British Trust for Ornithology

BTO Research Report No. 202

An Investigation of the Feeding Sites of Grey Herons *Ardea cinerea* Producing Deformed Chicks at the Besthorpe Colony

Authors

N.H.K. Burton & N.A. Clark

Report of work carried out by the British Trust for Ornithology under contract to the Environment Agency through Nottinghamshire Wildlife Trust

October 1998

British Trust for Ornithology, The Nunnery, Thetford, Norfolk IP24 2PU
Registered Charity No. 216652

N.H.K. Burton & N.A. Clark

An Investigation of the Feeding Sites of Grey herons *Ardea cincerea* Prodicing Deformed Chicks at the Besthorpe Colony

Published in October 1998 by the
British Trust for Ornithology, The Nunnery, Nunnery Place, Thetford, Norfolk IP24 2PU, U.K.

ISBN 1-902576-02-0

CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

1. Monitoring of the Grey Heron *Ardea cinerea* colony at Mons Pool, Besthorpe in 1998 revealed that a minimum of two chicks from one nest were suffering from deformities (in comparison to 27 from 19 nests in 1997). Wet spring weather may have masked the problem this year, however, as chicks may have died before deformities became apparent, either due to exposure or because adults may not have been able to find sufficient food for them.

2. Postmortem evidence, from 1997, suggested that chicks were suffering from rickets, possibly due to low calcium levels. The softness of the chicks' bones had resulted in a number of breaks. Selenium levels were very high in the livers and kidneys of at least some of the chicks analysed.

3. Observation of the flight lines of adult Grey Herons on leaving and returning to the Mons Pool suggested that the majority fed to the north of the colony.

4. Three complete field surveys of a study area, stretching from High Marnham in the north to Newark in the south and covering 70 km^2, found 33 feeding adult herons. The majority of these were on the River Trent (39% of birds) or on non-industrial freshwater sites, e.g. streams, dykes and former gravel pits (45.5% of birds). There were no obvious concentrations of birds and few fed at industrial sites.

5. In consequence of the small number of deformed chicks found in 1998, only a maximum of four adult herons were dye-marked, none of which were subsequently seen. Chicks that were ringed were also dye-marked on the throat, however. Two of these and three unmarked birds were seen away from the colony from 7 May 1998.

6. It is recommended that monitoring of the heron colony and of deformities amongst the chicks should continue next year. Further postmortems will also need to be undertaken. It is also recommended that adults should be radio-tracked to determine the foraging sites of those from affected nests. This will enable a shortlist of sites to be identified for detailed investigation and thus help to determine the source of the high selenium levels or of any other possible cause of the chicks' deformities.

1. INTRODUCTION

The Grey Heron *Ardea cinerea* colony at Mons Pool in the Trent valley, in Nottinghamshire, was first visited by the North Nottinghamshire Ringing Group (NNRG) in 1996, with permission from the owners, Redland Aggregates and with the agreement of Nottinghamshire Wildlife Trust (NWT). On this first visit nine Grey Heron chicks were found with deformities to both leg and wing bones. Two dead birds were later sent for postmortem, which revealed that they had a severe calcium deficiency (Kent 1997a). The problem was confirmed again in 1997, when 27 chicks (20% of the total produced) from 19 nests were found to have deformities (Kent 1997c). Postmortems on some of these birds (taken dead or culled under licence from English Nature) suggested that the birds were suffering from rickets. The birds' livers and kidneys held high levels of selenium however, and it is thought possible that this may be associated with the deformities.

The aim of this study was to identify the feeding locations of adult herons and thus determine the source of the high selenium levels or of any other possible cause of the chicks' deformities.

2. METHODS

2.1 The Study Site

The Besthorpe heronry is found at Mons Pool (53°10'N, 0°47'W), a former site of gravel extraction, nowadays part of a NWT reserve on land to be leased from Lefarge Redland Aggregates. The herons nest in hawthorns on a small island, which also holds a substantial colony of Cormorants *Phalacrocorax carbo*. In 1997, 63 nests were occupied by herons (Kent 1997c), and in 1998, 56 (Kent 1998).

The colony lies in an area with substantial numbers of suitable feeding locations for the adult herons, which may move considerable distances away from the colony to feed. Although herons are renowned as fish-eaters, the adults and chicks may also eat substantial numbers of amphibians, small mammals and even young birds (Cramp & Simmons 1977; Marquiss & Leitch 1990; Voisin 1991). Figures 2.1.1 and 2.1.2 show the extent of the study area which stretched from Newark in the south to High Marnham in the north and covered approximately 70 km^2. Mons Pool itself is just 100 m away from the River Trent, which flows from south to north and at this point is tidal (Figs. 2.1.1 & 2.1.2). A weir and lock system at Cromwell, 2 km south, prevents tidal waters reaching any further upriver. Many other watercourses and waterbodies are also available to the herons, however. A slow-flowing stream, the Fleet, runs approximately 1 km away from the Trent, joining it at Girton. Smaller streams and drainage ditches also bound many of the arable and pasture fields along the valley. Freshwater lakes are found in many former and still active gravel workings. Many of these, and some purpose made ponds, are used for fishing. Other small lagoons have been created to act as waste-disposal sites, for fly-ash from the High Marnham power station, before ultimately being reverted to farmland. Fly-ash is known to contain high levels of selenium (Wadge & Hutton 1986; Brieger *et al.*1992). Sediment settlement pools are also found at a sugar beet plant by the Trent at Newark (Fig. 2.1.2).

2.2 Study Methodology

Visits to the colony by members of NNRG, between 21 March 1998 and 28 June 1998, indicated the progress of the herons' breeding season and the incidence of deformities among the chicks. Using this information, fieldwork was timed to the period when the number of chicks was at its maximum. Initial work aimed to determine the flight lines of adults on leaving and returning to the colony and thus whether feeding areas were distributed evenly around the colony (H_0) or concentrated in a given direction (H_1). Data were collected over seven days, between 15 April and 12 May 1998. Flights of fledged juveniles later in this period were excluded from the analysis, as were flights of adults returning to the colony with nesting material rather than food. In total, the colony was observed for 515 minutes (at times between 0830 and 1730). Previous studies have shown that Grey Herons primarily feed their young in the early morning (Owen 1955; Milstein *et al.* 1970) and that feeding visits peak when young are small (van Vessem & Draulans 1986).

Field surveys aimed to determine the feeding distribution of all herons within the study area described above, but, in particular, of adults from nests with affected chicks. These adults were distinguished by dye-marking. Birds were marked at the nest, using sponges soaked with picric (a yellow dye) and supported by wire. This method meant that birds were dyed on the chest. All healthy chicks ringed, and some just too small to ring, were also dye-marked on the sides of the throat.

A preliminary survey of the central part of the study area took place on 16 April 1998. At this time water levels were particularly high, due to heavy rain, and floodwater still lay in one area near Girton. Three complete surveys of the study area, each taking approximately two and a half days, took place from 27 April - 1 May, 6 - 7 May and 11 - 13 May 1998. Each of these surveys covered all water bodies (excluding garden ponds), rivers, streams and larger ditches in the study area (see Figs. 2.1.1 & 2.1.2).

