Enhanced Biodiversity and the risk to food safety: Campylobacter and poultry

Elm Farm Research Centre, February 2005

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ABSTRACT

Organic farming is well documented and widely accepted as having a beneficial impact on the environment. However, this benefit is perceived to be combined with a risk to food safety. It is suggested that as the biodiversity and biomass of wild animals and birds increase, the risk of these creatures introducing and transmitting food borne pathogens to farm animals, and then into the human food chain, is increased. Campylobacter has been suggested as a particular risk for organic and free-range poultry systems. This is because wild animals and birds are known to be potential carriers of this pathogen. It has been suggested that, through contact with faecal matter from these animals and birds, the pathogen could be transmitted to poultry flocks (Bates, *et al.* 2004) and create a risk to subsequent carcase meat and therefore food safety. It is currently unclear if increasing biodiversity does increase the risk and presence of campylobacter.

Preliminary trials based at a UK organic farm were used to explore this issue. The presence of campylobacter through the production cycle, and around the range, was investigated, alongside the various areas of the farm, including livestock and biodiversity 'hot spots' and aspects of management including vehicles used to service the poultry system. This was done to investigate whether, and if so how, where and when, campylobacter enters the system. The study was also undertaken to investigate whether campylobacter can be associated with increased biodiversity.

The preliminary study suggests no real effect of the increase in biodiversity found on organic farms, in the level of campylobacter. The samples, which were found to be campylobacter positive, are from species that are present on conventional broiler farms as well as organic farms, including rats and sparrows, and have been found to be transmission vectors for conventional broilers (Bates, *et al.* 2004, Chuma, *et al.* 2000, Hänninen 2004). This work suggests some possible issues with management that may be acting as a route of transmission of campylobacter between different flocks on the farm. The study also identified a possible role for livestock in the transmission of campylobacter between different flocks, and suggested that efforts should be made to keep these enterprises as separate as possible. However, issues have been raised about the difficulty, when sampling for biodiversity, of identifying samples with viable campylobacter pathogen within it. Although the fragility of the campylobacter pathogen in relation to oxygen and cold would seem to be an inhibiting factor in terms of the transmission from wild animals to poultry flocks, the sheer volume of poultry on the farm means that this fragility could be overcome. Further work is needed to explore the complex relationship between campylobacter presence and its transmission into organic poultry flocks.

1. INTRODUCTION

1.1 <u>Background</u>

Organic farming is well documented (Hole, *et al*. 2005), and accepted by the UK government, as having a beneficial impact on the environment (Costigan, *et al*. 2003). It has been accepted by the most progressive organic farmers that biodiversity has benefits to the production system and that management of both should, as far as possible, be complementary. This holistic approach is regarded as one of the strengths of good organic farming.

This benefit, however, can be perceived to be combined with a risk to food safety. It is suggested that as the biodiversity and biomass of wild animals and birds increase, the risk of these creatures introducing and transmitting food borne pathogens to farm animals, and then into the human food chain, is increased. Of particular concern are *salmonella, E. coli and campylobacter*.

Campylobacter is the most common cause of gastroenteritis in the United States, (Altekruse, *et al*. 1999, Bryan and Doyle 1995), the UK (Anon 2003, Frost 2000) and indeed worldwide, especially in developed countries (Bates, *et al.* 2004, Charlett *et al.* 2003, Tam *et al.* 2003b, Saleha, *et al*. 1998). Its route of transmission to humans is varied but it is most commonly cited as being through the ingestion of raw or undercooked poultry meat and milk, as it is found on poultry meat and within un-pasteurised milk. It can also be acquired through pets, wild animals, directly from farm animals and from water sources (Javid and Ahmed 2002).

Campylobacter jejuni has been identified as the predominant cause of campylobacter related gastroenteritis (Tam *et al.* 2003a), but *C.coli* (Anon 2003, Tam *et al.* 2003b) and other species and their sub-types, such as *C.lari* (Newell 2000), *C.upsaliensis*, *C.fetus* and *C.hyointestinalis* (Javid and Ahmed 2002) can be responsible. Alongside the risk to humans from gastroenteritis, *C.jejuni* infection can result in a Guillan-Barre syndrome a rare but serious condition (Nachamkin *et al.* 1998, Tam *et al.* 2003a).

