The changing flora of the Lancaster Canal in West Lancaster (v.c. 60)*

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ABSTRACT

An account is provided of the history of the Lancaster Canal in West Lancaster (v.c. 60). During its 200 year history the changing flora is described showing it has provided a habitat for a characteristic flora. However, the changes are consistent with general eutrophication, which more recent detailed studies suggest is accelerating. In addition changes and especially losses appear to confirm a correlation with increasing boat traffic.

KEYWORDS: aquatic flora, eutrophication, boat traffic.

INTRODUCTION

The second half of the 18th century was a time of change across much of England. Despite the American Wars of Independence and the Napoleonic wars it was a time of gradually rising wealth as industrial development accelerated. It was a period of entrepreneurship and innovation with new manufacturing processes and a developing factory system. However, transport was a problem facing the new industrialists. Packhorse trails and even the new toll roads were inadequate. The solution was to build canals, which in England were pioneered in the Mersey basin with the opening of the St Helens Canal (1757) and the Bridgewater Canal (1765), which were used primarily for transporting coal (Hadfield & Biddle 1970).

Changes were also taking place in rural areas with the enclosure of common lands, drainage of wetlands and general agricultural improvement requiring marl (calcareous clay) and lime (Holt 1795).

As a consequence of these changes there was a rapid growth in the size of towns, particularly in Lancashire south of the River Ribble, whilst in the rural areas in the north and west of the county agricultural improvements took place providing food for the growing and increasingly urban population (Crosby 1998). These changes had a dramatic impact on the landscape; many habitats, especially wetlands and heaths, were reclaimed for farming. Yet at the same time new habitats were created. Amongst these were ponds derived from marl pits and canals (Day *et al.* 1982). They provided refugia for aquatic and marsh species at a time when the more natural wetland habitats were lost.

THE LANCASTER CANAL

The idea of a canal linking Kendal in Cumbria with the Leeds–Liverpool Canal via Lancaster and Preston was proposed at a meeting held in Lancaster on 8 June 1791 and work commenced on building the canal in January 1793. However, financial difficulties prevented the original scheme being implemented. Instead a tramway linked the northern end that terminated in Preston with a

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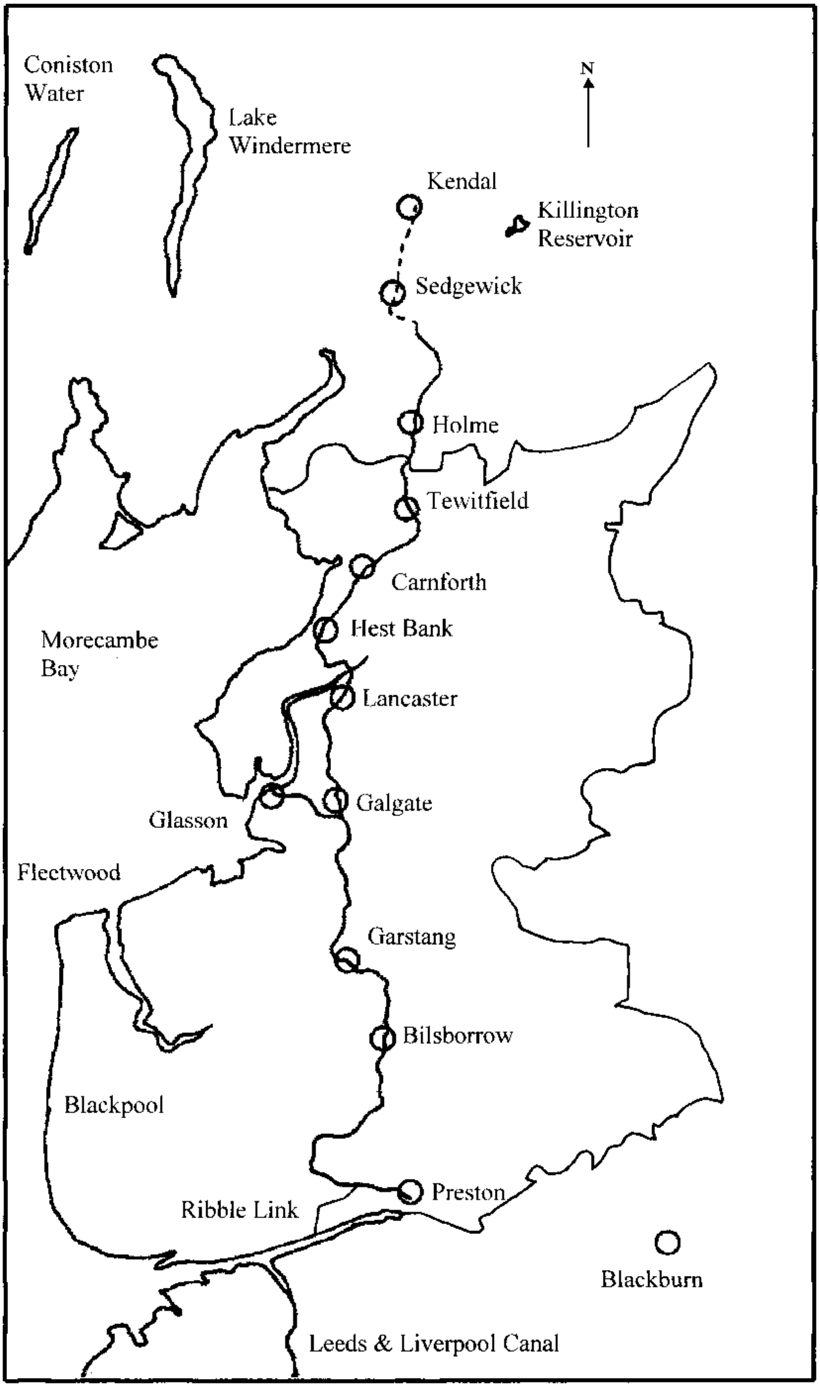

FIGURE 1. Location of the Lancaster Canal. The v.c. 60 boundary is shown by a solid line. The canal north of Tewitfield in Cumbria is un-navigable and the final section (shown by a dotted line) to Kendal is de-watered. The sketch map is based on images used by the Lancaster Canal Trust.

bridge over the R. Ribble to the south end at Walton-le-Dale, c. 5 km southeast of Preston. The northern end was built in three stages. The first section from Preston to Borwick was opened on 22 November 1797 and the second, from Borwick to Kendal via a flight of eight locks at Tewitfield, was opened in 1819. Finally a connection from Galgate to the sea at Glasson Dock, via another flight of six locks, was opened in 1826. Although there was a link to the sea the Lancaster Canal was effectively isolated from the rest of the canal system until 2002. Then, a short section near Preston was built to the River Ribble enabling leisure craft to cross the tidal estuary and join the rest of the canal system via the Rufford branch of the Leeds–Liverpool Canal (Fig. 1).

The main line of the canal from Preston to the locks at Tewitfield is c. 68 km long and has no locks. It was built as a ‘contour’ canal and therefore takes a meandering route at a constant level (25 m above mean sea level). Between 1797 and 1819, when the northern reaches (Tewitfield to Kendal) were built there were no outflows or water movement in the canal except by leakage or planned overflows into streams or rivers. The only water supply was from streams, natural drainage into the canal and by pumping water from the River Ribble at Preston (Anon no date) and from the River Keer at Capernwray near Carnforth (Hadfield & Biddle 1970). It was essentially a large ditch or elongated pond. However, the construction of the northern reaches also involved the building of Killington Reservoir on Killington Common in the Howgill Fells (close to the present day Tebay south services on the M6) to provide a water supply.

THE CANAL’S STRUCTURE

The total width of the canal is c. 13.7 m with a waterway width of c. 6·5 m. It is a broad gauge canal, in contrast to the narrow gauge of many other English canals, with embayments at many bridges to allow barges to pass and turn. The barges were 24 m long and 4·75 m wide with a draught of 1·25 m when fully laden with 50 tons of cargo. The canal was dug with sloping sides and a flat bottom to leave an operating depth of water of 1·96 m. It was built by hand using pick, shovel and wheelbarrow. Most of the canal south of Tewitfield was dug in clay and only occasionally was it necessary to cut through rock. The excavated clay was used to build embankments. To make the canal watertight the bottom and sides of the canal were lined with a layer of puddled clay 0·3–1 m thick. To puddle the clay navvies (diggers) stamped up and down on the clay with their bare feet until all the air bubbles were driven out. Sometimes cattle were used to assist the process. Today with the accumulation of organic matter and reduced maintenance the navigable depth is often no more than 0·82 m. The boundary fence on the towpath side was to be of ‘Quicks and pricked’, presumably *Crataegus monogyna* (RAIL 1795; Anon no date; Philpotts 1993; D. Slater pers. comm.).

The towpath was surfaced with small stones and grit. It is believed that the bare earth on the banks etc. was sown with grass seed (possibly a mixture of grasses and herbs found locally in pastures and meadows). In a few places trees, usually *Fagus sylvatica* (Philpotts 1993), were planted. In general the canal passes through a pastoral landscape with fields sloping gently to the canal on the eastern side whilst on the western, or towpath side, the canal was bounded by a hedge with *Crataegus monogyna*, as originally specified but now with other species and the fields often slope away from the canal. Thus the canal receives water from springs and general run-off on the eastern side and is therefore part of the general drainage system for the area through which it passes.