3. RESULTS

3.1 Breeding Performance

The breeding performance of Grey Herons at the Besthorpe colony in 1997 and 1998, as recorded by NNRG, is summarised in Tables 3.1.1 and 3.1.2. Young were presumed to have fledged if they were large and healthy when last seen and were old enough to have fledged before the next nest visit. As some may have been lost before then, however, the number of young fledged is a maximum figure. A small percentage of young were still in the nest when last checked, but were apparently healthy and therefore may also have fledged.

A total of 27 chicks (20% of the total produced) from 19 nests were found to have deformities in 1997 (Kent 1997c). In 1998, however, only two deformed chicks were found, both from the same nest. These were culled under licence from English Nature and taken freshly dead for postmortem analysis. Twenty chicks with no obvious deformity also died in 1997 and a further 69 in 1998. Overall mortality was slightly higher in 1998 than in 1997, although not significantly ($\chi^2 = 2.216$, df = 2, ns). There were significantly fewer deformities amongst those that died in 1998 than in 1997 ($\chi^2 = 42.632$, df = 1, $P < 0.001$). Many chicks are believed to have died in the spring of 1998 due to the wet weather, either as a result of exposure or because raised water levels and high turbidity decreased the adults' ability to find adequate food for them (Kent 1998).

Pairs hatched an average of 2.54 chicks per clutch laid in 1998 ($n = 68$ clutches). An average of 1.18 chicks per clutch laid were presumed to have fledged. A maximum of 1.50 may have fledged, if all those still in nests when last checked on 28 June 1998 were successful. As this figure was based on an assumption of survivorship unless there was incontrovertible evidence otherwise, however, it may be a significant over-estimate.

3.2 Postmortem Results

Summaries of postmortems were available for seven deformed Grey Heron chicks from the 1997 breeding season, although a number of other corpses were presented for analysis. One chick was found dead and the other six culled under licence from English Nature. Postmortems suggested that the chicks were suffering from rickets. Chicks exhibited soft leg and/or wing bones and, in some cases, beaks. The softness of the bones had led to a number of breaks. The bone ash (*i.e.* mineral) content of the leg/wing bones was low and in at least two chicks analysed, ALP enzyme activity was raised - both factors indicative of rickets. Although the percentage of calcium in the bone ash of one bird was low, it was normal in at least four others. The percentage of phosphate was normal in all these cases. Selenium levels were very high in the livers and kidneys of at least three chicks and in the livers taken from two further chicks. However, selenium levels were also high in the liver of a control bird taken previously in Yorkshire. Unfortunately, it is not known that Grey Herons in this control area were not subject to the same problem. Similar incidents have been noted previously in Scotland (Kent 1997c).

The stomachs of at least three chicks examined were almost empty. This may not have been due to a lack of food, however, but simply due to the chicks' inability to feed when disabled with broken bones (Kent 1997b). In some cases, it has been the largest chick in a brood that has developed deformities and subsequently died.

Postmortems of the two chicks culled in 1998 have been undertaken, but toxicology data were not available at the time of writing and will be reported on separately at a later date.

3.3 Flight-lines of Adult Grey Herons

Flight lines of adult Grey Herons, on leaving and returning to the nesting colony, are shown in Figures 3.3.1 and 3.3.2. Flights were direct, both into and out of the colony (Cramp & Simmons 1977). Moving position to view the colony from different angles minimized the obstruction caused by trees. Adult herons predominately left the colony in a north-westerly direction, fewest birds going to the south-east. This difference was significant ($\chi^2 = 13.467$, df = 3, $P < 0.01$; Table 3.3.1), and thus the null hypothesis, that the feeding areas that birds flew to from the colony were evenly distributed around it, was rejected. Returning adults also predominately flew from the north-west or north-east, although this difference was not significant ($\chi^2 = 6.308$, df = 3, $P < 0.10$; Table 3.3.1).

3.4 Field Surveys

An initial survey on 16 April 1998, between Cromwell Lock in the south and the gravel and waste disposal pits to the north of Girton, found six adult Grey herons away from the colony (Fig. 3.4.1). Two of these were on Mons Pool, three on the River Trent and one on a fly-ash waste disposal pit. None were seen on the Fleet or smaller dykes.

The three complete surveys of the study area, undertaken between 27 April 1998 and 13 May 1998, revealed that feeding adult herons were concentrated on the River Trent (39.4% of observations, $n = 33$) and on other non-industrial freshwater sites, e.g. streams, dykes and former gravel pits (45.5% of observations) (Figs. 3.4.2 & 3.4.3; Table 3.4.1). The most frequently used sites were Winthorpe Lake, with five records, and the Fleet at Besthorpe, where a single bird was recorded on each survey. One adult was recorded on a pool in still active gravel workings, one on a fly-ash waste disposal site, two on a pool at the Newark sugar beet plant and one other on a trackside puddle. Although observations of flight-lines suggested that the majority of adults were feeding to the north of the colony, field surveys indicated that equal numbers fed north and south. Undeniably, some of those viewed to the south would have come from the heronry at Rolleston Gorse (53°04'N, 1°52'W) which is only 5½ km from South Muskham. However, it is probable, particularly considering the relatively small proportion of herons seen on surveys, that some adults from Besthorpe flew north to feed outside of the study area.

A maximum of four adult herons were dye-marked. On 12 April 1998, picric-soaked sponges were placed amongst the replacement clutch of the pair whose chicks were found deformed and removed for postmortem in March. Sponges were also placed at another nest, on 21 March 1998, of a pair whose two young were obviously unhealthy and were suspected of developing deformities (J. Kent pers. comm.). One of these later died, although not apparently having become deformed, whilst the other is believed to have fledged. As neither of these two nests were observable from the hide, however, it was not possible to confirm that dye-marking had been successful prior to field surveys, although it is unlikely that adults could have avoided the sponges. No dye-marked adult herons were subsequently seen on these surveys.

All chicks ringed, and some just too small to ring, were also dye-marked on the sides of the throat. Fledged juveniles were first seen flying around the colony on 29 April 1998, but were not recorded away from Mons Pool until the second of the three surveys on 7 May 1998. A total of five fledged juveniles were recorded on these surveys, three on the Trent and two on a pool at the Newark sugar beet plant (Fig. 3.4.4). Four of these were accompanied by their parents. Only the two sighted nearest the colony were dye-marked and it is possible that the others may have come from another colony to the south. One dye-marked juvenile was also reported on the Trent near Kelham (53°06'N, 1°50'W), approximately 9 km to the SSW of the colony.