Campylobacter has been suggested as a particular risk for organic poultry systems and products as wild animals and birds, e.g. sparrows, are known to be potential carriers of campylobacter (Chuma, *et al.* 2000, Hänninen 2004). Although the method of transmission of campylobacter into poultry flocks is still unclear (Hiett, *et al.* 2003), it has been hypothesised that through contact with faecal matter from these animals and birds the pathogen can be transmitted to poultry flocks. This would then create a risk to subsequent carcase meat and food safety. It has been suggested that organic poultry are at particular risk from *campylobacter* as they are more likely to pick up campylobacter from the environment, than flocks in conventional housing systems (Engvall 2001, Heuer *et al.* 2001, Humphrey 2002). Some research has suggested that free-range poultry and products (Atterbury *et al.* 2003) are also more likely to harbor campylobacter than conventional or standard products. One study in particular suggests over 50 percent flock infection in conventional flocks and 80 percent flock infection in free-range broilers (Avrain *et al*. 2003). However it is currently far from clear whether increasing biodiversity, as occurs in organic farming, does in fact increase the risk or presence of campylobacter within these systems.

There have been proposals of how to overcome this perceived risk to food safety. In particular it has been proposed that poultry flocks should be kept free of pathogens. To achieve this poultry will have to be either kept permanently housed or isolated from the sources of contamination such as wild birds.

These proposals run counter to the principles of organic production and prohibit the production for organic poultry. There are also animal health and welfare issues of raising poultry within fully housed systems. They could also have a detrimental impact on the, currently positive, public perception of the interface between conservation and increasing biodiversity. Currently there is little evidence as to risk to food safety and organic bio-diverse systems relative to other risk sources. There is therefore a strong case to "get a handle" on this issue and gather more information to evaluate the risk.

1.2 Aims and Objectives

To carry out a preliminary investigation to establish whether, and if so how, when and where campylobacter enters the poultry system on organic farms and whether this can be associated with the increased biodiversity of the system.

2. METHODOLOGY

2.1 Location

A UK based organic farm (to EU regulations) was the site for this preliminary investigation. This farm has an active policy of biodiversity enhancement, including significant efforts to increase the wild bird population.

2.2. Test Sites

The presence of campylobacter through the production cycle, in the birds themselves and their environment, and around the range was investigated. In addition to this, the general farm environment was investigated for the presence of campylobacter. This included various areas or 'sites' on the farm that could potentially transmit the campylobacter pathogen to the poultry. These were generally areas of the farm with different activities and levels of biodiversity, with particular attention to 'areas' close to or relevant to the poultry enterprise. Broadly, these areas covered poultry sites, biodiversity 'hotspots', other livestock, and aspects of poultry management, including vehicles used to service the poultry system and stock team.

2.2.1 Production tests – Batch of birds

One batch of birds was followed through its production cycle. This was planned to be for a ten-week period. However, after early positive campylobacter results subsequent testing was viewed to be unnecessary. Samples taken for this batch of birds included both faecal and samples from the shed environment.

Environmental swab samples were obtained from the prepared brooder sheds before the arrival of the day-old birds. These included, samples from the shed furniture (perches 1 swab, walls 2 swabs, shavings 1 swab, and cardboard 1 swab), and from the feeders and drinkers (feeders 1 swab, feed 1 swab, drinker 1 swab, apple drinker 1 swab). Shed furniture swabs for each brooder shed were combined and analysed on one plate; as were all feeder and drinker swabs (see figures 1a and b and picture 1, for brooder layout and sample sites). In addition, environmental swabs were obtained from chick crates in which the birds arrived.