In building the canal stone was only used for bridges, aqueducts and quays etc. so that the completed canal, with its sloping, puddled clay sides and bottom, provided an ideal habitat for plant colonisation (Fig. 2).

It is difficult today to imagine the impact constructing the canal had on the environment and people of this rural part of Lancashire at that time. A temporary work force was required to build what was the 18th century equivalent of a 21st century motorway.

THE CANAL AS A MEANS OF TRANSPORT

Traffic gradually built up after opening and during its busiest period in the early 1840s a twice-daily passenger service (the special barges averaged 10 mph) operated between Preston and Kendal, although the main cargoes were coal going north and limestone going south. In 1804 c.

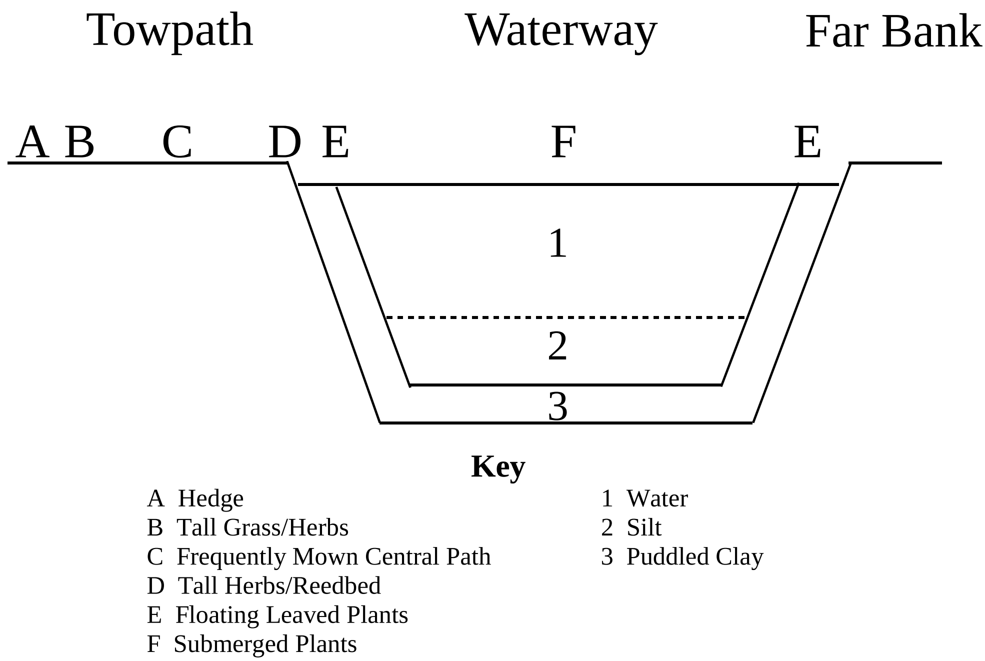

FIGURE 2. Cross-section of the Lancaster Canal.

102,000 tons of cargo was carried rising to 193,000 tons in 1840 (Anon no date). However, once the railways became competitive, traffic gradually declined until the canal was finally closed for commercial use in 1947. Before then, increasing difficulties in maintaining the canal north of Tewitfield led to the abandonment of that section in 1944. Although commercial boat traffic no longer used the canal it was being increasingly used as an aqueduct to supply industrial users along its length, and through a pipeline from Garstang to chemical works at Fleetwood. This probably saved the canal from total abandonment, and with increasing leisure use, especially by anglers and later small boats, the canal gradually became an important part of the leisure industry.

Nevertheless traditional canal maintenance continued with mechanical dredging and weed clearance, although at a reduced standard. However, in the late 1960s experimental weed control using herbicides was carried out and in the early 1970s an iron revetment was fixed to protect the towpath from erosion boat wash.

MACROPHYTES OF THE LANCASTER CANAL

PLANT COMMUNITIES

Today a transverse section of the canal reveals the following zones (Fig. 2, Plate 2.)

A. Hedge. Consists mostly of *Crataegus monogyna* but occasionally abuts on to plantation woodland or consists of another species, e.g. at Capernwray, north of Carnforth the main shrub species is *Prunus padus*. In places the hedge is replaced by a stone wall.

B. Tall grass/herb zone. *Arrhenatherum elatius* is usually abundant making this an *Arrhenatherum elatius* grassland (MG1 – see Rodwell 1991–2000 for a description and terminology of plant communities). In places this gives way to stands of other species, e.g. *Eupatorium cannabinum*, *Filipendula ulmaria*, *Carex acutiformis* or *Phragmites australis*.

C. A frequently mown central pathway. This is often dominated by *Lolium perenne* (possibly a *Lolium perenne–Cynosurus cristatus* grassland (MG 6) with occasional open areas where ruderals, e.g. *Poa annua*, *Matricaria discoidea* or *Juncus bufonius* may be found. *Juncus tenuis* has also been found in open areas in this zone. Formerly this area was a bare gravel path (Plate 1).

D. Tall herb/reed-bed zone between the frequently cut area of the towpath and the open water of the canal. The vegetation here gradually changes from a tall grassland through marshy areas to an emergent reed bed zone. Typical species in the marshy areas include *Lycopus europaeus, Lythrum salicaria, Iris pseudacorus, Stachys palustris, Stachys* × *ambigua, Mentha aquatica* and *Mentha* × *verticillata.* Emergent vegetation adjacent to the open water is often dominated by *Acorus calamus.* Rodwell (1991–2000) refers this community to S15 *Acorus calamus* swamp and notes the particular concentration of this community in Lancashire. Occasionally *Phalaris arundinacea* (S28) or *Phragmites australis* (S25) may dominate this zone. In places it is missing.

E. Floating leaved communities. The open water of the canal may have floating leaved aquatics (more usually on the far side and in embayments) often dominated by *Nuphar lutea* (A8), *Persicaria amphibia* (A10) or *Sparganium emersum*.

F. Submerged aquatics. A variety of free-floating and rooted submerged aquatics are found in the canal. These include fine-leaved pondweeds (*Potamogeton* spp.), *Potamogeton perfoliatus* and *Elodea nuttallii* (A11, variation of A15).

G. The far side of the canal. This may be bordered by a reed bed zone but more frequently grazed grassland with low marsh vegetation bordering the canal.

THE CHANGING VASCULAR FLORA

For the first 50 years after the canal was built there were few records of plants growing in the canal or along its banks, although *Dryopteris submontana* was recorded near Tewitfield in 1843 (Wheldon & Wilson 1907). There were, however, a number of active botanists living in the Lancaster area, including George Crossfield, father and son (1754–1820 and 1785–1847 respectively), Samuel Simpson (1802–1881) and his sister and brother in law Maria and Henry Borron Fielding (1804–1895 and 1805–1851 respectively). The latter lived within a few metres of the canal in the 1830s and 1840s.

From the 1850s until 1907 a number of observations of the canal's flora were made (Ashfield 1858, 1860, 1862, 1864; Wheldon & Wilson 1900, 1907) but apart from the report of a field meeting (Anon 1925) there were no further observations until the 1960s. Even then, apart from observations at Garstang (Greenwood 1974), no systematic survey of the canal's flora was undertaken until the 1980s when Livermore & Livermore (1989) undertook a survey in Lancaster District. In 2000 five of the richest sections were re-surveyed using the Livermores' methodology (see below). In addition other studies of the canal's flora have been undertaken since 1980 (e.g. Environmental Management Consultants 1993; Murphy & Eaton 1983).

Despite the absence of systematic surveys until recently it is possible, using the data that are available, to make some observations on the canal's changing flora. Table 1 draws together the data for observations of the noteworthy taxa that were observed growing in or on the banks of the canal since 1800.

Prior to 1850 few species were noted. From the canal itself the only aquatic recorded was *Groenlandia densa* from Lancaster whilst the other species noted were grassland or ruderal plants. *Groenlandia densa* persisted until the 1980s. In the early years of this period there would have been many open grassland habitats on the banks. It was also a time when commercial traffic (cargo and passenger) reached its peak. No doubt wash limited or prevented much colonization of the waterway and the horse traffic on the towpath kept the gravel walkway of the towpath free of plants. Assuming that all barges were fully laden and traversed the full length of the canal and with one passenger boat in each direction daily then at any one point on the canal there were 4590 boat movements per annum. Bearing in mind that the Fieldings lived close to the canal it is inconceivable that had interesting species grown in or by the canal they would not have noted them. The absence of records therefore probably represents a genuine absence.