4. DISCUSSION

Although only two Grey Heron chicks from the Besthorpe colony were confirmed to have deformities in 1998, there was a slight increase in the mortality rate in comparison to the previous year. It is probable that this was partly due to the wet spring weather. Chicks may have died as a result of exposure or because raised water levels and high turbidity decreased the adults' ability to find adequate food for them. Such problematic feeding conditions are thought to have prevented adults from using the Fleet and other smaller watercourses on 16 April 1998. The high percentage of small mammals found amongst prey at nests on 12 April 1998 also suggested that adults were having difficulty in finding fish. The high mortality of young chicks in 1998 is believed to have masked the problem of deformities. In 1997, the problem only became apparent when chicks were old enough to climb around the nest and exercise their wings. This lead to breaks and poor setting of bones, and thus visible deformities. Those chicks that died young in 1998, therefore, would not have be known to be suffering from soft bones unless taken for postmortem. Unfortunately, the poor weather also reduced the number of fresh corpses that it was possible to collect. There are, however, three explanations as to why deformities may have actually been reduced in 1998. Firstly the factor causing the deformities, whether a contaminant or a lack of food, may itself have been reduced. Secondly, if the deformities were related to a contaminant, this may have been reduced in concentration by the high spring rainfall and associated floods. Alternatively, the high water levels may have forced adult herons to forage for alternate food sources, such as small mammals, which were not affected by the contaminant. Overall, the mortality of chicks recorded at Besthorpe was slightly greater than that seen in other previous studies. Milstein *et al.* (1970), for example, found that a mean of 2.3 chicks (81%) fledged from a mean of 2.8 hatched per clutch laid. In a five year study in Germany, Creutz (1981) similarly found that 87-94% of young fledged. Recorded mortality at Besthorpe actually probably underestimated the true figure, however, as chicks were presumed to have fledged if there was time enough between visits for them to do so. This problem would have been exacerbated in 1998 when visits to the colony were reduced to avoid exposing eggs and chicks to cold and wet weather.

In consequence of the small number of deformed chicks found this year, only a maximum of four adult herons were dye-marked, none of which were subsequently seen. Field surveys, however, did give a good understanding of the distribution of feeding adult herons in the study area. Whilst the majority fed on the River Trent or on non-industrial freshwater sites, e.g. streams, dykes and former gravel pits, no obvious concentrations were recorded. The highest number of birds seen at any one site was at Winthorpe Lake, where five adults were recorded over the three surveys. A total of 13 was recorded on the River Trent. Few were recorded at industrial sites. Van Vessem *et al.* (1984) similarly found that adult radio-tagged Grey Herons typically foraged singly when raising chicks and actively defended sites from other herons. Assuming that the deformities are a result of a food source, rather than a lack of food, as has been suggested (Kent 1997b), it is possible that such a food may be found at a number of locations. A minimum of 19 adults and a maximum of 38 (*i.e.* one or both of a pair from the 19 nests affected) must have been collecting such food in 1997.

The effect of the high levels of selenium found in the chicks remains unclear and there is no definite link with the mortalities. A previous study (van der Molen *et al.* 1982) actually found that herons with lethal mercury levels did not die (except in cold weather) due to the antagonistic effect of high selenium residues. The mercury itself was associated with agricultural pesticides.

Other studies have indicated that high levels of selenium in the diet of adult waterbirds may lead to deformities of embryos and thus affect hatching success (Ohlendorf *et al.* 1986; Hoffman & Heinz 1988). However, Hoffman *et al.* (1992a, 1992b) also found that selenium in the diet may affect the growth, physiology and thus survival of Mallard *Anas platyrhynchos* ducklings, particularly when dietary protein is diminished.

5. RECOMMENDATIONS

The wet spring weather is believed to have masked the problem of deformities amongst the heron chicks at Besthorpe in 1998. Some chicks may have died before deformities became apparent, as in 1997. Post mortems in this earlier year indicated that some dead chicks which did not seem deformed or physically damaged did actually have soft bones. Adults may also have been forced to forage away from their usual feeding sites by high water levels.

It is clear therefore that the colony should be monitored to determine the incidence of deformities next year. Postmortems of dead chicks should also be undertaken, whether chicks are outwardly deformed or not and also analysis made of addled eggs. Postmortems of chicks from another colony would be needed to act as controls. Further dye-marking of chicks should take place to establish their feeding locations after fledging, when they are initially accompanied by adults. This would require further field surveys. To determine the foraging sites of adults from affected nests, however, radio-tracking is required. Ten adults should be caught and fitted with transmitters at the start of the breeding season in late winter. Use of the hide would enable those from affected and unaffected nests to be distinguished. Radio locations of tagged adults would be mapped in order to detect whether birds from affected nests forage at locations that are not used by others and to detail foraging locations outside the existing study area. This will enable a short list of sites to be identified for detailed investigation.

Acknowledgements

Thanks are due to Jenny Kent, Adrian Blackburn and other members of the North Nottinghamshire Ringing Group for their data on the breeding performance of Grey Herons at the Besthorpe colony and on the incidence of deformities among the chicks. Jenny Kent helped considerably during fieldwork and was kind enough to let NHKB stay at her house whilst undertaking surveys. Thanks are also due to Julian Branscombe, Stephanie Hilborne and John McMeeking of Nottinghamshire Wildlife Trust. Alan Hunt of Sutton Bonnington Veterinary Investigation Centre provided data on postmortems of heron chicks.

The discussion of parts of this project with other members of the BTO staff was of considerable value. Nicki Read and Dawn Morris gave considerable assistance in the completion of this report.

The study was funded by the Environment Agency through Nottinghamshire Wildlife Trust.

References

Brieger, G., Wells, J.R. & Hunter, R.D. (1992) Plant and animal species composition and heavy-metal content in fly-ash ecosystems. *Water, Air and Soil Pollution*, **63**, 87-103.

Cramp, S. & Simmons, K.E.L. (1977) *The Birds of the Western Palearctic, Vol. I.* Oxford University Press, Oxford.

Creutz, G. (1981) *Der Graureiher.* A. Ziemsen-Verlag, Wittenberg-Lutherstadt.

Hoffman, D.J. & Heinz, G.H. (1988) Embryotoxic and teratogenic effects of selenium in the diet of mallards. *Journal of Toxicology and Environmental Health*, **24**, 477-490.

Hoffman, D.J., Sanderson, C.J., Lecaptain, L.J., Cromartie, E. & Pendleton, G.W. (1992a) Interactive effects of arsenate, selenium and dietary-protein on survival, growth and physiology in Mallard ducklings. *Archives of Environmental Contamination and Toxicology*, **22**, 55-62.

Hoffman, D.J., Sanderson, C.J., Lecaptain, L.J., Cromartie, E. & Pendleton, G.W. (1992b) Interactive effects of selenium, methionine and dietary-protein on survival, growth and physiology in Mallard ducklings. *Archives of Environmental Contamination and Toxicology*, **23**, 163-171.

Kent, A. (1997a) *Besthorpe Heron Incident. Report 1 - up to and including 10/4/97.* 2pp.

Kent, A. (1997b) *Besthorpe Heron Incident. Report 4 - up to and including 5/5/97.* 2pp

Kent, A. (1997c) *Besthorpe Heron Incident. Report 5 - up to and including 27/5/97.* 2pp.

Kent, J. (1998) *Besthorpe Heronry Report for 1998.* 4pp.

Marquiss, M. & Leitch, A.F. (1990) The diet of Grey Herons *Ardea cinerea* breeding at Loch Leven, Scotland, and the importance of their predation on ducklings. *Ibis*, **132**, 535-549.

Milstein, P. le S., Prestt, I. & Bell, A.A. (1970) The breeding cycle of the Grey Heron. *Ardea*, **58**, 171-257.

van der Molen, E.J., Blok, A.A. & de Graaf, G.J. (1982) Winter starvation and mercury intoxication in Grey Herons (*Ardea cinerea*) in the Netherlands. *Ardea*, **70**, 173-184.