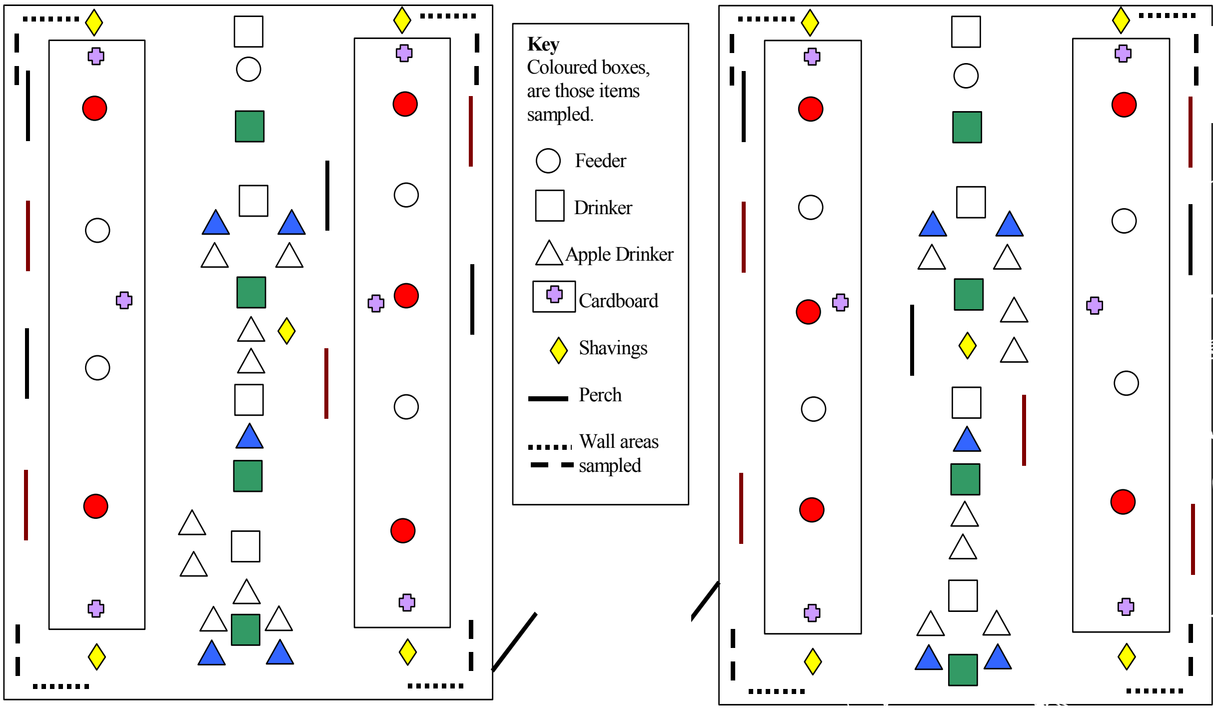

Figure 1a. *Brooder five set up and tests carried out* ***Figure 1b.*** *Brooder six set up and tests carried out*

Faecal samples were obtained from a sample of birds from each brooder, and analysed on week one, day one and week two, day eight.

Environmental swab samples were obtained from the prepared field sheds before the transfer of the birds to the field environment. Once again these included samples from the shed furniture (perches 1 swab, walls 2 swabs, straw 1 swab, and dustbather – based outside 1 swab), and from the feeders and drinkers (feeders 1 swab, feed 1 swab, drinker 1 swab, grit 1 swab). Shed furniture swabs for each brooder shed were combined and analysed on one plate; as were all feeder and drinker swabs (see figures 2a and b and picture 2 for field shed layout and sample sites). In addition, environmental swabs were obtained from module crates in which the birds were transported.

Faecal samples were obtained from a sample of birds from each shed, and analysed on week four, (day 22/24) and week seven (day 44) (as part of the "all birds on site" sampling).

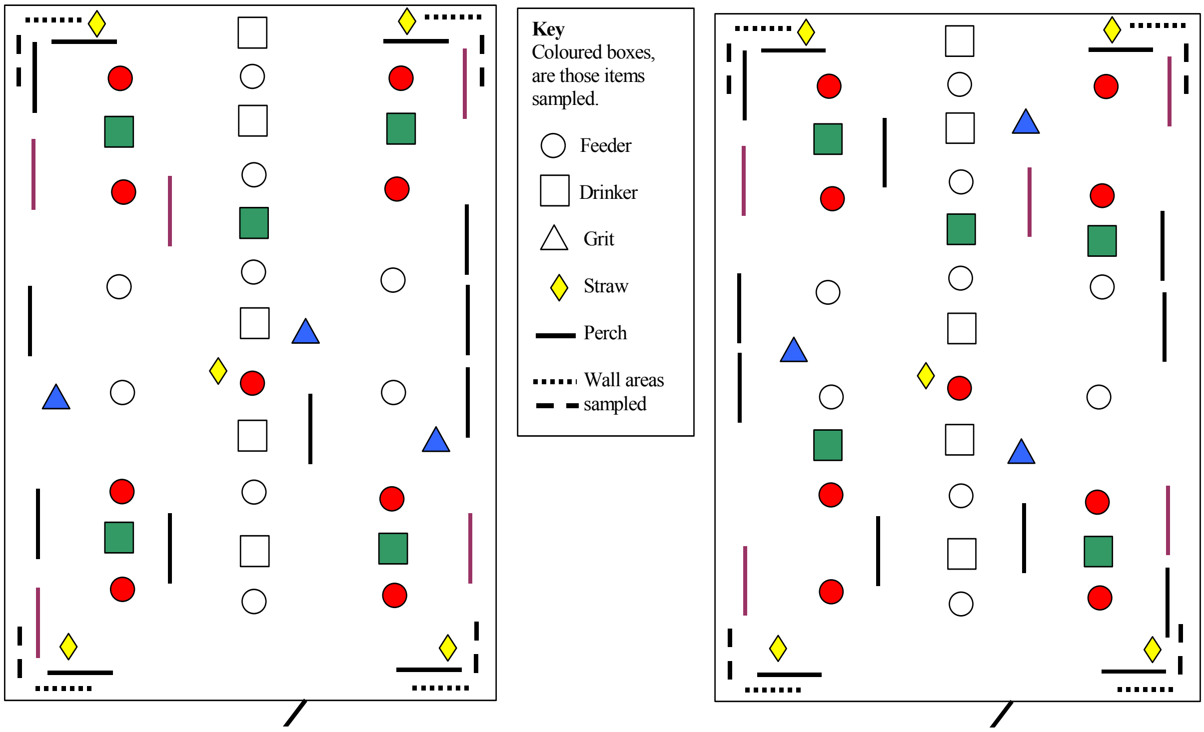

Figure 2a. *Field shed one set up and tests carried out* ***Figure 2b.*** *Field shed two set up and tests carried out*

2.2.2 Production tests – All birds

Faecal samples were obtained from a sample of birds from all field sheds on site, on a selected day, to get a snapshot of the loading of campylobacter across the poultry system at any one time.

