The Epidemiology and Control of an Outbreak of Foot-and-Mouth Disease in Ireland in 2001
J M. Griffin and P.J. O'Reilly

Introduction
A new epidemic of foot-and-mouth disease was detected in Great Britain in 2001 with the confirmation of the disease in pigs at a slaughter plant in Essex on the 20th of February. The index case was believed to have been a pig herd in Heddon on the Wall, Northumberland (Ferguson et al., 2001). From there, the disease spread rapidly due to local contact, windborne transmission and animal contact in markets combined with long-distance sheep movements. Cumbria, Dumfries, Galloway and Devon were particular foci of infection. Outbreaks were also recorded in France, Holland, Northern Ireland and Ireland. The epidemiological evidence suggested that these cases occurred as the result of movement of infected animals from Great Britain prior to the detection of the index case there.

Four outbreaks were recorded in Northern Ireland. The index case was confirmed in a flock of sheep at Meigh, Co. Armagh on March 1st. It is believed that this case arose as a result of the importation of a consignment of sheep from Great Britain on February 19th. Some of the sheep were present at a market in Carlisle at the same time as known infected animals. The consignment was certified for immediate slaughter in Northern Ireland. The sheep, however, were not slaughtered in Northern Ireland. Some of them were subsequently traced to two abattoirs and five farms in Ireland. Clinical examination of the remaining imported and the in-contact animals, and serological testing of these animals showed no evidence of foot-and-mouth disease.

Details of investigations conducted by staff at the Department of Agriculture and Rural Development in Northern Ireland along with the clinical observations on the nature of the disease in the infected sheep at Meigh were described by McManus and others (2001).

An outbreak of foot-and-mouth disease was confirmed in a flock of sheep on a farm in the Cooley peninsula in Co. Louth on March 22nd, 2001. Nucleotide sequencing on the virus protein one (VP1), demonstrated that the virus was similar to other viruses of the serotype “O” of the Pan Asian strain and the topotype was virtually indistinguishable from other isolates from Co. Armagh, Northern Ireland and Great Britain (Knowles et al., 2001; Knowles, pers. comm.).

This paper describes the outbreak in Ireland and the measures that were taken to eradicate it.

Description of the outbreak
The infected holding
The farm consisted of a mixed cattle, sheep and mushroom enterprises. A father and his two sons managed the holding. The father, who was in semi-retirement, was the registered herd owner. Most of the work involving the livestock was undertaken by one of the sons, who acted as the stock manager. The other son ran a mushroom enterprise adjoining the home farm at Jenkinstown. The latter also helped out with the livestock on occasions.

1 Central Veterinary Research Laboratory, Department of Agriculture, Food and Rural Development, Abbotstown, Dublin 15.
The infected holding consisted of approximately 119 hectares in eight fragments that were widely dispersed throughout the Cooley Peninsula (Figure 1). Clinical signs of foot-and-mouth disease were observed in sheep on the fragments at Broughattin/Proleek Upper and at Proleek Lower. These fragments were about 250 metres from each other and were connected by two private lanes at each end and by a narrow public road in the middle. A total of 74 pregnant sheep was brought to Broughattin/Proleek Upper and 40 pregnant sheep were brought to Proleek Lower in late January/early February, 2001 from the fragments at Rampark, Castlecarragh and Rathcor. There had been no sheep on the lands at Broughattin/Proleek Upper or Proleek Lower since the previous year. The stock manager intended moving them to Jenkinstown after 20 days (around March 1st) but was unable to do so because of the movement restrictions on livestock arising from the foot-and-mouth outbreak at Meigh, Co Armagh on the 1st of March. He moved 23 ewes that had not lambed from Proleek Lower to Broughattin/Proleek Upper by foot. He believed it was about 2 weeks before the visit by a team of veterinary inspectors to his farm on March 16th to carry out clinical inspections, i.e. between the 2nd and 9th of March. One of the sheep that had been brought to Proleek Lower had already died leaving sixteen ewes at Proleek Lower at the time of the outbreak.