By the middle of the 19th century the canal's habitats would have become more mature and, with increasing competition from the railways, boat traffic gradually declined in the second half of the century. The declining boat traffic may have allowed plants that could have colonized the waterway earlier but unnoticed to flourish. Between 1858 and 1864 C. J. Ashfield wrote a series of papers on the 'Flora of Preston' and included several noteworthy species from the canal. Further

PLATE 1. The Lancaster Canal believed to have been taken at Garstang in about 1900. The photograph shows an absence of trees, almost no marginal growth of emergent aquatics and an absence of vegetation on the towpath. It is thought that the bridge carried the Garstang–Knott End railway over the canal. Photo reproduced from a post card from the collection of B. J .N. Edwards and embossed E. Hoole Preston.

PLATE 2. The Glasson Branch of the Lancaster Canal looking west in 2000 showing a 1 m wide tall herb/ reedbed zone on both sides of the canal, a central mown part of the towpath with less frequently cut grassland on either side. Photo: E. F. Greenwood.

PLATE 3. The Lancaster Canal at Garstang looking north in 2001. The bridge seen from the north in Plate 1 is removed leaving the bridge abutments now overgrown with shrubs and trees. Beech (*Fagus sylvatica*) trees line the canal on the right. Shade from the trees and boat traffic from the nearby Garstang Marina limit the growth of emergent aquatics but the towpath is mostly vegetated. Photo: E. F. Greenwood.

PLATE 4. The Lancaster Canal in about 1900 looking north to the Garstang basin from the aqueduct over the R. Calder. The photograph shows mechanical weed clearance taking place and floating/submerged aquatics are just discernible in the water. However there is no marginal tall herb/reed-bed zone. The flora of this area was recorded and illustrated by Greenwood (1974) when there was well developed marginal vegetation similar to that illustrated in Plate 2. Photo from a post card in the collection of B. J. N. Edwards.

TABLE 1. FIRST AND SUBSEQUENT RECORDS OF SELECTED SPECIES FOUND IN THE LANCASTER CANAL

Species	Prior to 1850	1851–1910	1911–1960	1961–1997	Post 1998
Acorus calamus		1907 (1)	1925 (2)	Present	Present
Angelica sylvestris			1925 (2)	Present	Present
Azolla filiculoides				1988 (3)	Present
Baldellia ranunculoides		1860 (4)	Not recorded	Not recorded	Not recorded
Butomus umbellatus		1858 (5)	1925 (2)	Present	Present
Callitriche hermaphroditica		1883 ((6)		Present	Present
Calystegia sepium	1830s (8)				
Carex nigra		1862 (7)		Present	Not recorded
Carex otrubae			1925 (2)	Present	Present
Ceratophyllum demersum				Present	Not recorded
Ceratophyllum submersum				Present	Present
Dryopteris submontana	1843 (1)	Not recorded	Not recorded	Not recorded	Not recorded
Elodea canadensis		1864 (9)		Present	Present
Elodea nuttallii				1979	Present
Epilobium palustre			1925 (2)	Present	Present
Gentianella amarella				1965	Not recorded
Groenlandia densa	1816 (10)	1858 (5)	1930s (11)	Present	Not recorded
Hippuris vulgaris		1907 (1)		Present	Present
Impatiens capensis					Present
Lemna gibba		1907 (1)	1930s (11)	Present	Present
Littorella uniflora		1891 (1)		Not recorded	Not recorded
Lycopus europaeus			1925 (2)	Present	Present
Mentha aquatica			1925 (2)	Present	Present
Menyanthes trifoliata			1925 (2)	Present	Present
Myriophyllum spicatum		1862 (7)		Present	Present
Nuphar lutea				Present	Present
Nymphaea alba		1907 (1)		Present	Present
Nymphoides peltata				1988 (3)	Present
Ornithopus perpusillus		1862 (12)		Not recorded	Not recorded
Peucedanum ostruthium			1925 (2)	Not recorded	Not recorded
Polygala vulgaris	1830s (8)				
Potamogeton alpinus		1907 (1)	1921 (10), 1959 (14)	Present	Not recorded
Potamogeton berchtoldii		1891 (13)	1946 (14)		Not recorded
Potamogeton crispus		1858 (5)	1946 (15)	Present	Present
Potamogeton natans			1925 (2), 1946 (15)	Present	Not recorded
Potamogeton obtusifolius		1900 (6)	1946 (14)	Present	Present
Potamogeton pectinatus			1939 (15)	Present	Present
Potamogeton perfoliatus		1858 (5)	1923 (12)	Present	Present
Potamogeton pusillus		1865 (14)	1939 (14)	Present	Present
Potamogeton trichoides			1946 (14)	Present	Present
Potamogeton x *lintonii*				1971 (12)	Not recorded
Pulicaria dysenterica			1925 (2)	Present	Present
Ranunculus circinatus		1899 (1)	Not recorded	Not recorded	Not recorded
Ranunculus peltatus			1930s (11)	Not recorded	Not recorded
Sagittaria sagittifolia		1875 (1)	Present	Present	Present
Scutellaria galericulata		1860 (4)	1925 (2)	Present	Present
Spirodela polyrhiza		1862 (7)	1930s (11)	Present	Present
Stratiotes aloides				1960s (16)	Not recorded
Trifolium campestre	1830s (8)				
Typha angustifolia		1907 (1)	1925 (2)	?	Present
Utricularia vulgaris		1858 (5)		Not recorded	Not recorded
Zannichellia palustris		1892 (1)	1923 (12)	Present	Not recorded

Notes: 1 = Wheldon and Wilson, 1907; 2 = Anon, 1925; 3 = Livermore and Livermore, 1988; 4 = Ashfield, 1860; 5 = Ashfield, 1858; 6 = **NMW**; 7 = Ashfield, 1862; 8 = Fielding, no date; 9 = Ashfield. 1864; 10 = **OXF**; 11 = France, no date; 12 = **LIV**; 13 = **YRK**; 14 = **BM**; 15 = correspondence between J. E. Dandy and E. F. Greenwood; 16 = Greenwood, 1974.

north at Lancaster, W. Hall (probably 1817–1891) also made a few records at this time (**LIV**) but interestingly there is little overlap in their observations. The end of this recording period is marked by the publication of the *Flora of Preston & Neighbourhood* (Preston Scientific Society 1903) with observations made between 1897 and 1902 and the *Flora of West Lancashire* (Wheldon & Wilson 1907).

Ashfield noted a number of the more interesting species for the first time. These included *Butomus umbellatus*, *Elodea canadensis* (also recorded by Hall), *Myriophyllum spicatum*, *Potamogeton crispus*, *P. perfoliatus*, *Spirodela polyrhiza* and *Utricularia vulgaris*, which was not seen again. The remaining species are still present. There were, however, a number of notable absentees including *Acorus calamus* that was not recorded until 1897–1902 at the Preston end (Preston Scientific Society 1903); *Hippuris vulgaris* from Galgate to Glasson (Wheldon & Wilson 1907), *Littorella uniflora* at Garstang in 1891 but not seen again; *Nymphaea alba* at Cabus and Garstang; *Potamogeton alpinus* at Lancaster that persisted until the late 1990s; *Ranunculus circinatus* first recorded at Lancaster in 1899 (Wheldon & Wilson 1907) and subsequently at several places but not since 1907; *Sagittaria sagittifolia* first recorded in 1875 but with still only two localities in 1907 (Wheldon & Wilson 1907; *Callitriche hermaphroditica* first recorded from near Preston in 1883 but Wheldon & Wilson (1907) found it throughout the canal; *Catabrosa aquatica* recorded in various places from 1888 in West Lancaster but Wheldon & Wilson (1907) had only one record from the canal at Garstang; *Baldellia ranunculoides* recorded by a Mr Pearson (Ashfield 1860) from Preston where it persisted until 1897–1902 and *Zannichellia palustris* first recorded in 1897 and recorded by Wheldon & Wilson (1907) from a few localities from Carnforth to Stodday south of Lancaster and last seen sometime between 1987 and 1997. Many of the species became well established, at least for a time, and many remain an important part of the canal’s flora today.

For many pondweeds identification difficulties meant that reliance was made on herbarium specimens. Amongst these were *Potamogeton berchtoldii* seen at Garstang in 1891 and again from the same area in 1946 as well as at Preston but with no further reliable records after that; *P. pusillus* at Lancaster in 1865 and still present throughout the canal and *P. obtusifolius* first seen at Winmarleigh in 1900 and still present.

Between 1911 and 1960 there were few observations and most were attributed to the Blackburn Field Club excursion (Anon 1925) that explored the canal between Preston and Garstang as it passed through the Fylde. They found *Peucedanum ostruthium* but otherwise they made few notable records although they saw a number of the more common species for the first time, e.g. *Bidens cernua*, *Carex otrubae*, *Pulicaria dysenterica*, *Lycopus europaeus* and *Mentha aquatica*. More noteworthy was *Menyanthes trifoliata*, which Wheldon & Wilson (1907) described as frequent in the vice-county. Between 1964 and 1987 nearly 50% of all sites for this species were from the canal but by 2000 it had almost disappeared from the waterway.

Amongst the pondweeds *Potamogeton natans* was recorded for the first time in 1925 but it must surely have been present before then. Also recorded for the first time were *P. pectinatus* in 1939 from Myerscough but now frequent in many places and *P. trichoides* seen at Preston in 1946 and still found occasionally in various places.