2.2.3 Environmental tests

Various sites were tested around the farm for campylobacter. These included environmental swabs on surfaces and faecal samples from wild animals and birds. These sites included biodiversity hotspots and some areas surrounding the poultry production areas. Photographs of some of the test sites can be found in the appendices and a full list of sites is included in table 5.

2.2.4 Management and vehicles tests

Swabs were collected from stock team's boots, vehicles used for the poultry enterprise and other key areas. Photographs of some of the test sites can be found in the appendices and a full list of sites can be seen in the table 6.

2.2.5 Livestock tests

Faecal samples were taken from livestock located in geographically different locations on the farm and tested for campylobacter. Photographs of some of the test sites can be found in the appendices and a full list of sites where livestock were tested can be seen in the table 7.

2.2.6 Multi-sites

Some of the sites in which either environmental or faecal samples were collected, are multi-sites, combining management, livestock and bio-diversity. These are sites that appear more than once across two of the results tables. For example site 22, Sheep Field, appears in the environmental sampling table and livestock table.

2.3 <u>Equipment and sample collection methods</u>

2.3.1 Equipment

Sterile charcoal swabs were used to collect all the swab samples, and sterile faecal pots were used to collect faecal samples.

2.3.2 Sample collection

Production Birds

Faecal Samples – For birds aged week one through four, ten birds were randomly selected and placed in clean pet box (see picture 3) to produce samples. All samples were placed in one faecal pot for dispatch and analysis.

For birds aged week five through seven, five birds were randomly selected and placed in clean pet box to produce samples. In addition samples were obtained by collecting five freshly produced faeces from inside the shed. This approach was used to prevent stressing the birds through catching and handling at this later stage in the production cycle. All samples were placed in one faecal pot for dispatch and analysis.

Picture 1. *Chicks in clean pet box, for collection of faecal samples.*

For birds aged week-eight through ten, a set of three birds and then two birds were randomly selected and placed in a clean pet box to produce samples. In addition samples were obtained by collecting five freshly produced faeces from inside the shed. This approach was used to prevent stressing the birds through catching and handling at this later stage in the production cycle. All samples were placed in one faecal pot for dispatch and analysis.

Environmental Samples - Samples were obtained by wiping the swab over the surface of the object in a X pattern, constantly turning the swab, for total coverage.

Other Samples

Environmental - Samples were obtained by wiping the swab over the surface of the object in a X pattern, constantly turning the swab, for total coverage.

Faecal - As many fresh faecal samples as possible that were found in the immediate vicinity were obtained for each species. In some cases this was not possible as only limited amounts of faecal matter were found, for example for the larger wild animals.

2.4 Sample testing

All samples were sent for testing using Royal Mail guaranteed next day delivery; to ensure samples were as fresh and viable as possible. They were tested at Wincanton Laboratories, Wincanton, Somerset.

3. RESULTS

3.1 Production birds – Batch of birds

Table 1 shows the results for the swabbing of the brooders prior to bird arrival, from the chick trays and week one faecal samples. The results from all of the analysis of these samples were campylobacter negative.

Week/Day	Brooder	Sample Type	Further details (Plate group)		Result
Week 1 / Day 1	5	Environmental swab	Feeders and drinkers	Feeders	Negative
				Feed	
				Drinkers	
				Apple Drinkers	
	5	Environmental swab	Shed and Furniture	Walls (short)	Negative
				Walls (long)	
				Perches	
				Shavings	
				Cardboard	
	5	Faecal			Negative
	6	Environmental swab	Feeders and drinkers	Feeders	Negative
				Feed	
				Drinkers	
				Apple Drinkers	
	6	Environmental swab	Shed and Furniture	Walls (short)	Negative
				Walls (long)	
				Perches	
				Shavings	
				Cardboard	
	6	Faecal			Negative
	5 & 6	Environmental swab	Chick trays	Trays for brooder five	Negative
				Trays for brooder six	Negative

Table 1. *Production batch, week one results, brooders, trays and faeces.*

Table 2 shows the results for the faecal samples for the production batch of birds in week two. The results from the analysis of these samples were campylobacter negative

Week/Day	Brooder	Sample Type	Result
Wk 2 / Day 8	5	Faecal	Negative
	6	Faecal	Negative

Table 2. *Production batch, week two results for faecal samples.*

Table 3 shows the results for the swabbing of the field sheds prior to the transition of the birds to the field, the module crates used to transfer the birds and week four faecal samples. At this stage the birds were analysed as campylobacter positive. In addition, the clean field shed and furniture was campylobacter positive, along with one module crate sample.