An examination of the farm records indicated that no sheep had been purchased since September 12th, 2000. The stocking rates in each fragment at the time of the outbreak are given in Table 1.

**Outbreak details**

The flock inspection on March 16th revealed no clinical evidence of foot-and-mouth disease.

The stock manager first noticed clinical signs during his own supervision of the flock at Broughattin/Proleek Upper on Monday, March 19th. He noticed a ewe with her legs spread. He caught her and observed lesions in her mouth. He also noticed mouth lesions in a ewe that was lambing. He did not observe any signs of disease in the sheep at Proleek Lower. When he returned home that evening, he was informed that a veterinary surgeon was due to carry out an inspection of the flock the following morning. He decided to wait until then to inform them of his observations.

On the following morning, the stock manager's suspicions were corroborated by the veterinary inspector and by a research officer from the Regional Veterinary Laboratory, Abbotstown. Detailed clinical examinations were undertaken in approximately 10 sheep. In some of these, classical lesions of foot-and-mouth disease were observed. There were distinctive erosions of the upper and lower lips and dental pad. There was wetness and lesions around the coronary band. No lesions were observed on the tongues. One of the animals had a healing lesion, about 4-5 days old, on the dental pad. Details of the cases were described by Murphy (2001) and by McManus and others (2001). All of the sheep at Broughattin/Proleek Upper were immediately slaughtered on the 20th of March and disposed of by burial on the holding.

Two of the five epithelial samples that were taken before slaughter and sent to the Institute for Animal Health, Pirbright, were positive using the antigen capture ELISA (Ferris and Dawson 1988) and all of the samples were positive on tissue culture. Five heparinised blood samples were also taken. One of these was positive on culture. Five clotted blood samples taken from clinically affected sheep were positive for antibody using the Liquid Phase Blocking Elisa (LPBE) (Hamblin et al., 1986). Blood samples were collected from an additional 28 animals. Seventeen of these were positive to LPBE.
Following confirmation of foot-and-mouth disease on samples taken from the animals at Broughattin/Proleek on Thursday, March 22nd, the sheep on the other fragments were immediately slaughtered. Clinical signs consistent with foot-and-mouth disease were observed by veterinary personnel in sheep located at Proleek Lower. Blood samples were collected from all 16 animals. Fifteen samples were subsequently positive for antibody to LPBE and to the virus neutralisation test (VNT). Blood samples were also collected from sheep located on the other fragments (Table 2). One sample, from a sheep at Slievenaglogh, of the ten sampled was positive to the LPBE and negative to the VNT. In his report on this sample, Dr Paul Kitching, Institute for Animal Health, Pirbright concluded that this result “could indicate an early stage of infection”. Blood samples were collected from three cattle at Jenkinstown and from three cattle at Rathcor. All samples were negative.

**Possible dates of initial infection of the flock**

The serological data indicates that two cycles of infection may have occurred in sheep at the Broughattin/Proleek Upper and Proleek Lower fragments. This conclusion is based on the fact that samples from 15 (93 per cent) of the 16 adult sheep at Proleek Lower and 17 (60 per cent) of the 28 sheep sampled at Broughattin/Proleek Upper were positive to the ELISA test and thirteen (81 per cent) of the sheep at Proleek Lower and nine (32 per cent) at Broughattin/Proleek Upper had maximal titres of 2048. Samples from flocks in the UK examined at the acute stage of infection with the pan Asiatic strain of foot-and-mouth disease at the Institute for Animal Health, Pirbright yielded 5 per cent of sheep with significant titres. One of five plasma samples submitted for virus isolation from Broughattin/Proleek Upper was positive for virus whereas none of 16 serum samples from Proleek Lower were positive on virus isolation. This is not surprising considering the antibody titres. The date of initial infection of the flock was likely to be between February 25th and March 6th. This was based on the assumption that the foot-and-mouth lesions at the time of examination on March 20th were up to 4-5 days old and that the incubation period had a range of 5-9 days.