Between 1964 and 1997 detailed recording at the tetrad level took place in West Lancaster and included the section-by-section survey of the canal in Lancaster District. New species were added to the list of records for the canal in this period. Perhaps the most surprising was *Nuphar lutea*. Today it is a common canal species but it is not known when it first appeared. Nevertheless it is clear it was a late arrival as Wheldon & Wilson (1907) did not record it, nor did Blackburn Field Club yet Wheldon & Wilson did record specific localities elsewhere. Other species that were recorded for the first time in this period were *Azolla filiculoides* at Tewitfield in 1985; *Elodea nuttallii* in 1979 from Halton; *Nymphoides peltata* at Carnforth in 1988 and at Newton-with-Clifton in 1998 and *Potamogeton* × *lintonii* at Lea near Preston in 1974 and in the Glasson branch in 1971–73 but not since. More remarkable was the appearance of *Stratiotes aloides*, first recorded in the Garstang area possibly in the 1950s but by 1963 was present between Garstang and Barton and became so abundant that it was a threat to navigation. Then, as suddenly as it appeared, it disappeared sometime in the mid-1970s. Other species to appear for the first time in this period include *Ceratophyllum demersum* first recorded in v.c. 60 by Perring & Walters (1962), possibly from the canal, where it became frequent before disappearing sometime in the 1990s and

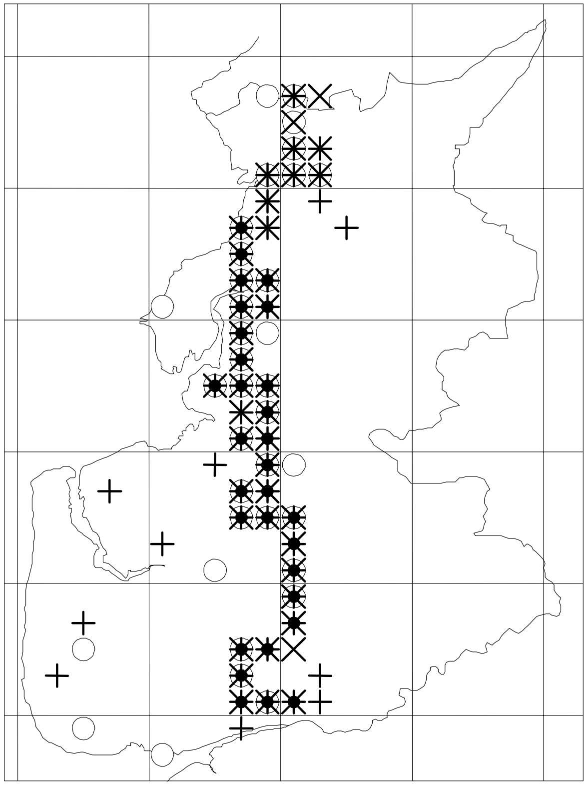

FIGURE 3. Coincidence map showing the 2 × 2 km square distribution of the Lancaster Canal (×), *Acorus calamus* (+), *Butomus umbellatus* (●) and *Sagittaria sagittifolia* (○) in v.c. 60. Map prepared using DMAP, a computer program supplied by Dr A. Morton.

Ceratophyllum submersum first seen at Borwick in 1966. Few noteworthy plants were found on the canal's banks but in 1965 *Gentianella amarella* was seen in mown grassland at Tewitfield Locks but was not seen there again.

Clearly the floral composition of the canal has changed over the years and continues to change. No doubt *Lemna minuta* seen on the canal at Crooklands in Cumbria (v.c. 69) in 2003 will soon appear in v.c. 60. Although the absence of records proves little there seems little doubt that in the first 50 years after the canal was built there were few noteworthy plants to be found in or on its banks. The few that that were recorded were mostly ruderal or grassland species. Most notably *Acorus calamus*, *Butomus umbellatus* and *Sagittaria sagittifolia* that later became characteristic species and found in few other places in v.c. 60 were absent (Fig. 3). If they had been present, at least in the Lancaster area, the Fieldings, Samuel Simpson and William Hall would surely have noted them, yet at **OXF** Simpson's specimens of *Butomus umbellatus* and *Sagittaria sagittifolia* came from the Leeds–Liverpool Canal with another specimen of *Butomus umbellatus* from Lytham. Despite living by the canal Mrs Fielding found her marsh plants for her 'English Flora' (Fielding no date) from other localities. These included characteristic plants of the canal's present flora, e.g. *Caltha palustris*, *Scutellaria galericulata*, *Iris pseudacorus* and *Lycopus europaeus*, all painted from specimens collected in ditches and streamside near her home at Stodday. For *Hippuris vulgaris* she travelled to Poulton (now Morecambe) and Southport whilst she found plants of *Nuphar lutea* and *Nymphaea alba* in Cumbria.

With the paucity of recording it is difficult to know how colonization of the canal proceeded or where the colonizing species came from. It is possible that pumping water from the River Keer at Capernwray, north of Carnforth introduced some species, e.g. *Groenlandia densa* described by Wheldon & Wilson (1907) as frequent in the area. For some, e.g. *Butomus umbellatus* and

Sagittaria sagittifolia the first records were at the Preston end of the canal and colonization appears to have proceeded northwards against the north–south flow of water in the canal. It is tempting to suggest that they were introduced from the Leeds–Liverpool Canal. *Acorus calamus* did not appear until late in the 19th century but by that time it was already common. However, it may too have been introduced from canals further south, although Shaw (1963) does not mention it as a South Lancaster canal species. Nevertheless Perring & Walters (1962) indicate the southern Lancashire and Manchester areas as two of its main centres of distribution in England and from which it seems to have spread (Preston, Pearman & Dines 2002).

For most species it is impossible to deduce how they colonized the canal or where they came from. For many species natural colonization from local populations must have taken place. Other species may have colonized the canal from garden throw outs or were introduced by anglers or boaters. It is also likely that different species colonized the canal from different or multiple starting points, e.g. *Callitriche hermaphroditica*, seems to have colonized from the north whilst *Stratiotes aloides* and *Potamogeton alpinus* appear to have colonized the canal from the Cabus and Garstang area in the middle whilst Livermore & Livermore (1988) suggest *Azolla filiculoides* colonized the canal at two places in Lancaster District almost simultaneously.

RECENT RECORDING

With the work of Livermore & Livermore (1989) more detailed and critical recording took place. However, they and others were confronted by plant identification problems not experienced by earlier workers who confined their observations to more noteworthy species. It is therefore important to describe these problems by analysing the detailed data derived from post-1985 observations.

It is clear that a number of species were misidentified. These include *Callitriche hamulata* which, whilst it might occur, was probably recorded in error for *C. hermaphroditica* and records for *C. hamulata* are therefore assumed to be *C. hermaphroditica.* This latter was never recorded if *C. hamulata* was noted and there are no voucher specimens for *C. hamulata*. The fine-leaved *Potamogeton* species, *P. berchtoldii* and *P. pusillus*, are often confused. Consequently only material named by referees was accepted and, as no post-1964 voucher specimens for *P. berchtoldii* were seen, all records after this date were assumed to be *P. pusillus*, which is frequent in, but largely confined to, the canal in v.c. 60. *Potamogeton praelongus* was also recorded but this is certainly an error for *P. alpinus.* Inexplicably, there were several records by one observer for *Glyceria maxima*, but this is a rare v.c. 60 plant and most known populations are probably of garden origin. It is, however, a common canal species elsewhere in Lancashire. Nevertheless it is difficult to know with what it was confused.

Some recorders (e.g. Environmental Management Consultants 1993) correctly observed that hybrids form an important component of the flora but not sufficiently rigorously to provide comparable data. *Mentha aquatica* and its hybrid *M.* × *verticillata* are common throughout the canal but they have only rarely been distinguished. Much more problematically *Stachys palustris* and its hybrid *S.* × *ambigua* were recorded but as plants showed varying degrees of sterility gatherings were made and checked using Rich & Jermy (1998) and Wilcock & Jones (1974). Morphologically most material agreed with *Stachys palustris* but plants varied from almost completely sterile to almost fully fertile and were slightly to moderately foetid (not as foetid as *S. sylvatica*). These plants could be a mixture of *S. palustris*, male sterile *S. palustris* or *S.* × *ambigua*. In addition a few plants were found that also agreed morphologically with *S.* × *ambigua*. Until more detailed work is carried out the identity of individual plants will often be unclear.

A number of other hybrids were also recorded and it is likely that more will be found, as their characteristics are better understood. Two nationally rare hybrids could be significant components of the vegetation although they have only been recognised recently.

Equisetum telmateia × *E. fluviatile* (*E.* × *willmotii*) was originally identified as *E.* × *litorale* (Livermore & Livermore, 1989) but it was later determined as this. It was abundant in a passing bay at Yealand Redmayne in a disused part of the canal.

Equisetum arvense × *E. telmateia* (*E.* × *robertsii*) was found shortly after the type specimen was described from a population in Anglesey (Dines & Bonner 2002). However, although typical it grows with luxuriant *E. arvense* in the marsh vegetation at Cabus and is very difficult to spot in the field. It could well be frequent but recorded as *E. arvense.* A second colony was found a few kilometres further south at Catterall in 2003.