<table>
<tr><th>Week/Day</th><th>Brooder / Field Shed</th><th>Sample Type</th><th colspan="2">Further details (Plate group)</th><th>Campylobacter Result</th></tr>
<tr><td rowspan="11">Week 4 / Day 22</td><td rowspan="4">5 / 1</td><td rowspan="4">Environmental swabs</td><td rowspan="4">Feeders and drinkers</td><td>Feeders</td><td rowspan="4">Negative</td></tr>
<tr><td>Feed</td></tr>
<tr><td>Drinkers</td></tr>
<tr><td>Grit & dispenser</td></tr>
<tr><td rowspan="5">5 / 1</td><td rowspan="5">Environmental swabs</td><td rowspan="5">Shed and Furniture</td><td>Walls (short)</td><td rowspan="5">Positive (2)</td></tr>
<tr><td>Walls (long)</td></tr>
<tr><td>Perches</td></tr>
<tr><td>Straw</td></tr>
<tr><td>Dustbather</td></tr>
<tr><td>5 / 1</td><td>Environmental swab</td><td>Module trays</td><td>Trays</td><td>Positive (2)</td></tr>
<tr><td>5 / 1</td><td colspan="3">Faecal</td><td>Positive</td></tr>
<tr><td rowspan="11">Week 4 / Day 24</td><td rowspan="4">6 / 2</td><td rowspan="4">Environmental swabs</td><td rowspan="4">Feeders and drinkers</td><td>Feeders</td><td rowspan="4">Negative</td></tr>
<tr><td>Feed</td></tr>
<tr><td>Drinkers</td></tr>
<tr><td>Grit & dispenser</td></tr>
<tr><td rowspan="5">6 / 2</td><td rowspan="5">Environmental swabs</td><td rowspan="5">Shed and Furniture</td><td>Walls (short)</td><td rowspan="5">Positive (2)</td></tr>
<tr><td>Walls (long)</td></tr>
<tr><td>Perches</td></tr>
<tr><td>Straw</td></tr>
<tr><td>Dustbather</td></tr>
<tr><td>6 / 2</td><td>Environmental swab</td><td>Module trays</td><td>Trays</td><td>Negative</td></tr>
<tr><td>6 / 2</td><td colspan="3">Faecal</td><td>Positive</td></tr>
</table>

Key

Positive — Isolated direct from culture

Positive (2) — Isolated from enrichment culture

Table 3. *Production batch, week four results, field shed, trays and faeces*

3.2 Production results – All birds

The results for the faecal samples obtained from a sample of birds from each shed on site on one day are shown in table 4. There is a trend for a campylobacter positive result in the older birds on the site.

Brooder / Field Shed	Batch No.	Age (weeks /days)	Campylobacter Results
B 7	4/260105	1 / 1	Negative
B 8	4/260105	1 / 1	Negative
B 3	3/180105	2 / 8	Negative
B 4	3/180105	2 / 8	Positive (3)
B 5	2/110105	3 / 15	Negative
B 6	2/110105	3 / 15	Positive (4)
B 1	1/040105	4 /22	Negative
B 2	1/040105	4 / 22	Positive (5)
F 5	53/281204	5 / 30	Positive
F 6	53/281204	5 / 30	Positive
F 3	52/211204	6 / 37	Positive
F 4	52/211204	6 / 37	Positive
F 1	51/141204	7 / 22	Positive
F 2	51/141204	7 / 44	Positive
F 15	50/071204	8 / 51	Positive
F 16	50/071204	8 / 51	Negative
F 13	49/301104	9 / 58	Positive
F 14	49/301104	9 / 58	Positive
F 9	48/231104	10 / 65	Positive
F 10	48/231104	10 / 65	Positive

Key

Positive (3) Grew on initial culture but could not be isolated

Positive (4) Possible campylobacter, overgrown by another organism identification difficult

Positive (5) Possible campylobacter, not typical on gram plate

Table 4. *Results for faecal samples for all birds on site.*

3.3 Environmental tests

Table 5 lists all the sites at which environment sampling was undertaken, the individual samples obtained at the sites and their nature and the result when that sample was analysed. There is large variability between the same kinds of sample obtained at different sites.