Based on the higher level of sero-conversion and higher titres, and failure to demonstrate viraemia in blood samples from Proleek Lower, infection was more likely to have originated at Proleek Lower than at Broughattin/Proleek Upper. This conclusion is consistent with the movement of sheep from Proleek Lower to Broughattin/Proleek Upper shortly before the observation of clinical signs.

**Source of infection**

No direct or indirect contacts could be confirmed with the outbreaks in Northern Ireland or Great Britain. However, the infected premises at Proleek Lower is located only nine kilometres from the infected premises at Meigh and there is strong circumstantial evidence of an indirect contact between the index case in Northern Ireland and a farm neighbouring the infected premises at Proleek Lower. The estimated time of infection, i.e. February 25th to March 6th was also closely related to the importation of a consignment of sheep to Meigh on February 19th. The topotype of the virus isolated from the infected sheep at Broughattin/Proleek Upper was virtually indistinguishable from that isolated in Northern Ireland and Great Britain. This suggests that the infected sheep at Meigh or other sheep from Great Britain in the same consignment were the source of infection for the sheep kept at Proleek Lower.

A plume model was used to assess the possibility that wind borne spread from premises in Meigh could have been responsible for the outbreak of foot-and-mouth disease in Broughattin/Proleek Upper and Proleek Lower (McGrath, Hammond and Towey, 2002). This analysis indicated that wind borne spread was very unlikely. The plume model was also used to assess the possibility that
wind borne spread from Great Britain. Again, this analysis indicated that wind borne spread was very unlikely.

The most likely mode of transmission of virus to the sero-positive sheep on the Slievenaglogh fragment, assuming that it was exposed, was the farm manager. He visited each fragment daily to feed and observe the sheep.

**Sero-conversions in other flocks in the Cooley peninsula**

One animal in each of two other flocks (Flocks A and B) and two wild goats were also sero-positive. The sero-positive sheep in Flock A grazed in a field adjoining the infected fragment at Broughattin/Proleek Upper (Figure 1). Twenty-five blood samples were taken from animals on this holding before the entire flock was slaughtered on 22\textsuperscript{nd} of March. One sample was positive to the LPBE with a titre of 362 and negative to the VNT. Assuming that this test result indicates recent exposure to virus, it is probable that it arose from contact with the infected flock.

The sero-positive animal in Flock B was part of a flock of approximately 226 sheep, mainly of the Kerry Hill breed. These sheep were kept on land adjoining the Jenkinstown fragment of the infected holding. Foot lesions were observed in two sheep on March 26\textsuperscript{th}. Tissue samples and blood samples were taken from these animals and forwarded to Pirbright for analysis. Fifty-seven blood samples were also taken from apparently healthy sheep. All of these samples were negative for foot-and-mouth disease. Because of the geographical association with a non-infected fragment of the infected holding, most of Flock B was slaughtered on 27\textsuperscript{th} and 28\textsuperscript{th} of March. Because of the rarity of the Kerry Hill breed, the flock owner made a case to the Department of Agriculture, Food and Rural Development to retain a small number of sheep. An agreement was reached permitting him to keep nine ewes and three rams under strictly controlled conditions, including regular serological testing. Blood samples were taken from these animals on the 28\textsuperscript{th} of March and one was positive to LPBE with a titre of 2048 and 64 to the virus neutralisation test. When these results became available on the 4\textsuperscript{th} of April the sheep were immediately slaughtered. The 12 animals were sampled again prior to slaughter. The animal that had previously been positive to the LPBE had a titre of 1448 and was again positive to the VNT. The other sheep were negative.

