moved to the Powfoot section, the first time during the study they had been seen there at low tide in such large numbers and for such a prolonged time. This is where they were thought previously to feed most regularly (Moser 1984). The area is rich in Mussel beds suggesting that the Scaup reverted to their original preferred prey.

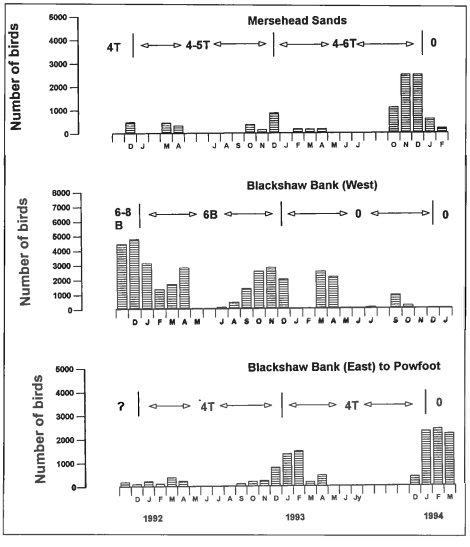
Discussion

Significance and accuracy of long-term trends

Given the difficulties in detecting Scaup on the Solway and the poor coverage by WeBS counts until recent years, the accuracy of the observed long-term trend should be treated with caution. From month to month, the results clearly showed that low tide counts were the only way to get accurate estimates of numbers present because birds were far from the shore at high tide. However, it can not be assumed that Scaup were also undercounted in other years. It is possible that, in the absence of cockling, Scaup fed

predominantly on mussels (traditionally thought to be their main prey) which occur on the Solway in greatest abundance within 500 m of the shore where the Scaup are more likely to be seen. The Cockle beds are in places 4 km from the shore. If this is true, then the trend before 1987 is more likely to be accurate.

Figure 6. Numbers of Scaup counted at low tide on the three main areas in the Solway Firth from November 1991 to March 1994. At the top of each graph, the maximum numbers of tractor-dredges ("T") and boat-dredges ("B") operating in any one year are indicated using arrows.



Explanation of trend

Despite the limitations in the data, major points of inflection in the trend are likely to be real. The initial decline in the 1960s coincided exactly with the emergence of the Forth as Britain's most important site for Scaup. The large Scaup count in 1960-61 is probably representative of numbers in the 1950s. Large rafts of Scaup were believed to occur on the Solway throughout the 1950s (R.T. Smith, pers. comm.; Atkinson-Willes 1963), although there are no published data to support this. If Scaup did shift from the Solway to the Forth in response to the sudden discovery of an abundant food source at the sewage outfalls, it may be a further indication of their mobility that they did not return to the Solway when they abandoned the Forth and instead presumably moved on to an alternative wintering feeding area.

The increased numbers of Scaup counted in 1987-88 occurred at the time when cockling began and there was a significant correlation between the size of the Cockle harvest and Scaup numbers from 1986 to 1993. This suggests that Scaup benefited in some way from cockling, most likely by exploiting Cockles rejected by dredges because of their size or damage. Although not conclusive, due to a lack of good data on where cockling took place, Scaup occurred in largest numbers where most cockling took place. At Mersehead Sands, direct observations were made on several occasions of Scaup roosting at low tide adjacent to where tractor dredges operated. As the tide began to rise, the Scaup moved in over the Cockle beds where the tractors had been operating only an hour previously and could be seen diving *en masse* for food.

When cockling finally ceased in early 1994, Scaup shifted back to Powfoot and Priestside where it is assumed they reverted to feeding on Mussels, thought by Moser (1984) to be their preferred prey on the Solway. In the 1992-93 season, however, most Scaup were still found over Blackshaw Bank even though only 18 tonnes of Cockles were extracted between October and June (Howell *et al.* 1995). It is possible that the Scaup were feeding on Cockles or other molluscs in the absence of cockling and certainly were seen occasionally doing so on a rising tide over Blackshaw Bank. Given that Howell *et al.* (1995) estimated the biomass of Cockles at Blackshaw Bank apparently fell by 90% between 1990 and 1993, it is more likely that they were feeding mainly on Mussels at Carsethorn in the 1992-93 season.

Implications of cockling for Scaup and Cockle populations

Experiments on the Burry Inlet in Wales showed that up to 50% of Cockles were lost

following a single pass of a tractor dredge (Cotter *et al.* 1993) and that, even though small one-year-old Cockles were thrown back, they still suffered mortality. The authors suggested that the latter was caused by their vulnerability to tidal removal and predation when left on the surface.

Various reports by SOAFD have shown how much the Cockle biomass fell since cockling began on the Solway, emphasising the need for rigorous monitoring of the stock. Although it can not be assumed that Cockles do not normally form an important part of the Solway Scaup's diet, it seems unlikely that they are normally of major importance. It seems more likely that their preferred prey is the Mussel. Thus cockling has probably only had a positive affect on Scaup. In many areas, flatfish (Todd 1915, Jones 1952) and Oystercatchers *Haematopus ostralegus* (Drinnan 1957; Sutherland 1982; Quinn & Kirby 1993) rely heavily on Cockles as a food source so these species in particular could be negatively affected by cockling. Cockling may also have an impact on other invertebrate species because of both the direct damage caused and increased vulnerability to predation.

Scaup on the Solway also take Cockles in the absence of cockling (pers obs) and were sometimes seen taking them during shallow dives or by dabbling on the tide's edge, most often on a rising tide. But if their rate of predation over a season is increased greatly because of cockling, any attempt to assess the impact of cockling on Cockle stocks should take this into account. No information is available on food intake rates by Scaup but, based on information published for other species (Stempniewicz 1995), a single bird may require up to two kilograms of Cockles (shell included) per day.

The suddenness with which Scaup apparently discovered the new source of food provided by cockling on the Solway is remarkable and suggests regular movement between sites in winter. With the likelihood that cockling will re-open on the Solway in the future, this will provide an ideal opportunity to investigate this phenomenon using satellite tracking. More importantly, an effort should be made to investigate the impact of cockling on invertebrates and their main predators, including Scaup.

High tide counts were provided by WeBS, a joint venture by WWT, BTO, RSPB and JNCC on behalf of the countryside agencies. Thanks to Mark Pollitt for providing the data. Low tide counts between November 1991 and August 1993 were undertaken as part of a contract for BNFL. Thanks to the following people who helped with low tide counts on the Solway: Peter Cranswick, Jeff Stenning, John Drew, Tim Drew and Ken Bruce. Richard Mearns provided the low tide counts for Priestside in early 1994. Roy Cameron (SNH) and Nick Bailey (SOAFD) provided information on cockling as did several of the local Cockle fishermen. We are grateful to them all.

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