Ohlendorf, H.M., Hoffman, D.J., Saiki, M.K. & Aldrich, T.W. (1986) Embryonic mortality and abnormalities of aquatic birds: apparent impacts of selenium from irrigation drainwater. *Science of the Total Environment*, **52**, 49-63.

Owen, D.F. (1955) The food of the Heron *Ardea cinerea* in the breeding season. *Ibis*, **97**, 276-295.

van Vessem, J. & Draulans, D. (1986) The adaptive significance of colonial breeding in the Grey Heron *Ardea cinerea*: inter- and intra-colony variability in breeding success. *Ornis Scand.*, **17**, 356-362.

van Vessem, J., Draulans, D. & de Bont, A.F. (1984) Movements of radio-tagged Grey Herons *Ardea cinerea* during the breeding season in a large pond area. *Ibis*, **126**, 576-587.

Voisin, C. (1991) *The Herons of Europe.* T & AD Poyser, London.

Wadge, A. & Hutton, M. (1986) The uptake of cadmium, lead and selenium by barley and cabbage grown on soils amended with refuse incinerator fly ash. *Plant Soil*, **96**, 407-412.

Nests occupied	63
Minimum number of eggs laid	162
Minimum number of young hatched	137
Number of young presumed to have fledged	75 (54.7%)
Number of young not fledged when last checked on 26 May 1997, but apparently healthy	15 (10.9%)
Number of deformed young	27
Dead young	47 (34.3%)

Table 3.1.1 Breeding performance of Grey Herons at the Besthorpe colony in 1997 (data from NNRG). The total number of eggs laid is only a minimum figure, as some may have been laid and then lost between nest visits. Likewise, the figure for the number of young hatched is only a minimum, as some young may have hatched and then been lost before nests were revisited. Young were presumed to have fledged if they were large and healthy when last seen and were old enough to have fledged before the next nest visit. As some of these chicks may have died, however, the number of young fledged (by 26 May 1997) is a maximum figure. Grey Heron chicks fledge when between 42 and 55 days old (Cramp & Simmons 1977; Voisin 1991).

Nests occupied	56
Minimum number of eggs laid	217
Minimum number of young hatched	173
Number of young presumed to have fledged	80 (46.2%)
Number of young not fledged when last checked on 28 June 1998, but apparently healthy	22 (12.7%)
Number of deformed young	2
Dead young	71 (41.0%)

Table 3.1.2 Breeding performance of Grey Herons at the Besthorpe colony in 1998 (data from NNRG). The total number of eggs laid is only a minimum figure, as some may have been laid and then lost between nest visits. Likewise, the figure for the number of young hatched is only a minimum, as some young may have hatched and then been lost before nests were revisited. Young were presumed to have fledged if they were large and healthy when last seen and were old enough to have fledged before the next nest visit. As some of these chicks may have died, however, the number of young fledged (by 28 June 1998) is a maximum figure. Grey Heron chicks fledge when between 42 and 55 days old (Cramp & Simmons 1977; Voisin 1991).

	North-east	North-west	South-west	South-east
Flights from the colony	9	15	4	2
Flights into the colony	9	10	5	2

Table 3.3.1 Flight lines of adult Grey Herons on leaving and returning to the nesting colony. (Data were collected over seven days, from 15 April to 12 May 1998, and over a total of 515 minutes).

River Trent tidal	River Trent freshwater	Streams / dykes	Active gravel workings	Other freshwater	Fly-ash waste disposal sites	Sugar beet pools	Other
9	4	5	1	10	1	2	1

Table 3.4.1 Habitats used by adult Grey Herons on three surveys of the study area between 27 April and 13 May 1998.

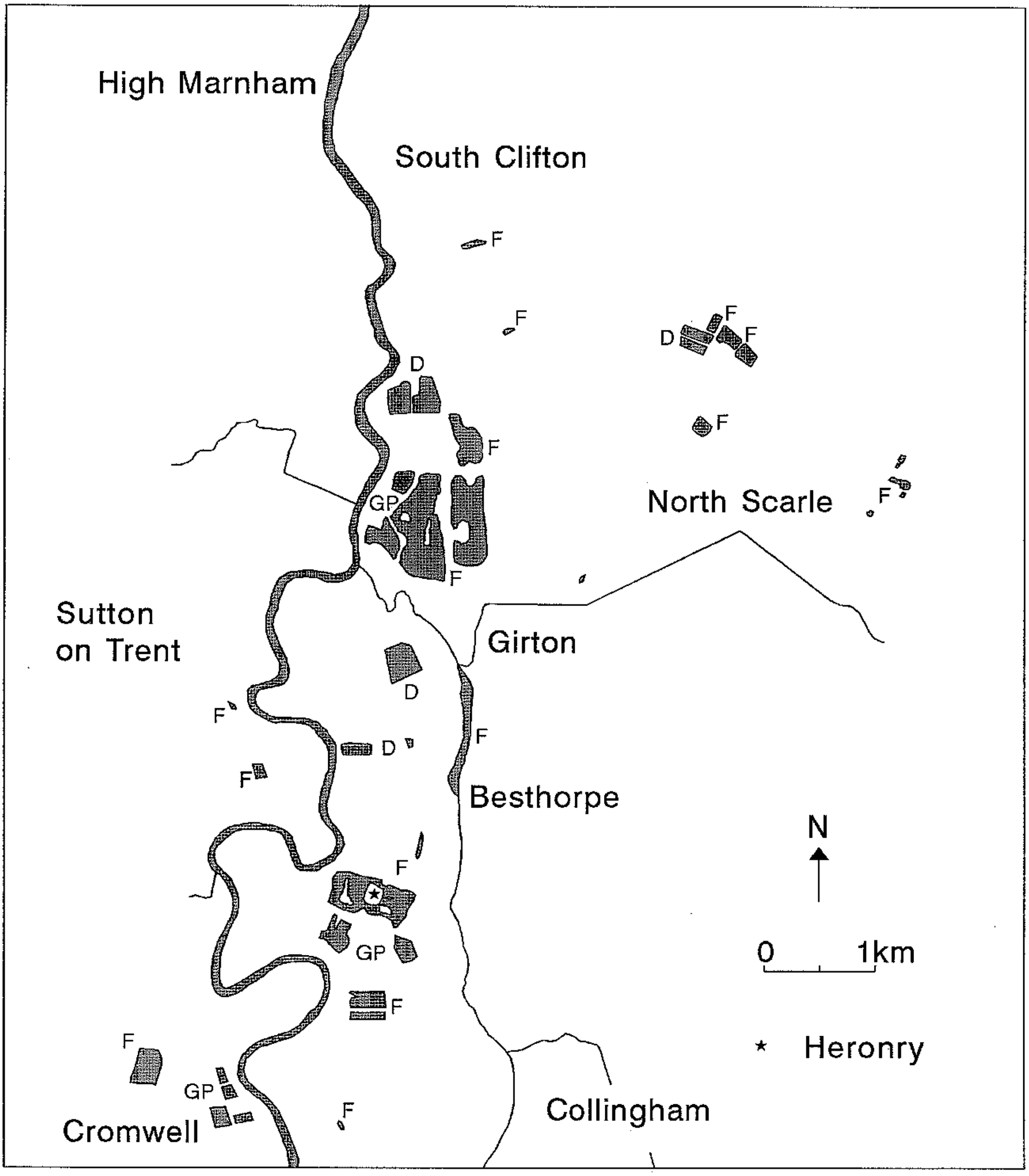

Figure 2.1.1. The northern part of the study area showing the heronry, waterbodies and larger watercourses. F = freshwater; GP = gravel pit in an area of active gravel extraction; D = fly-ash disposal site.