Site No.	Site Name	Sample Type	Further details (Plate group)		Result
1	Grange	Swab	Barn area	Stock dove nest box	Negative
				Floor	Negative
				Walls	Negative
		Faecal	Wild bird faeces		Negative
		Other	Owl pellet		Negative
2	Rabbit Burrow	Faecal	Rabbit faeces		Negative
3	Badger Set & Latrines	Swab	Nest material	Bedding expelled from nest	Negative
		Faecal	Badger faeces		Negative
4	Melvilles Trees	Faecal	Wild bird faeces		Negative
			Badger faeces		Negative
			Rat / mammal faeces		Negative
5	Melvilles Trees - fence line	Faecal	Fox faeces		Negative
			Wild bird faeces		Negative
6	Black Barn	Faecal	Rat faeces	By box	Negative
			Rat faeces	Drier sample	Positive
		Swab	Owl pellet and droppings		Negative
7	Composting	Other	Mixed sample from compost strips		Negative
8	YSB	Faecal	Sparrow faeces	Underneath mounted nest boxes	Negative
9	Willow Bed	Faecal	Fox faeces		Negative
10	Nut Wood	Faecal	Rabbit faeces		Negative
			Badger faeces		Positive
11	Beeches Wood	Faecal	Sparrow faeces	From underneath bird feeder	Negative
12	Brooders	Faecal	Sparrow faeces	From underneath bird feeder	Positive
		Swab	Nest boxes	Under boxes on wall	Negative
13	Feed container	Swab	Sparrow faeces	Underneath by brooder sheds	Positive (6)
14	Brooder Barn	Faecal	Wild bird faeces		Negative
15	Feed Store	Faecal	Wild bird faeces		Negative
			Rat faeces		Negative
16	Trial Crops	Swab	Fence		Negative
		Faecal	Rabbit faeces	Edge of field	Negative
				Centre of field	Negative
			Wild bird faeces		Negative
17	Production Crops	Faecal	Wild bird faeces	By fence	Negative
			Rook and Seagull faeces		Positive
			Rabbit faeces		Negative
18	Dog Walk	Faecal	Dog faeces	Dog walking route	Positive
19	Pig Field	Swab	Wild bird faeces	Fence	Positive
		Faecal	Rook and Seagull faeces		Negative
			Rook faeces		Positive

Site No.	Site Name	Sample Type	Further details (Plate group)	Result
20	Pig Wood	Faecal	Wild bird faeces	Negative
22	Sheep Field	Faecal	Wild bird faeces	Negative
24	Pig Field	Faecal	Wild bird faeces	Positive
26	Sheep Field	Faecal	Rabbit faeces	Negative

Key

Positive (4) Possible campylobacter, overgrown by another organism identification difficult

Positive (5) Possible campylobacter, not typical on gram plate

Positive (6) Not truly typical campylobacter

Wild bird faeces - Relates to any unidentified bird faecal sample –could contain any of the identified examples (sparrow, seagull or rook) or that of other birds

Table 5. *Results for environmental sampling*

3.4 Management and vehicle tests

Table 6 lists all the sites at which samples relating to poultry management and vehicles used for the poultry enterprise were undertaken, the individual samples obtained at the sites and their nature and the result when that sample was analysed.

Site No.	Area Type	Site Name	Sample Type	Further details (Plate group)	Result
27	Management	Processing	Faecal	Chicken faeces from module holding area	Positive
28	Management	Feed Wagon	Swab	Feed shot	Negative
29	Management	Poultry Team	Swab	Boots of stockpeople	Positive (4)
30	Management	Dirty site	Swab	Previous field shed site	Negative
31	Management	Clean herb strip	Swab	New site for clean shed	Negative
32	Vehicles	Quads	Swab	Bikes and tyres	Positive
33	Vehicles	Tractors	Swab	Tyres and forks	Positive (4)
34	Vehicles	Manitou	Swab	Tyres and forks	Negative
35	Vehicles	Other Vehicles	Swab	Tyres Truck	Positive (4)

Key

Positive (4) Possible campylobacter, overgrown by another organism identification difficult

Table 6. *Results for management and vehicles samples.*

3.5 Livestock tests

Table 7 lists all the sites at which livestock samples were obtained, and the result when that sample was analysed. The majority of these samples are positive, with at least one positive result for each livestock group.

Site No.	Site Name	Sample Type	Further details (Plate group)	Result
19	Pig Field	Faecal	Pig faeces	Positive
21	Cattle Shed	Swab	Feeder	Negative
		Faecal	Cattle faeces	Positive
22	Sheep Field	Faecal	Sheep faeces	Negative
23	Sheep Field	Faecal	Sheep faeces	Negative
24	Pig Field	Faecal	Pig faeces	Positive
25	Sheep Field	Faecal	Sheep faeces	Positive
26	Sheep Field	Faecal	Sheep faeces	Negative

Table 7. *Results for livestock samples.*

DISCUSSION

4.1 Production tests – Batch of birds

The production birds entered a clean, campylobacter free environment, this tallies with other research which suggests that after adequate cleaning and disinfecting campylobacter cannot be found (Evans and Sayers 2000). The birds entered this system clean and remained campylobacter free (based on a one percent sample of birds, 10/1000) moving into the second week. However, this trial indicated that some time after this and prior to leaving the brooder this batch of birds had become infected with campylobacter, as the results in the fourth week upon moving to the field environment were positive for campylobacter.