RECENT PLANT SURVEYS

In 1989 Livermore & Livermore published an account of the Canal's flora. This was based on species lists compiled from observations made along sections of the canal in the Lancaster District. This embraced the northern 32 kilometres of the canal to the Cumbrian border north of Tewitfield and included the Glasson Branch. A section was defined as the distance between two bridges and thus the sections were of uneven length. Although most observations were made from the towpath, occasional observations were made from bridges and the other side of the canal where access was possible. Lists were compiled at three different times of the year: spring, summer and autumn and on each visit the species observed were recorded on one traverse of each section in each direction. Species were recorded from the boundary hedge or wall bordering the towpath to the marsh vegetation on the far side of the canal.

In 2000 the survey was repeated for five sections of the canal chosen to provide geographical spread of sample points and that represented maximum species diversity.

ANALYSIS OF SURVEY DATA

In a preliminary analysis of floristic change on the Lancaster Canal (Greenwood 2003) it was shown that changes could be correlated with possible eutrophication of the waters. However, it was also pointed out that boat traffic affected macrophyte growth and species diversity. In this account the data have been revised and re-assessed.

HISTORICAL DATA

Table 2 shows that 15 aquatic species (Ellenberg value of F >10; for an explanation of Ellenberg values see Hill *et al.* 1999) were identified as having colonized the canal before 1907 and were known to be present in 2000. However, prior to 1974 (Greenwood 1974) only the more noteworthy species were recorded so that other species regarded by Wheldon & Wilson (1907) as too common to list were probably present but unrecorded. A good example might be *Persicaria amphibia*, plentiful in 2000. Table 2 also shows that the average Ellenberg N value for these species is 5·9 denoting moderately nutrient-rich waters.

Few observations were made between 1907 and 1940 and it is believed that there were few changes in this period. In Table 3 species present prior to 1940 but apparently absent in 2000 are shown alongside species that have colonized the canal since 1940 together with a few species that have been gained and lost since 1940.

Eleven species were lost with an average Ellenberg N value of 4·8 whereas five species were gained with an average N value of 6·6 suggesting that eutrophication had occurred. On the other hand several of the lost species were ones that could be easily damaged by boat traffic.

However, they were mostly found in the mid-19th century when, although past its peak, there was plenty of commercial traffic. Similarly the recent immigrants are interesting. Today *Nuphar lutea* is a common plant yet it was not recorded until sometime after 1964. Preston & Croft (1997) discuss the autecology of *Elodea canadensis* and *E. nuttallii.* Both are North American introductions represented by female plants so that spread is by vegetative means only. The explosive spread of *E. canadensis* is a classic example after its first observations in the English canal system in 1847. By 1864 it was abundant and widespread in the Lancaster Canal (Ashfield, 1864) and it remained so until the 1980s.

Elodea nuttallii was at first confused with *E. canadensis* so that its spread is less well documented. It was first recorded in 1966 from a ditch at Stanton Harcourt, Oxfordshire (Simpson 1984; Killick *et al.* 1998) but from the early 1970s it was recorded at an increasing number of localities in England. In v.c. 60 the first records were from a reservoir and the River Lune near Lancaster (1976 and 1978 respectively) and it first appeared in the Lancaster Canal near Lancaster in 1979. By 2000 it was apparent that *E. nuttallii* had replaced *E. canadensis.*

These two species are both able to withstand heavy boat traffic and both favour eutrophic waters. They can grow together but *E. nuttallii* favours slightly more eutrophic conditions than *E. canadensis* and often out competes it (Simpson 1989). This appears to be the situation on the Lancaster Canal.

TABLE 2. AQUATIC SPECIES COLONIZING THE LANCASTER CANAL BEFORE 1907 AND PRESENT IN 2000

Name	N Value
Acorus calamus	7
Butomus umbellatus	7
Callitriche hermaphroditica	5
Hippuris vulgaris	4
Lemna gibba	8
Lemna trisulca	5
Myriophyllum spicatum	7
Nymphaea alba	4
Potamogeton crispus	6
Potamogeton obtusifolius	5
Potamogeton pectinatus	7
Potamogeton perfoliatus	5
Potamogeton pusillus	6
Sagittaria sagittifolia	6
Spirodela polyrhiza	7
No. of species 15	Average 5·9

Status of some species uncertain, e.g. *Potamogeton natans* (not seen 2000) and *Persicaria amphibia* (plentiful 2000)

TABLE 3. LOSSES/GAINS OF SELECTED AQUATIC SPECIES IN THE LANCASTER CANAL

Species lost by 2000 Present pre 1940		Species gained since 1940 Present 2000	
Name	N Value	Name	N Value
Baldellia ranunculoides	2	*Azolla filiculoides*	8
Elodea canadensis	6	*Elodea nuttallii*	7
Groenlandia densa	5	*Nuphar lutea*	6
Littorella uniflora	3	*Nymphoides peltata*	6
Menyanthes trifoliata	3	*Potamogeton trichoides*	6
Potamogeton alpinus	5		
Potamogeton berchtoldii	5		
Ranunculus circinatus	7		
Ranunculus peltatus	6		
Utricularia vulgaris	4		
Zannichellia palustris	7		
No. of species 11	Average 4·8	No. of species 5	Average 6·6

SPECIES GAINED AND LOST POST 1940

Name	N Value
Ceratophyllum demersum	7
Stratiotes aloides	6
Potamogeton × lintonii	5·5
No. of species 3	Average 6·2

A small group of three species were both gained and lost after 1940. One, the hybrid *Potamogeton* × *lintonii*, may still be present as it is difficult to identify. However, a thorough search of the Glasson Branch was unsuccessful and with an Ellenberg N value of between 5 and 6 it is probably susceptible to eutrophication. Boat traffic is low in the Glasson Branch and unlikely to be a factor. *Ceratophyllum demersum* and *Stratiotes aloides* are known to have critical nutrient tolerances and disappear rapidly when nutrient levels become too high. Although there was an erroneous record for *Ceratophyllum demersum* from the River Hodder (Anon 1891) the first confirmed but unlocalised records for v.c. 60 were in Perring & Walters (1962) probably from the canal. It then spread throughout the Lancaster Canal and into ponds in the Fylde. However, by 1998 it seemed to have gone from the Canal.

Stratiotes aloides was known from a few ponds since at least 1868 but it was not known from the Lancaster Canal until the 1950s with records from Garstang. It subsequently colonized most of the canal southwards to Preston. Its growth was explosive and was a major impediment to boat traffic and anglers and led to the experimental use of herbicides (Greenwood 1974). These were largely unsuccessful yet at some stage during the mid-1970s *S. aloides* disappeared.

THE SURVEYS OF 1989 AND 2000

The surveys of five sections of the Canal in 1989 and 2000 enabled a closer examination of changes over a much shorter time scale and involved both the dry land habitats associated with the towpath as well as the wetland habitats of the waterway.

Table 4 shows that in this period for the five survey lengths 25 species with an average Ellenberg N value of 4·6 were lost whilst 35 species with an average Ellenberg N value of 5·1 were newly recorded. The newly recorded species were all grassland and marginal plants associated with the towpath.

However, if the species involved are analysed for their Ellenberg N values according to their moisture (F) preferences a more complex picture emerges. In species with an Ellenberg F value of <8 (more or less dry land species) the difference between lost (N = 4·7) and gained (N = 5·1) is less marked. This is consistent with the view that the only significant source of nutrient enrichment is atmospheric. When the aquatic and marginal plants (i.e. Ellenberg F values 8–12) are analysed a marked preference for more eutrophic waters is noted with lost species having an average Ellenberg N value of 4·2 whilst new species have an average Ellenberg N value of 5·2.

Although only a few species are involved if aquatics with Ellenberg F values of 10–12 are examined, the lost species have an average Ellenberg N value of 4·8 whilst new species have an average value of 6·6. This apparent gradient can be accounted for by the eutrophication taking place in the waters of the canal from atmospheric nitrogen deposition as well as run-off from adjacent fields. However, perhaps more significant is the black-headed gull (*Larus ridibundus* L.) colony that started to colonize the island and some of the banks around Killington Reservoir in 1985. Their numbers increased rapidly, stabilizing at around 3000 pairs in 1990. In addition about 20 pairs of Canada geese nested on the banks of the reservoir in the 1970s; these increased to over 40 pairs by 1988 and have remained at this level since then (Fig. 4; F. Gould, pers. comm.). It is not clear where the gulls came from or why Killington Reservoir was chosen but it is suggested that there may be a link to a former colony at Sunbiggin Tarn some 17 km to the north east. (J. Wilson pers. comm.; Halliday 1997; Ratcliffe 2002; Stott *et al.* 2002). Their faeces have killed much of the vegetation in the nesting area and must provide a major source of eutrophication for the canal. Furthermore, treated effluent from the nearby motorway service station may also enter the Peasey Beck, into which the reservoir empties, before reaching the canal at Crooklands, north of Holme. Clearly these sources of pollution will raise the levels of phosphates and nitrogen in the canal's waters. Lateral movement into the towpath will be at least hindered by the iron revetment separating the two zones. Furthermore at least some of the emergent plants (Ellenberg F values 8 & 9) grow on the towpath side of the revetment. Interestingly in this analysis there are more new species than lost ones.