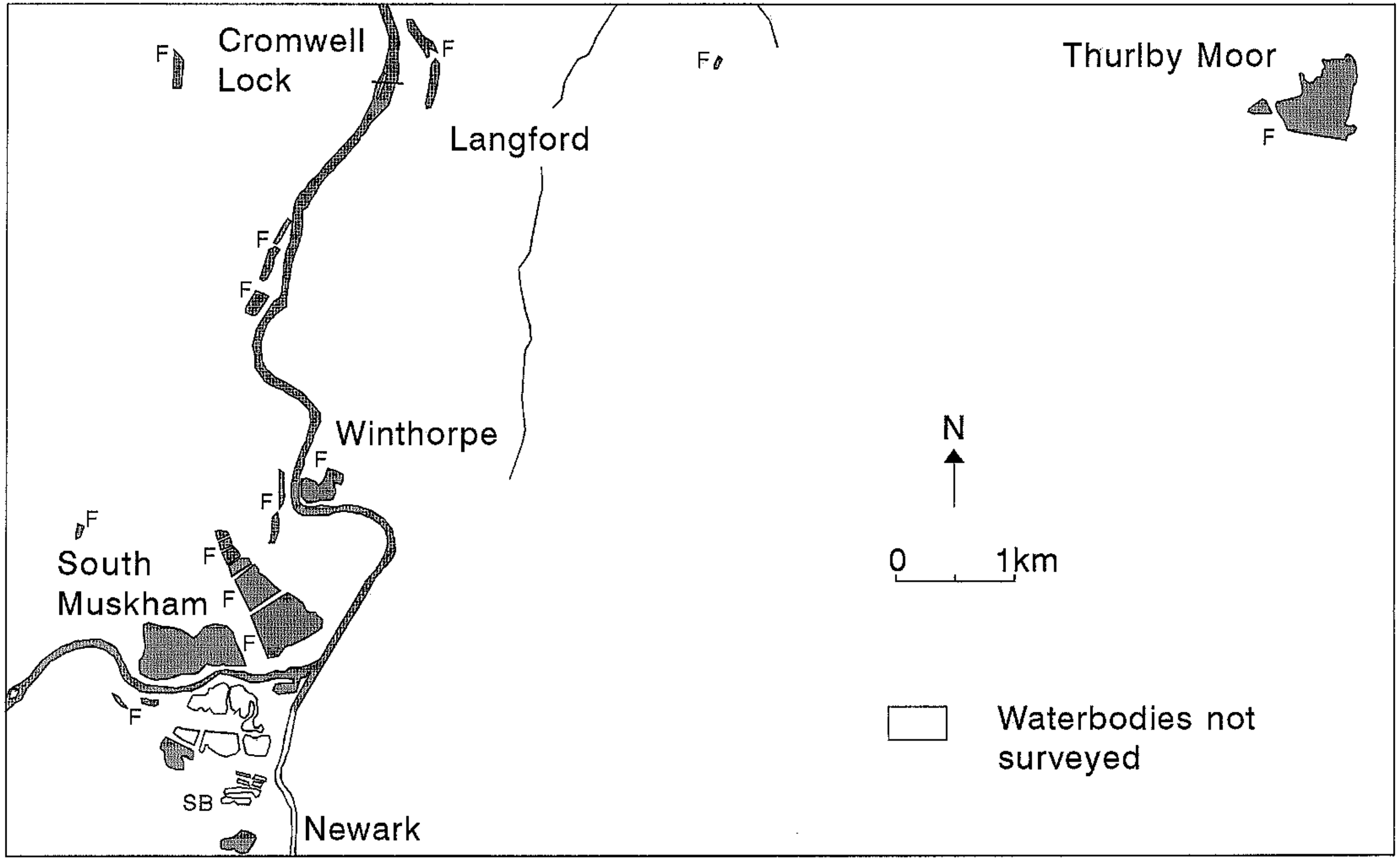

Figure 2.1.2. The southern part of the study area showing waterbodies and larger watercourses. F = freshwater; SB = sugar beet settlement pools.