This result was unexpected as the brooder is a sealed environment, without access to the outside or any enhanced biodiversity in that environment. However, this could be the result of management practice, as stockperson boot swabs tested positive for campylobacter, despite the fact that footbaths are in use at the entrance to each shed. This will be discussed in more detail under management practices.

It is possible that this early infection with campylobacter in the brooder could be the result of horizontal infection through the water supply, as non-chlorinated water has been suggested to be a vehicle for infection (Gregory, *et al*. 1997, Shane 1992, Zimmer, *et al.* 2003, Shane 2000). It is highly possible that this early infection may be through similar routes of transmission that might also occur on conventional broiler farms also. Despite the lack of biodiversity and the high level of control and isolation from the sources of contamination such as wild birds, one study found over 40 percent of broilers within a flock were campylobacter positive (Atanassova and Ring 1999).

The field shed and its furniture tested positive in both sheds for campylobactor. This sample included a swab from the shed's dustbather, which is outside of the shed, and although this had been cleaned down, exposure to elements may have caused it to become contaminated with campylobacter. The module crates also tested positive in one case, this will be discussed in more detail below.

An important point to remember when considering this data is that this analysis was carried out at flock level and not at final product level. Previous testing of dressed carcases from this organic system have failed to produce campylobacter positive results, this to some extent tallies with research carried out in this area. A study by Hald *et al.* (2000) found that, when tested for campylobacter, species prior to processing 52 percent of the flock was infected, however post processing this had reduced to 24 percent. It is possible, and has been noted, that some subtypes of campylobacter may not survive processing but it has been suggested that others may survive well and spread (Newell *et al.* 2001). Further research is required to follow a positive testing flock / or birds into a processing unit for repeat analysis of the carcases on completing processing to confirm this suggestion.

4.2 Production tests – All birds

The testing of a faecal sample from each shed on site, so covering all the different ages of bird on this multi-age site, demonstrated a trend for a campylobacter positive result in the older birds. This result was in the direction expected, based on the result from the batch of production birds tested. There were a few early campylobacter results but the testing of these was hampered as campylobacter was not conclusively identified in these plates. In addition there was one sample, from the birds at week 8, for which the sample was campylobacter negative. On the basis of previous sampling at this late stage this result would be expected to be campylobacter positive. However, the sample obtained was from a very small subset of birds from each shed, one percent. It has been shown that even in large conventional broiler sheds, in which the flocks live in very close proximity, these do not experience one hundred percent intraflock infection (Atanassova and Ring 1999). Further investigation could be undertaken to follow up on this preliminary work, exploring the presence or absence of campylobacter in individual birds within a flock, so prevalence within a shed can be assessed.

In addition further work could consider the strains and species present on the farm to gain information about the passing of campylobacter between the different species of animal and bird on the farm. It is important to note that most animals and birds carry most species of campylobacter and most of these are pathogenic to humans (Tam *et al.* 2003a).

4.3 Environmental tests

The results from the environmental/biodiversity sampling were mixed. The large majority of the results were campylobacter negative.

As noted in other studies wild birds appear to be a reservoir of the campylobacter pathogen (Gregory, *et al*. 1997, Chuma, *et al.* 2000, Hänninen 2004). In some sites wild bird samples, including sparrow, seagull, rooks and those from unidentified birds, were found to be positive for campylobacter, but in other sites they were not. This could be due to a mixed loading of campylobacter presence in the populations of these birds, as was discussed in relation to broilers. It could also be due to the fact that there were difficulties when sampling for biodiversity, of identifying samples with viable campylobacter pathogens within it, as the pathogen is to susceptible to cold and oxygen overexposure (Cole, *et al*. 2004). Although the fragility of the campylobacter pathogen in relation to oxygen and cold would inhibit the transmission from wild birds and animals to poultry flocks, the sheer volume of poultry on the farm means that this fragility is overcome.

Although wild birds seem to be a reservoir of campylobacter pathogen that could be transmitted to the poultry flocks, research has demonstrated that this is not always the case. In some instances the environmental samples had campylobacter with identical genotypes to those in the poultry flock they were near, but in others the environmental samples possessed campylobacter with genotypes that were distantly related to samples from the flock (Hiett, *et al*. 2002). This research suggests that the external environment can contribute to campylobacter contamination during poultry production but that this is not always the case.