The changes in floristic composition of the five survey lengths were also analysed to see if there were any differences in the Ellenberg Reaction Values (R) for lost and gained species (Table 4). Overall there was little difference but this hid a difference between the changes for aquatic species (F = 10–12) and marginal and dry land species. Aquatic species showed that lost species had a mean value of 5·8 whilst new species had a mean value of 6·8.

TABLE 4. LOSS/GAIN OF ALL SPECIES IN THE LANCASTER CANAL 1989–2000 OVER THE FIVE SURVEY LENGTHS

Species lost	F	N value	R value	Species gained	F	N value	R value
Aesculus hippocastanum	5	7	7	*Apium nodiflorum*	10	7	7
Allium scorodoprasum	6	7	7	*Betula pendula*	5	4	4
Briza media	5	3	7	*Campanula latifolia*	5	6	7
Carex nigra	8	2	4	*Cardamine hirsuta*	5	6	6
Chaerophyllum temulum	5	7	7	*Carex panicea*	8	2	4
Daucus carota	5	3	7	*Catabrosa aquatica*	9	7	7
Epilobium ciliatum	6	6	6	*Cerastium diffusum*	4	3	6
Euphorbia helioscopia	5	6	6	*Chrysosplenium oppositifolium*	9	5	5
Helictotrichon pubescens	4	3	7	*Cymbalaria muralis*	5	6	7
Juncus conglomeratus	7	3	4	*Epilobium obscurum*	8	5	5
Larix decidua	4	3	3	*Epilobium palustre*	8	3	5
Luzula multiflora	6	3	3	*Galeopsis bifida*	5	6	6
Menyanthes trifoliata	10	3	4	*Galeopsis speciosa*	5	7	7
Myrrhis odorata	6	7	7	*Galeopsis tetrahit* s.s.	5	6	6
Orchis mascula	5	4	7	*Geranium dissectum*	5	6	7
Pinus sylvestris	6	2	2	*Hyacinthoides hispanica*	4	6	6
Potamogeton alpinus	12	5	6	*Juncus acutiflorus*	8	2	4
Potamogeton natans	11	4	6	*Lemna gibba*	11	8	7
Saxifraga tridactylites	2	2	7	*Lemna minor*	11	5	6
Sinapis arvensis	5	7	7	*Leontodon saxatilis*	5	3	6
Sonchus oleraceus	5	7	7	*Lysimachia nemorum*	7	5	4
Sparganium erectum	10	7	7	*Lysimachia punctata*	6	5	7
Tragopogon pratensis	4	5	7	*Mycelis muralis*	5	5	7
Ulex europaeus	5	5	6	*Pimpinella saxifraga*	5	3	7
Veronica arvensis	4	3	5	*Potamogeton trichoides*	12	6	7
				Primula vulgaris	5	4	6
				Ribes alpinum	5	6	8
				Sagina procumbens	6	5	6
				Sanguisorba officinalis	7	5	6
				Spirodela polyrhiza	11	7	7
				Stachys officinalis	5	3	5
				Trifolium dubium	4	5	6
				Veronica filiformis	6	7	7
				Veronica hederifolia	5	6	7
				Veronica serpyllifolia	5	5	6
Mean (20) species F = < 8		4·7	6·1	Mean (24) species F = < 8		5·1	6·3
Mean (5) species F = 8–12		4·2	5·4	Mean (11) species F = 8–12		5·2	5·8
Mean (4) species F = 10–12		4·8	5·8	Mean (5) species F = 10–12		6·6	6·8
Total No. species 25				Total No. species 35			
Mean all species		4·6	6·0	Mean all species		5·1	6·1

Survey sections varied from 0·6 km to 1·3 km with an average length of 0·8 km

If the composition of the emergent and aquatic flora of the five survey lengths is analysed in terms of net loss and net gain a less clear picture emerges. This analysis introduces species that may be lost from one section and gained in another. They include species that are perhaps less sensitive to eutrophication but respond to other more localised events (Table 5).

If only aquatics (F = 10–12) are considered the figures clearly indicate eutrophication has taken place (N = 5·4 for decreasing species and N = 6·3 for increasing species). Also the number of decreasing species (13) is only slightly more than increasing species (12). When the emergent species (F= 8–9) are analysed the species found indicate the soils have become less nutrient-rich (N = 5·3 for decreasing species and 4·8 for increasing species). However, the total number of

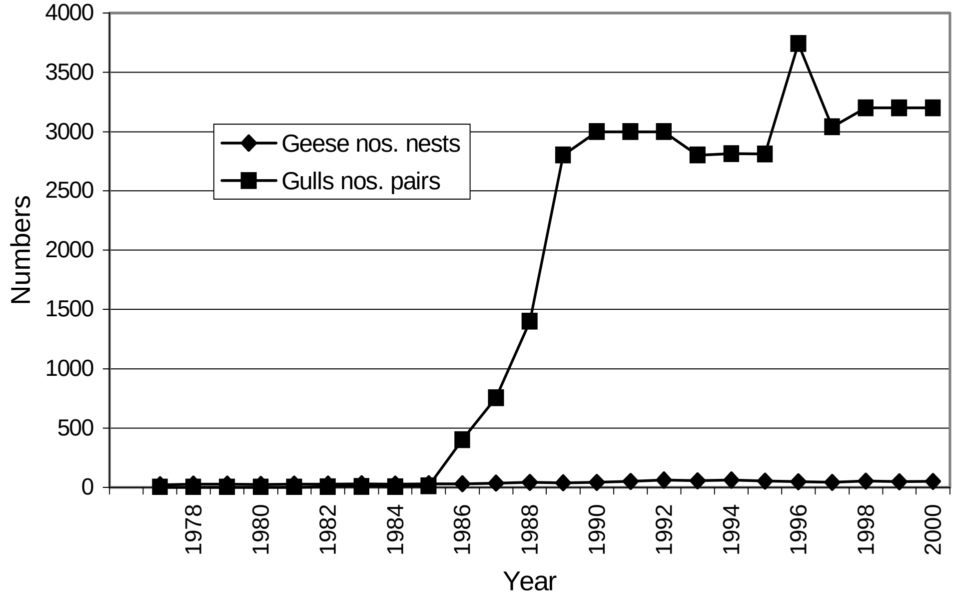

FIGURE 4. Graph showing the numbers of nesting black-headed gulls and Canada geese at Killington Reservoir, Cumbria 1977–2000.

decreasing species is 26 as against 20 for increasing species. The reaction preferences of species with moisture preferences F = 8 & 9 and those with preferences 10–12 were also different. For species where F = 10–12 some increase in the base status of the canal's water is indicated but for marginal species (F = 8 & 9) the reverse seems to have occurred.

Analysis of the changes in the number of species lost and gained (Table 6) within each survey length is also less meaningful as numbers are small. At best the changes are indicative especially as confusion between *Callitriche hamulata* and *C. hermaphroditica* and *Potamogeton berchtoldii* and *P. pusillus* is significant. However, bearing in mind the assumptions made earlier it appears that in the waterway there is evidence of increased nutrient and base status for four out of the five lengths. On the other hand when the species on the towpath and marsh plants (F = 8 & 9) usually found on the towpath side of the iron revetment are considered evidence for increased nutrient and base status is less clear and on the Glasson Branch the reverse is true.

It is difficult to explain these changes, for whereas more traditional methods of grassland management for the towpath zones appear to have favoured increased diversity, the taller emergent species close to the waterway seemed to have become less diverse. This zone may have become more of a closed community, which reduces species diversity. Greenwood (1974) demonstrated how the creation of more open habitats following herbicide treatment increased species diversity. Perhaps more significantly the changes occurring in the waterway itself and on the towpath appear to be different. In the canal the water appears to be getting increasingly nutrient-rich with enhanced base status whilst on the towpath the soils may be getting more acid and less nutrient-rich, at least in some places. The boundary between the two regimes appears to be the iron revetment separating the waterway from the towpath.

THE EFFECT OF BOAT TRAFFIC

Murphy & Eaton (1983) demonstrated that macrophyte growth and species diversity of canal waterway plants was affected by boat traffic. They developed a model of boat movements that took account of the breadth and depth of the canal. Using this model they predicted that, for a hypothetical canal 1 km long, 10 m wide and 1 m deep, between 2000 and 4000 boat movements per year (my) represented a critical range above which most macrophytes would suffer. Furthermore they and other workers suggested that the susceptibility of different species varies with boat movements.