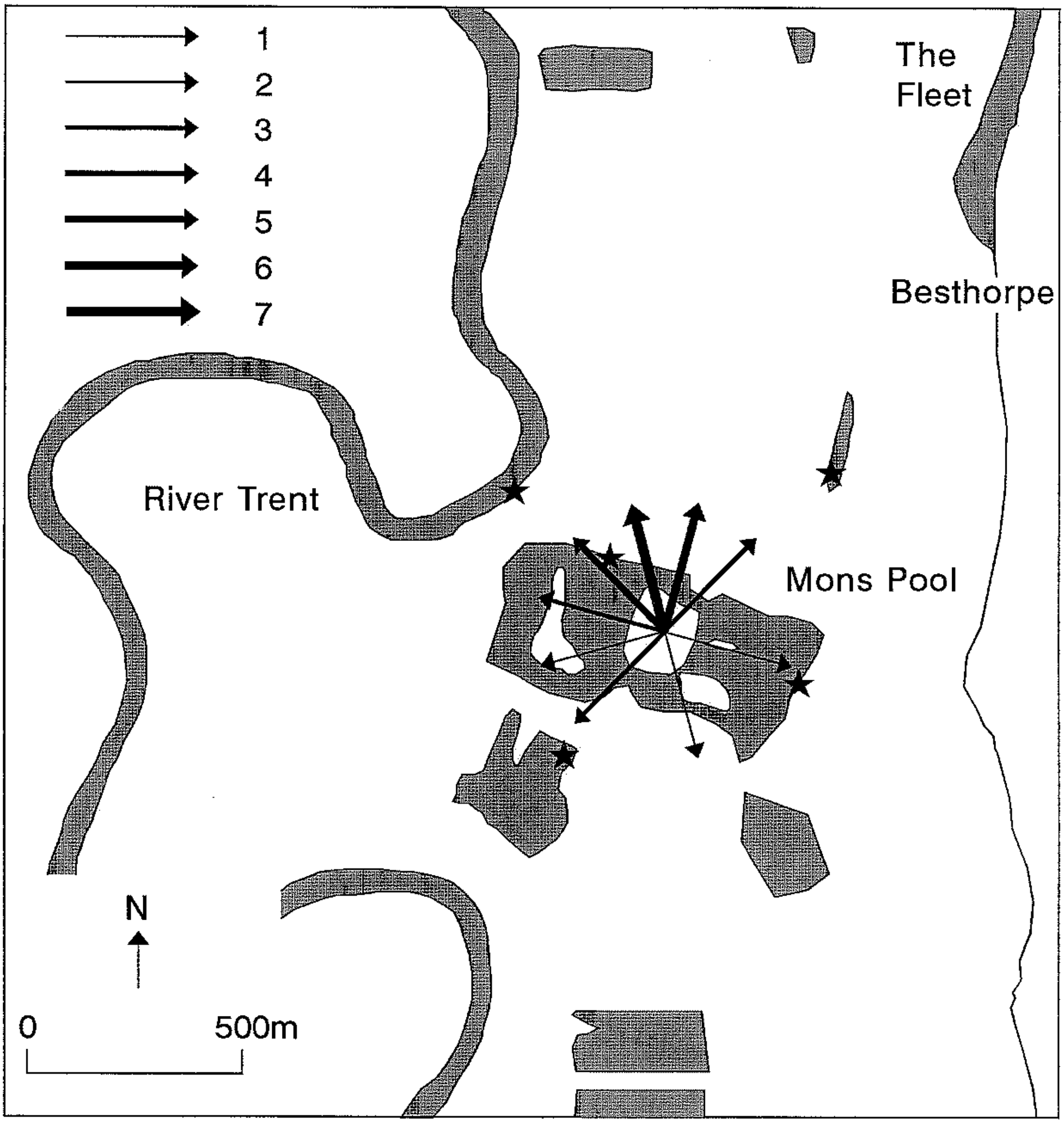

Figure 3.3.1. Flight lines of adult Grey Herons on leaving the nesting colony (n = 30). The number of flights recorded in a given direction is indicated by the thickness of arrow. Asterisks indicate places where birds were seen to land.

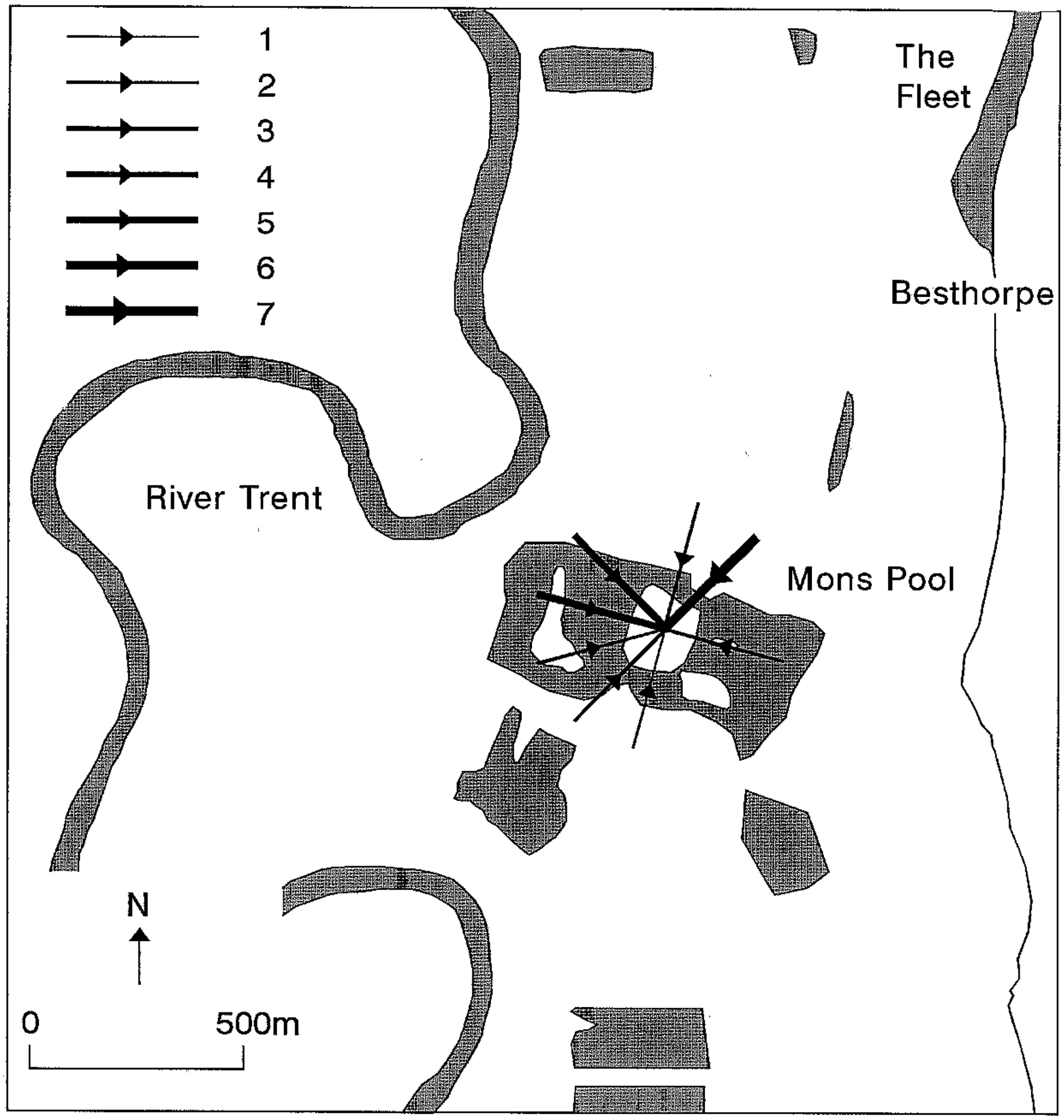

Figure 3.3.2. Flight lines of adult Grey Heron returning to the nesting colony (n = 26). The number of flights recorded from a given direction is indicated by the thickness of arrow.