Some of the sheep in Flock B were kept on land directly adjoining the Jenkinstown section of the infected holding where ten sheep had been sampled with negative results. The reason for the seroconversion of the sheep in Flock B has not been determined.

Blood samples were taken from twenty-four wild goats that were culled from a mountain adjoining the land fragment at Slievenaglogh (where one sheep had been positive of ten sampled). Two of these were positive to the LPBE with titres of 256 and 181 and had inconclusive titres to the VNT. It was possible for the wild goats to graze on the affected land fragment. Assuming that the test result for the wild goats indicate exposure to virus, it is probable that they resulted from contact with the flock.
Control and eradication measures in the Cooley Peninsula

**Culling**

A small area of County Louth was inside the protection zone surrounding the Meigh, Co. Armagh outbreak (Figure 2). There were 11 holdings partially or completely within this area. A precautionary cull of sheep was carried out on four of the 11 holdings in early March when mouth lesions were discovered in three of the flocks during clinical inspections. This involved a total of 474 sheep. Samples were taken from the three flocks. All were negative.

All sheep at the holding in Broughattin/Proleek Upper were slaughtered on suspicion on Tuesday, March 20th. The sheep and cattle on the other fragments of the infected holding were slaughtered on March 22nd and March 23rd following the confirmation of the outbreak. The animals were buried, under the supervision of Louth County Council engineers, at four sites within the holding. The infected groups at Broughattin/Proleek Upper and Proleek Lower were buried on-site. The carcasses from the other fragments were transported and buried on two of the fragments at Castlecarragh and Rathcor. A total of 778 sheep (including lambs) and 113 cattle was slaughtered.

All cattle, sheep and goats on holdings within a 1 kilometre radius of the holdings at Broughattin/Proleek Upper and Proleek Lower were also slaughtered. Following the confirmation of a positive result in a sheep at the Slievenaglogh fragment and in Flock B, a decision was made to remove all cattle within one kilometre of these holdings also.

There was an extensive commonage on the Cooley Mountains. This covered an area of approximately 4,430 hectares and extended over a large part of Cooley peninsula (Figure 2). It contained a population of wild goats, wild deer and farmed sheep. Part of the commonage on which the wildlife grazed extended into the protection zone of the Meigh outbreak. The animals grazing in this area had access to the rest of the commonage. Following the receipt of positive blood tests in two wild goats and in a single sheep in Flock B on April 4th, a decision was made to remove all sheep in Co. Louth east of a line drawn northwards along or close to the R177 road from its junction with the N1 in Dundalk (Figure 2). The owners of sheep flocks in Co. Louth located west of this line and north of the N53 road were given the opportunity of a voluntary cull. A total of 2,067 sheep was slaughtered in 21 flocks. Ten flock owners declined to participate in the cull.

The total number of animals culled as a result of the outbreak at Meigh, Co. Armagh and Broughattin/Proleek, Co. Louth was 1,029 cattle from 46 holdings and 47,958 sheep from 260 holdings. A compulsory slaughter policy was also put in place for all farmed goats, deer and pigs in and the Cooley peninsula and that part of Louth north of the N53 road. A total of 98 farmed goats from 39 holdings, 282 farmed deer from two holdings and 70 pigs from 9 holdings was culled.

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2 In this paper a holding means all land either used by an owner of animals, whether solely or jointly with any other person or persons, for farming purposes or used by a dealer for or in connection with an animal purchased or disposed (by sale or otherwise) by him. This definition was taken from Statutory Instrument Number 308 of 1989.

3 This figure is the actual number of animals slaughtered. Other figures in this section were obtained from a database that contained details of animal valuations agreed between the herd owners and the Department of Agriculture, Food and Rural Development. In most cases a ewe and its nursing young was considered to constitute a single unit for valuation purposes. Thus some of the figures in this section are an underestimate of the number of animals culled.
The animals from the non-infected holdings were slaughtered at an abattoir located about 1 kilometre from the infected premises. This abattoir which had not been in use for the previous six years and was re-commissioned specifically for the foot-and-mouth cull and facilitated a rapid cull. Following slaughter, the carcasses were transported approximately 43 kilometres in sealed containers to a rendering plant in Co. Meath for disposal. All cattle and sheep within one kilometre and all sheep within three kilometres of the infected premises were slaughtered and removed to the rendering plant within 48 hours of confirmation of the outbreak. The whole cull was completed by April 11th, 2001.