TABLE 5. NET CHANGES IN AQUATIC SPECIES COMPOSITION (* F = 8 & 9; OTHER SPECIES F = 10–12)) IN THE LANCASTER CANAL 1989–2000 (5 SURVEY SECTIONS)

Species showing net loss	N Value	R. Value	Species showing net gain	N Value	R. Value
Alisma plantago-aquatica	7	7	*Acorus calamus*	7	7
*Angelica sylvestris**	5	6	*Apium nodiflorum*	7	7
Callitriche stagnalis	6	6	*Callitriche hermaphroditica*	5	7
*Cardamine amara**	6	7	*Carex panicea**	2	4
*Carex acutiformis**	6	7	*Catabrosa aquatica**	7	7
*Carex nigra**	2	4	*Epilobium palustre**	3	5
*Carex otrubae**	7	7	*Galium palustre**	4	5
Eleocharis palustris	4	6	*Juncus acutiflorus**	2	4
Elodea nuttallii	7	7	*Lemna gibba*	8	7
*Epilobium parviflorum**	5	7	*Nuphar lutea*	6	7
Equisetum fluviatile	4	6	*Oenanthe crocata**	7	6
*Juncus articulatus**	3	6	*Phragmites australis*	6	7
Lemna trisulca	5	7	*Potamogeton obtusifolius*	5	6
*Lotus pedunculatus**	4	6	*Potamogeton pusillus*	6	7
*Lycopus europaeus**	6	7	*Potamogeton trichoides*	6	7
*Mentha aquatica**	5	7	*Rorippa palustris**	7	7
Menyanthes trifoliata	3	4	*Salix viminalis**	6	6
*Myosotis scorpioides**	6	6	*Sparganium emersum*	6	7
Potamogeton alpinus	5	6	*Spirodela polyrhiza*	7	7
Potamogeton berchtoldii	5	6	*Veronica beccabunga*	6	6
Potamogeton natans	5	6			
Potamogeton perfoliatus	5	6			
Rorippa nasturtium-aquaticum	7	7			
*Rumex conglomeratus**	7	7			
*Salix fragilis**	7	7			
Sparganium erectum	7	6			
Mean of species F = 8 & 9	5·3	6·5	Mean of species F = 8 & 9	4·8	5·5
Mean of species F = 10 - 12	5·4	6·2	Mean of species F = 10 - 12	6·3	6·8
Total No. of species 26			Total No. of species 20		
Mean all species	5·4	6·3	Mean all species	5·7	6·3

Using boat model data from British Waterways based on boat log-book records Fig. 5 shows that boat movements vary along the Lancaster Canal with levels in excess of 4000 my from 12 to 42 km from Preston. This is a 30 km length, with the Garstang Marina not far from its centre. This is the largest marina on the canal with moorings for over 100 boats increased to 194 from 2003 (D. Lumb, pers. comm.). A two-hour cruise from the Garstang Marina almost coincides with this length of the canal where boat movements exceed 4000 my. However, only one of the 1987–2000 survey sections included this length of canal. Nevertheless four survey sections were lengths where boat movements varied from 3664 my to 2208 my; all were within the critical zone. For the surveyed section on the Glasson Branch there were only 1829 my - well below the critical level. This is also a level which Murphy & Eaton (1983) suggest achieves a satisfactory balance between ecological features and the needs of leisure users. Below this level the amount of plant growth starts to impede leisure use and with increasing plant growth seral development proceeds and in time plant diversity is reduced (see also Willby, Pygott & Eaton 2001).

If the number of licences is proportional to boat movements as recorded in log-books, then critical levels of boat movements throughout much of the canal were reached in the mid-1980s.

In general, Table 6 shows that within each survey length the numbers of species lost slightly exceeds the numbers gained. At Ellel, where boat movements were over the 4000 my threshold, losses greatly exceeded gains. Ellel is at the northern limit of a two-hour cruise from the Garstang Marina.

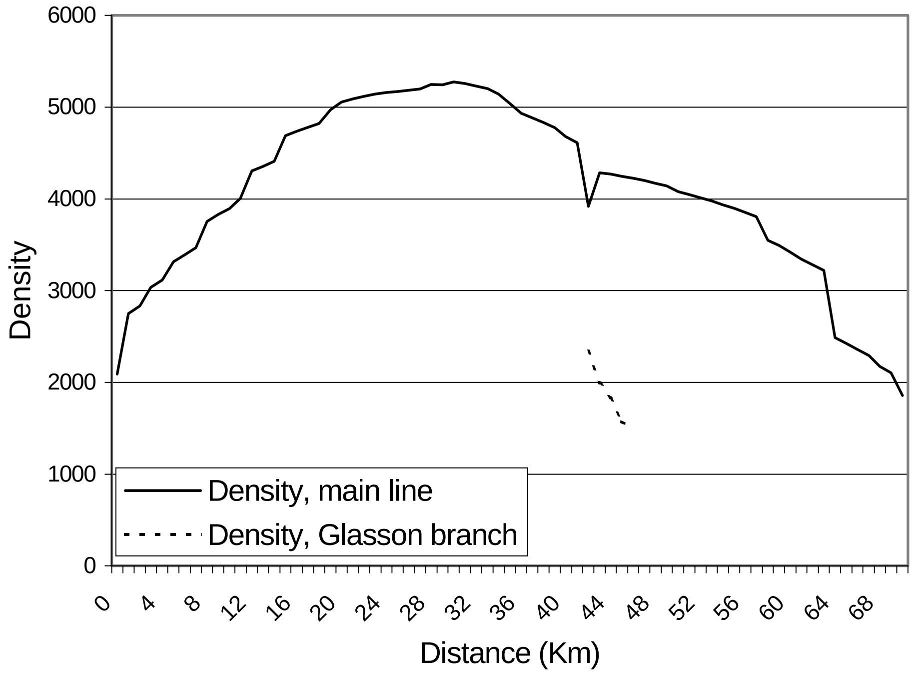

FIGURE 5. Average annual boat traffic density, Lancaster Canal in 2000.

Between 1966 and 1970 surveys of the emergent and aquatic species at Garstang were undertaken to assess the affects of herbicide treatments (Greenwood 1974). This showed that herbicides had little affect on the submerged aquatics but although the treatments eliminated the emergent species they returned with increased diversity. At that time it is believed that about half the 2000 level of boat licences were issued, implying that boat movements were between 2000 and 3000 my. In 1970 nearly twice as many species were recorded as in 1966 before herbicide treatments took place. The section chosen for these experiments was south of the present Garstang Marina at the Garstang Basin (Plate 4). This was later also developed for boat moorings including the towpath side of the canal for approximately half of the surveyed section. However, in 2000 the whole length was within a zone where boat movements were nearly 5000 my and well above the threshold for satisfactory macrophyte growth.

In 2000 this section was re-surveyed and the change in species composition observed from the towpath was dramatic. With one exception (*Elodea nuttallii*) there were no submerged aquatics and, where boats were moored, there were no emergent species. South of the mooring zone some emergent species were found but there was no well-developed tall herb/reed-bed zone. These qualitative changes can be represented quantitatively by the loss of 34 aquatic and emergent species (F = 8–12) whilst there were just two gains (Table 7). Further south, 24 km from Preston, but still with over 5000 my tall herb/reed-bed and floating leaved communities were well developed but there were no submerged aquatics.

These figures suggest that Murphy & Eaton (1983) correctly identified the importance of boat traffic and that as 4000 my is approached there is an increasingly adverse impact on aquatic and possibly emergent plants. Much above 4000 my and most aquatic macrophytes are unable to survive. The submerged aquatic, *Elodea nuttallii*, is thought to be one of the most resistant species to boat traffic and it favours highly eutrophic waters. It is, perhaps, not surprising that this is the only aquatic species to survive at Garstang. However, the adverse impact of boat traffic on emergent and floating leaved communities may not be so clear cut.

TABLE 6. MARSH AND AQUATIC SPECIES LOSSES AND GAINS, 1989–2000 (WHERE F = 8–12) FOR INDIVIDUAL SURVEY LENGTHS OF THE LANCASTER CANAL (FIGURES IN BRACKETS ARE FOR SPECIES WHERE F = 10–12)

Bridge Nos. (Location)	Losses		Gains		Boat movements
	Nos.	Mean N. Value	Nos.	Mean N. Value	Nos./ annum
84–85 (Ellel)	15 (10)	5·2 (5·2)	3 (1)	6 (6)	4679
105–106 (Lancaster)	10 (5)	5·5 (5·2)	9 (7)	6 (6·3)	3975
115–116 (Hest Bank)	10 (5)	5·4 (5·8)	6 (5)	5·7 (5·6)	3855
130–131 (Borwick)	10 (5)	6·0 (5·6)	9 (6)	6·5 (6·5)	2425
3–4 (Glasson)	11 (8)	5·5 (6·0)	8 (3)	4·6 (6·3)	1829

TABLE 7. CHANGES IN THE MARSH AND AQUATIC FLORA (F > 8) OF THE LANCASTER CANAL AT GARSTANG BETWEEN 1966–1970 AND 2000 (TABLE DERIVED FROM GREENWOOD, 1974)