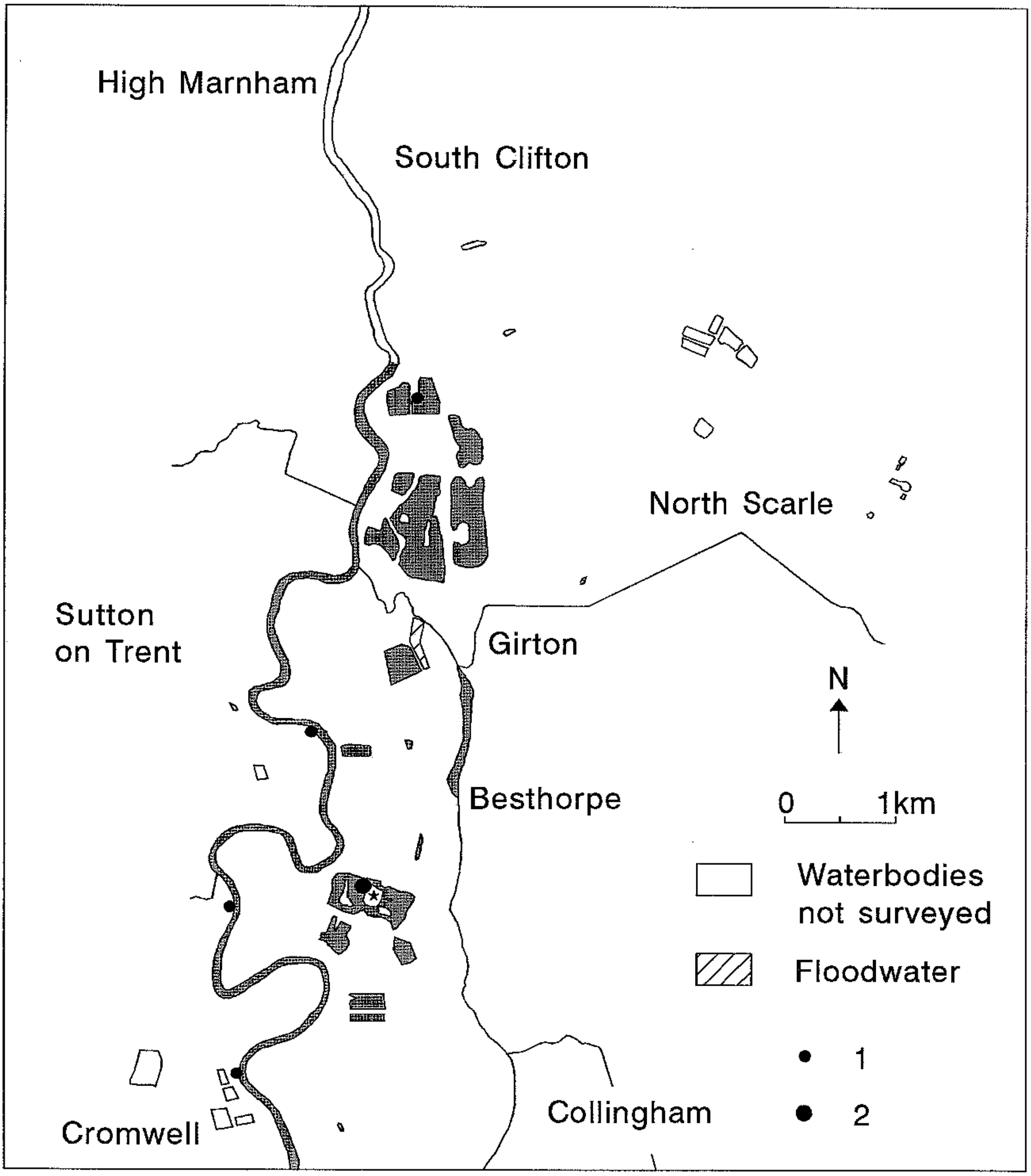

Figure 3.4.1. Distribution of adult Grey Herons (excluding those at the nesting colony) on an additional survey on 16 April 1998. Dot sizes indicate numbers of birds.

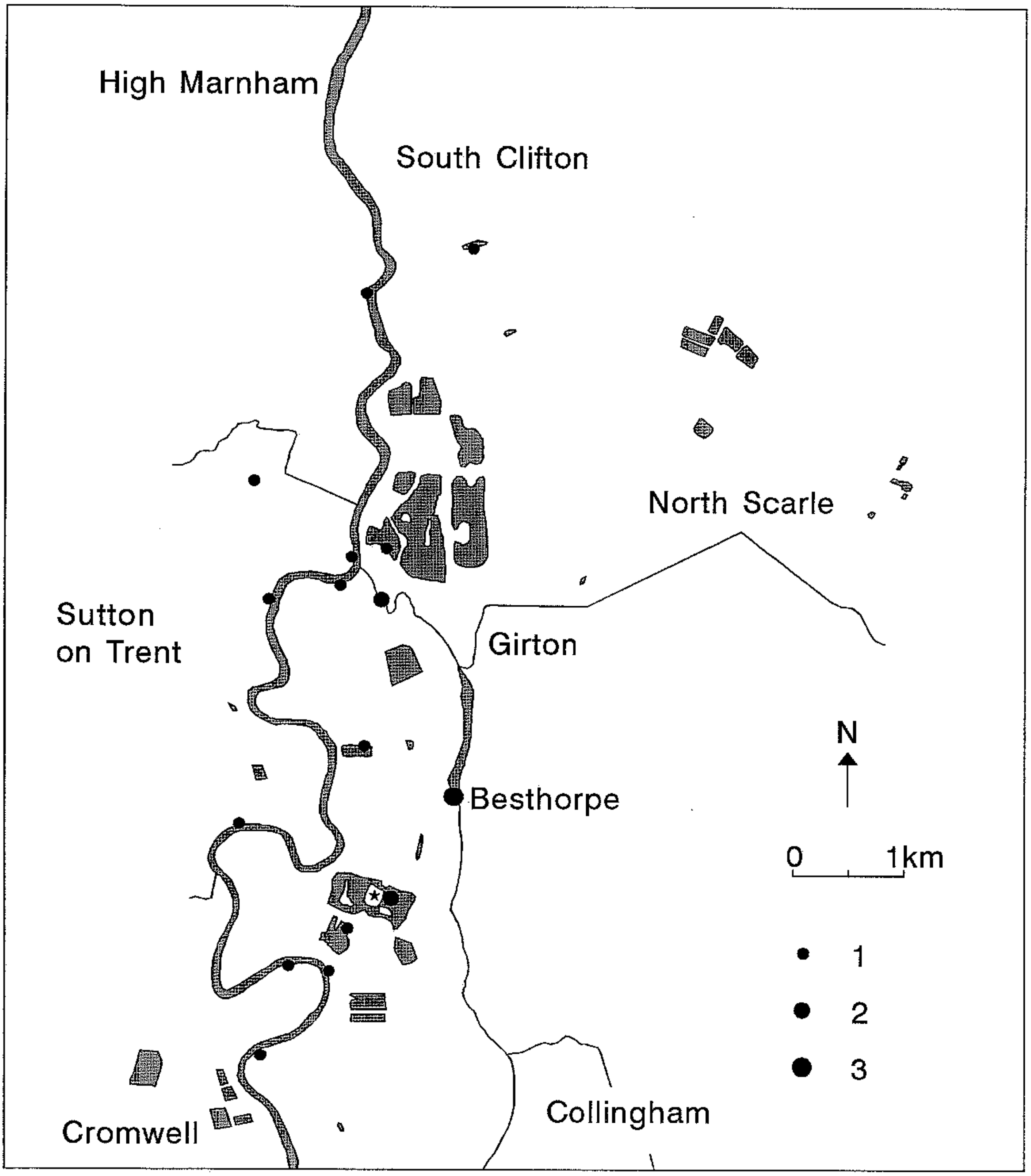

Figure 3.4.2. Distribution of adult Grey Herons (excluding those at the nesting colony) on three surveys from 27 April to 13 May 1998 (in the north of the survey area). Dot sizes indicate numbers of bird days.