**Surveillance Programme following the outbreak at Broughattin/Proleek**

A programme of clinical inspections operated in tandem with the slaughter programme. Prior to slaughter all animals were subjected to a clinical inspection carried out by a veterinary surgeon on the holding of origin. On completion of the slaughter programme, clinical inspections were carried out on the cattle remaining in the protection zone. A total of 114 visits to 111 holdings were completed between April 9th and April 11th. Blood samples were taken from 795 animals during these visits. All of these were negative.

Clinical inspections were also carried out on all herds remained in the surveillance zone. These were mainly cattle herds but there were also a few goatherds and ten sheep flocks. A total of 321 visits was completed between April 19th and April 23rd. Blood samples were taken from 5,783 cattle, 1,273 sheep and 6 goats. All of these were negative.

**Control of wildlife**

The wild goats and wild deer on the Cooley Mountains constituted a potential reservoir of foot-and-mouth disease for sheep that grazed the commonages in winter and for the lowland flocks at the foot of the mountains. These were slaughtered as a precautionary measure.

The cull of wildlife started on the 28th of March and was completed by the 1st of May. It was carried out by Irish Army Rangers, local units of the army and hunters under the supervision of Duchas, the National Parks and Wildlife Service. Wild goats were observed and culled in 11 locations (Figure 3 and Table 3).

A total of 238 free-roaming wild goats was culled. An additional nine wild goats which had strayed onto and remained on the lands of local farmers were also culled. Blood samples were taken from 99 goats. No additional positives were found to the two positives in the 24 animals sampled at Slievenaglogh.

A number of sheep could not be located when flock owners were rounding up their sheep on the commonages. Thirty-nine of these were subsequently located and culled by personnel involved in the wildlife cull. Blood samples were taken from 11 of these. All were negative.

Two red deer and two Japanese Sika were culled in Dromad forest. Blood samples were taken from the Japanese Sika deer. Both were negative.

**Discussion**

It is considered that the illegal importation of sheep from an infected area of Great Britain which were later unloaded in Northern Ireland was the indirect source of infection for the sheep at Proleek Lower. At the time of the outbreak, the identification of individual sheep was not compulsory. Legislation...
requiring all sheep to be individually identified was introduced in Ireland on 25th of May 2001. This measure should reduce the possibility of introducing the foot-and-mouth virus in the future by discouraging the illegal importation of sheep and facilitate the tracing of sheep movements.

The infected holding was located within the surveillance zone of the Meigh outbreak in Northern Ireland. This facilitated prompt identification of the outbreak and led to prompt and effective action, which involved the removal of susceptible animals over a wide geographical area at an early stage. This action was justified because of positive antibody titres for FMD on two other holdings in the Cooley area and in two wild goats and the over-riding importance of the livestock industry to the Irish economy. The subsequent absence of cases has confirmed that the eradication programme was successful.

A subsequent national serological surveillance programme showed that no other sources of disease remained in the country. In the period, May to July 2001, 159,868 blood samples were taken from sheep flocks and tested for antibody to FMD using the LPBE. None were positive.

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Herd/flock owners for providing information, particularly the owner of the infected premises.
Management, technical and administrative staff at the Local Disease Control Centre and the National Disease Control Centre. In particular, I would like to thank Mr Brendan Smith, SVI and Mr. Michael Fallon, SSVI for their help.
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Murphy, F. (2001).
Observations on FMD-infected sheep. The Veterinary Record 148: 791.