Species not seen 2000	N, Value	Species seen 2000 but not 1966 - 1970	N, Value
Alisma plantago-aquatica	7	*Elodea nuttallii*	7
Apium nodiflorum	7	*Sparganium erectum*	7
Butomus umbellatus	7		
Callitriche sp.	-		
Caltha palustris	6		
Carex nigra	2		
Carex paniculata	6		
Ceratophyllum demersum	7		
Eleocharis palustris	4		
Epilobium palustre	4		
Epilobium parviflorum	5		
Equisetum fluviatile	4		
Equisetum palustre	3		
Galium palustre	4		
Hippuris vulgaris	4		
Lemna gibba	8		
Lemna minor	6		
Lemna trisulca	5		
Lotus pedunculatus	4		
Lycopus europaeus	6		
Menyanthes trifoliata	3		
Myosotis scorpioides	6		
Myriophyllum spicatum	7		
Potamogeton alpinus	5		
Potamogeton crispus	6		
Potamogeton natans	4		
Potamogeton perfoliatus	5		
Ranunculus aquatilis	5		
Rorippa nasturtium-aquaticum	7		
Sagittaria sagittifolia	6		
Scutellaria galericulata	6		
Sparganium emersum	6		
Stratiotes aloides	6		
Veronica beccabunga	-		
No. of species 34		No. of species 2	
Mean	5·3	Mean	7

DISCUSSION

Unlike experimental science, work of this kind can only use data that happen to be available. In this account data were assembled from observations made over 200 years. Over most of this period records were made casually and only plants that interested the observers were noted. Over the last 20 years more systematic data were gathered allowing for more detailed analysis.

The Canal was opened over 200 years ago and with the data available it is difficult to know the source of the colonizing species or to know how the colonization process proceeded. Normally when new habitats are created the source of colonizing species is assumed to be local. However, the natural colonization of a new habitat is a complex issue discussed by Bradshaw (1999) in the context of urban areas. Nevertheless there is evidence that the source of the colonizing species is not always local. Greenwood & Gemmell (1978) argued that many of the more interesting species colonizing inland industrial sites were derived from plants growing on the coast 48–64 km to the west. For the Lancaster Canal at least some of the more interesting species may have been derived from the Leeds–Liverpool Canal opened in stages from 1774 (Clarke 1994). The canals in Lancashire and the Mersey basin were amongst the earliest to be built in England and are well known for their interesting flora (Shaw 1963). Nevertheless little is known about the origin of their flora. As many of the species are clearly introduced, were some of these species garden escapes, as long ago as the 18th century, accidentally or intentionally introduced into the canal? Undoubtedly some more recent colonizers are derived from garden escapes, although perhaps accidentally introduced, into the Lancaster Canal, e.g. *Azolla filiculoides* and *Nymphoides peltata*. On the other hand it is probable that most species colonized the canal by natural spread from nearby populations.

However, observations over the last 100 years show a consistent trend in the changing aquatic flora. That trend is for species favouring more eutrophic conditions to replace those characteristic of less fertile conditions. Some species have an apparently narrow nutritional tolerance range, e.g. *Ceratophyllum demersum* and *Stratiotes aloides*, and, whilst favouring generally nutrient-rich conditions, disappear when conditions are too eutrophic (Preston & Croft 1997).

Boat traffic affects the growth of plants and once it reaches critical levels (2000–4000 my) some species appear more sensitive than others to its effects. More work is needed to assess the sensitivity of different species to boat traffic but at about 4000 my most aquatic species disappear. However, on the Lancaster Canal it appears that adverse affects are not clear cut. Unfortunately it was not possible to compare the effects of boat traffic in the 19th century, where horse drawn barges were used, with the current leisure craft. The boats are very different in size, structure and means of propulsion. Nevertheless it can be calculated that as many as 4500 barges passed along the canal each year, and the ‘Swift’ passenger boats (at least four a day at the busiest period in the 1850s) caused considerable wash. Also it is presumed that in the 19th century boat movements showed little seasonality whereas current boat movements are greatest in the summer. Nevertheless it may be that the traffic was such that in the first 40–50 years barge traffic was sufficient to impede plant colonization (Plates 1 & 4).

There is no information about the abundance of plants in the canal or on its banks. From pictorial evidence it is suggested that the centre of the towpath used by horses for towing boats was a gravel surface free of plants (Plates 1 & 4). Similarly tall plants between the horse and barge were kept low, as taller vegetation would have impeded movement. However, this does not imply that the flora was species poor. Indeed Ashfield’s records (Ashfield 1858, 1860, 1862, 1864) suggest that both the aquatic and emergent flora of the canal near Preston was diverse. Furthermore recent studies suggest that when the tall herb/reed-bed zone has developed a fully closed community it is floristically less diverse than in the earlier colonizing stages where open communities prevail.

Throughout its history the vegetation of the canal was managed, although from about 1940 the amount of management decreased sharply, so that by the mid-1960s some parts of the navigable canal were nearly closed by the encroaching vegetation and siltation. For most of its history management was mechanical and often by hand (Plate 4). This is a slow and relatively inefficient system that rarely removes all plant propagules. Thus species that can take advantage of this management system are able to exploit newly created open habitats thrive. Such plants need not reproduce sexually and many of the most successful species were represented by one sex of a dioecious species, e.g. *Acorus calamus,* and *Elodea* spp., or were sterile hybrids, e.g. *Stachys* × *ambigua*, and *Mentha* × *verticillata* etc. For these taxa, and others capable of reproducing sexually, spread is vegetative. Thus mechanical systems of management and moderate levels of propeller driven craft aid rather than hinder both plant propagation and dispersal.

The Lancaster Canal was of a size and construction (i.e. with sloping sides) that provided a favourable environment for the growth of many species of marginal, grassland and aquatic habitats. However, the habitats created and subsequently managed also provided a dynamic system constantly responding to changing environmental circumstances. An apparent continuing process of eutrophication in the waterway is one factor causing change and perhaps some loss of species diversity but on the towpath, especially on the Glasson Branch, where little eutrophication appears to be occurring or there may even be nutrient loss, current management may be leading to some species diversification. Whilst eutrophication appears to be detectable over the last 100 years it is perhaps only in the last 50 years that major nutrient enrichment has occurred. The growth of *Stratiotes aloides* in the 1960s followed by catastrophic decline is characteristic of continuing nutrient enrichment probably caused by the large increase in fertiliser use in the surrounding countryside. However, the loss in the 1990s of further species, e.g. *Potamogeton alpinus,* may be due to further enrichment, possibly caused by the black-headed gull colony at Killington Reservoir. Although some nutrients may be removed by vegetation on the Peasey Beck and in the canal above Tewitfield this may be negligible in comparison to the nutrient load entering the canal.

Exhaustive archive searches have failed to provide a complete inventory of boat licences issued by British Waterways but it is believed that in 1967 about 400 licences were issued or 44% of the 2000 total. This had risen to 537 in 1985 (59%) and during the 1980s the number of licences rose more sharply so that by 1994 nearly 900 licences were issued. There is also a suggestion that there was a substantial increase of licences issued about 1973. However, if the boat licence data are related to the boat model data, critical levels of boat movements for much of the canal were not reached until 1985. Since then boat movements have increased to over 4000 my within a two hour cruise time of Garstang where most boats are located. As a consequence most aquatic plants and many emergent species have been lost in this zone.

The two processes of eutrophication and increasing levels of boat traffic are identified as probably causing change to and loss of aquatic and marsh species in and on the banks of the canal. Furthermore by disturbing the sediments in the canal, boats may be affecting the nutrient status of the water and substrate. Moss (2001) reviewed the problems affecting plant growth in the shallow waters of the Broads in eastern England, including Hickling Broadwhere roosting black-headed gulls caused problems. He demonstrated that, whilst nutrient enrichment was a cause of plant loss, this was not a simple issue of cause and effect but involved a delicate balance of plant and animal communities where, if clear water was maintained, macrophytes flourished even at high nutrient concentrations. Unlike the Broads turbidity in the Lancaster Canal is caused by boat traffic, but during the winter with fewer boats using the canal the water generally clears and clear water is usually present in the Glasson Branch. Like the Broads the canal is an excellent coarse fishery, suggesting that the phytoplankton and their animal grazers are currently plentiful. However, that could easily change.

It appears, therefore, that whilst there has been change in the composition of the aquatic flora, probably caused by eutrophication, elimination of aquatic species is caused by boat traffic. The Glasson Branch demonstrates that in the absence of boat traffic over 2000 my there is an abundance of aquatic plants, but all the species favour nutrient-rich waters. On the other hand in the main line of the waterway, with boat movements over 4000 my, aquatic species do not survive.

With an increasing appreciation of canals as leisure facilities developments on the Lancaster Canal include the link to the River Ribble near Preston opened in 2002. For the first time this provides a link via a tidal river crossing to the rest of the canal network. It is also intended to re-open the northern reaches and provide a navigable waterway to Kendal in the English Lake District. In themselves these do not necessarily imply increased boat traffic but no doubt new marinas will be created and these will increase boat traffic in currently less well used parts of the canal with consequential adverse affects on plant life, especially if boat movements exceed 4000 my.

Therefore there is the danger that one of the charms of the waterway, the profusion of wild flowers on its banks, not to mention the unseen aquatic species, will be lost.

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