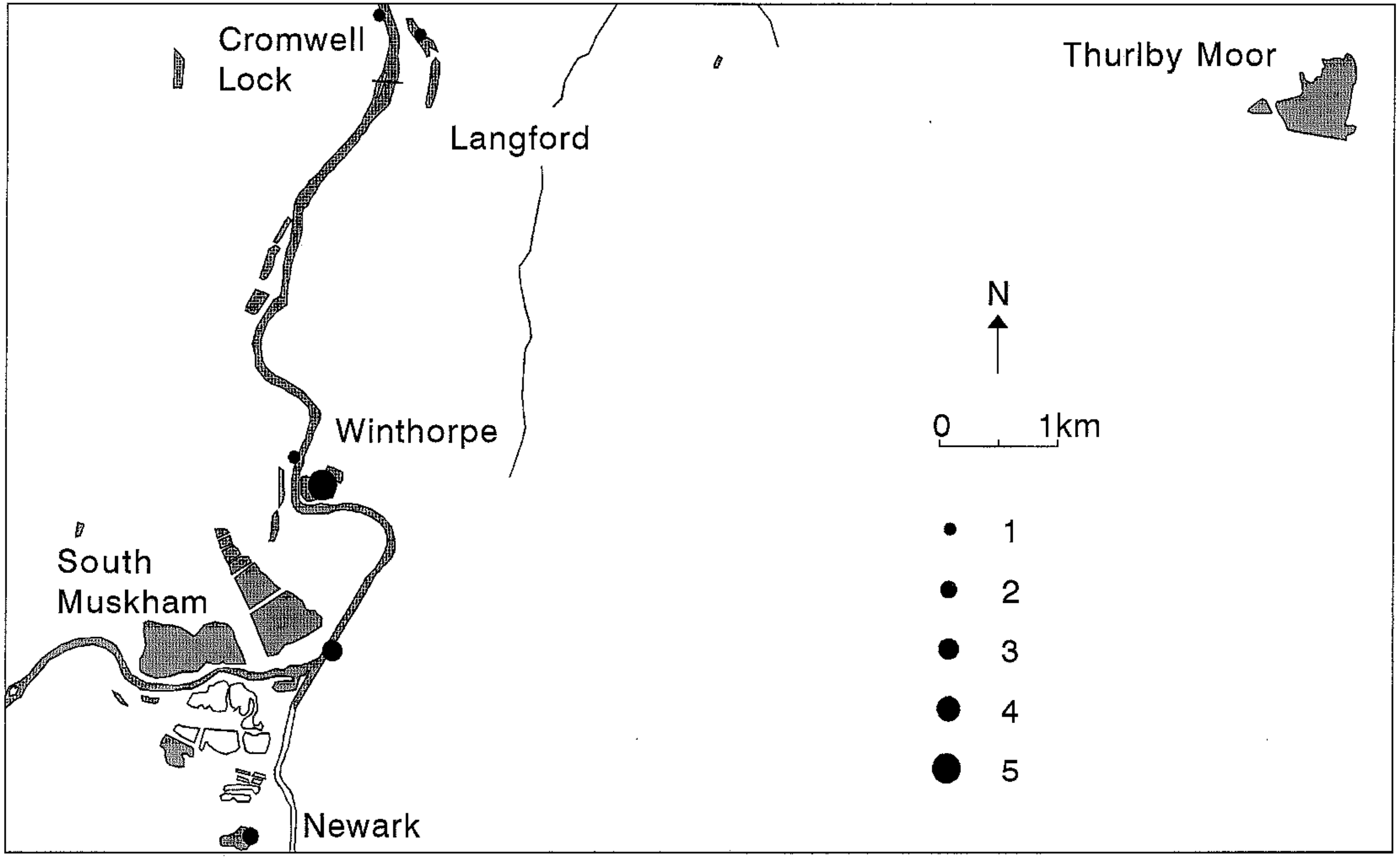

Figure 3.4.3. Distribution of adult Grey Herons on three surveys from 27 April to 13 May 1998 (in the south of the study area). Dot sizes indicate numbers of bird days.

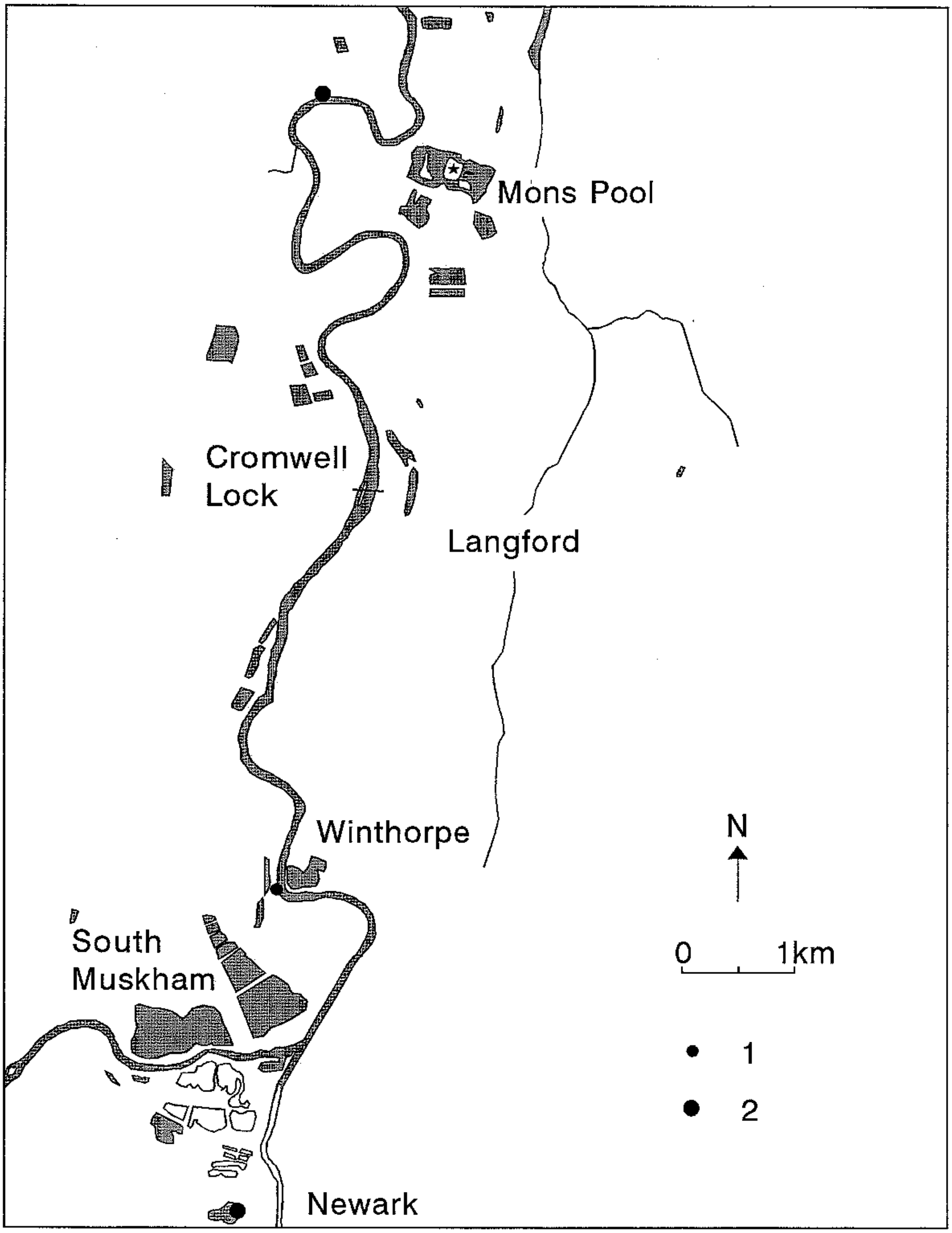

Figure 3.4.4. Distribution of juvenile Grey Herons (excluding those at Mons Pool and the nesting colony) on three surveys from 27 April to 13 May 1998. Dot sizes indicate numbers of bird days.