This study suggests no real effect of the increase in biodiversity on organic farms, and that, although the prevalence of campylobacter was fairly high, this is comparable to that of conventional broiler systems or free-range systems and does not appear to be the result of the increase in biodiversity on this farm, as other species for which a positive campylobacter result was found were rats, badgers and dogs. These are not really species that have directly increased as a result of organic farming and increasing bio-diversity.

It could be argued that the sampled collected did not accurately represent the extent of the biodiversity found on organic farms. It could have included a larger range of species, such as raptors, small mammals, and even insects and flys, as these have been suggested as a route of infection for poultry (Bates, *et al.*2004, Hänninen 2004, Shane, 1992). However this was a preliminary study and time and resources would not permit a study to this extent. Further research should investigate this more closely.

4.4 Management and vehicle tests

The results from the management swabs highlighted some potential areas that may be possible routes of transmission into and around the poultry system. The swabs taken from the stock team's boots tested positive for campylobacter, although this was overgrown and difficult to identify. This confirms evidence from previous studies that catchers and poultry worker's boots often carry campylobacter (Gregory *et al.* 1997, Ramabu *et al*. 2004). This study, like others (Ramabu *et al*. 2004), identified vehicles commonly used by the poultry staff, trucks, forklifts, tractors and quads, as campylobacter positive and therefore possible vectors for transmission. These findings suggest a potential route of transmission of the pathogen to the poultry, as stock people and vehicles and constantly moving around the farm and between the different age sheds. Tighter management, increased awareness of the need for good bio-security may decrease the prevalence of campylobacter as research has shown that significant larger numbers of campylobacter isolates were recovered from conventional poultry units with poor management (Kazwala *et al.* 1993).

Samples from the processing plant's module holding area and the module crates themselves were found to be campylobacter positive. This tallies with the evidence from the literature, which suggests that despite washing, transport modules are often contaminated with campylobacter pathogens and thus are a potential route of infection (Berrang *et al*. 2003, Slader *et al*. 2002).

The soil from the herb strip of a 'clean site' was analysed as campylobacter negative, this was an interesting find in terms of management and biodiversity. In terms of management this is positive as it means that a clean site is a clean site, in terms of it campylobacter loading. This is also a positive result in terms of the effect of biodiversity, as many pheasant pairs nest in the herb strips. Further work should be considered to investigate this result, as it was one sample within vast area.

4.5 Livestock tests

As the current research suggests (Gregory *et al.* 1997, Ziprin *et al.* 2003), the livestock on the farm is a possible source of campylobacter contamination, as results from the livestock samples found positive campylobacter results for all types of livestock tested. The livestock enterprise should be kept as separate from the poultry systems, as possible, in terms of their management and geographical distance. This would ensure campylobacter infection in the poultry flocks is not originating from livestock sources. As with the management issues, with stock people this source is potentially difficult to control, as the movement of livestock around the farm is necessary for grazing and housing.

CONCLUSION

In conclusion, the work suggests no real effect of the increase in biodiversity on organic farms. The samples, which were found campylobacter positive, are species that are likely to be present on conventional broiler farms, such as rats and sparrows and have been found to be transmission vectors for conventional broilers (Chuma, *et al*. 2000, Hänninen 2004).

The work suggests some possible issues with management that may be acting as a route of transmission of campylobacter between different flocks on the farm.

The study identified a possible role for livestock in the transmission of campylobacter between different flocks, and suggested that efforts should be made to keep these enterprises as separate as possible.

It is important to remember that although this study has highlighted some areas of concern relating to management and avoiding contact with other livestock on the farm, and a lack of a real role for the enhanced biodiversity beyond those affecting conventional systems and free-range systems – this was a preliminary investigation. Issues have also been raised about the difficultly when sampling for biodiversity, of identifying samples with viable campylobacter pathogen within it.

Although the fragility of the campylobacter pathogen in relation to oxygen and cold would appear to be a benefit, when considering its transmission from wild animals to poultry flocks, the sheer volume of poultry on the farm means that this fragility could easily be overcome. As any positive wild animal faecal samples would rapidly deteriorate in terms of their potential to spread campylobacter to the poultry flock, contact with one bird may cause infection. Due to the numbers in the poultry flock, in excess of 22,000, the chance of this happening is high.

Further in-depth work will need to be carried out to explore the complex relationship between campylobacter presence and its transmission into organic poultry flocks.

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APPENDICIES

Photograph 1. *Site 3 - Badger set*

Photograph 2. *Site 19 –Pig field (bird faeces on post)*

Photograph 3. *Site 12 – Brooders (sparrow feeder)*

Photograph 4. *Site 12 – Brooders (nest boxes)*

Photograph 5. *Site 28 – Feed wagon*