G.I.S Integration and Utilisation of the Foot and Mouth Disease Dispersion Model, In:Veterinary Epidemiology and Tuberculosis Investigation Unit, Selected Papers 2000 - 2001, 53 - 56.
Table 1. Number of cattle and sheep on land owned or rented at the time of the outbreak.

<table>
<thead>
<tr>
<th>Townland name(s)</th>
<th>Size (ha)</th>
<th>Owned/rented</th>
<th>Number of cattle</th>
<th>Number of sheep*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broughattin/Proleek Upper</td>
<td>8.8</td>
<td>Owned</td>
<td>0</td>
<td>97</td>
</tr>
<tr>
<td>Proleek Lower</td>
<td>4.7</td>
<td>Owned</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>Jenkinstown</td>
<td>25.9</td>
<td>Owned</td>
<td>46</td>
<td>89</td>
</tr>
<tr>
<td>Slievenaglogh 1</td>
<td>8.4</td>
<td>Rented</td>
<td>0</td>
<td>37</td>
</tr>
<tr>
<td>Slievenaglogh 2</td>
<td>14.0</td>
<td>Owned</td>
<td>0</td>
<td>88</td>
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<tr>
<td>Rampark</td>
<td>18.6</td>
<td>Owned</td>
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<td>106</td>
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<td>Castlecarragh</td>
<td>15.9</td>
<td>Owned</td>
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<td>88</td>
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<tr>
<td>Rathcor</td>
<td>22.6</td>
<td>Owned</td>
<td>67</td>
<td>105</td>
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<tr>
<td><strong>Total</strong></td>
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<td></td>
<td><strong>113</strong></td>
<td><strong>538</strong></td>
</tr>
</tbody>
</table>

*Lambs were not included in the count

Table 2. Serological results from sheep on the infected holdings.

<table>
<thead>
<tr>
<th>Townland name(s)</th>
<th>Total number of adult sheep on fragment</th>
<th>Number of sheep sampled</th>
<th>Positive to antibody titre ELISA</th>
<th>Positive to virus neutralisation test</th>
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<tbody>
<tr>
<td>Broughattin/Proleek Upper</td>
<td>97</td>
<td>28</td>
<td>17</td>
<td>Not tested</td>
</tr>
<tr>
<td>Proleek Lower</td>
<td>16</td>
<td>16</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Jenkinstown</td>
<td>89</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Slievenaglogh 1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Slievenaglogh 2</td>
<td>37</td>
<td>10</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Rampark</td>
<td>106</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Castlecarragh</td>
<td>88</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rathcor</td>
<td>105</td>
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<td>0</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>538</strong></td>
<td><strong>93</strong></td>
<td><strong>33</strong></td>
<td><strong>15</strong></td>
</tr>
</tbody>
</table>

Table 3. Number of wild goats and sheep culled at different locations.

<table>
<thead>
<tr>
<th>Location</th>
<th>Goats</th>
<th>Sheep</th>
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<tbody>
<tr>
<td>Feede/Dromad Wood</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>Edentubber</td>
<td>19</td>
<td>4</td>
</tr>
<tr>
<td>Ravensdale</td>
<td>57</td>
<td>4</td>
</tr>
<tr>
<td>Annaverna/Black Mountain</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>Clermont</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Rockmarshall</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Annaloughan</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>Slievenaglosh</td>
<td>49</td>
<td>0</td>
</tr>
<tr>
<td>Carlingford Mountain</td>
<td>27</td>
<td>22</td>
</tr>
<tr>
<td>Bavan/Tullaghomeath</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>Ballymakellett</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>On farm</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>247</strong></td>
<td><strong>39</strong></td>
</tr>
</tbody>
</table>
Figure 1  Map of Cooley Peninsula, Co. Louth showing relevant holdings.
Figure 2  Location of commonage and cull zones.
Figure 3  Locations at which wild goats and stray sheep were culled.