Campylobacter in food and the environment examining the link with public health: Pathway Attribution

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CAMPYLOBACTER IN FOOD AND THE ENVIRONMENT EXAMINING THE LINK WITH PUBLIC HEALTH:

PATHWAY ATTRIBUTION

CROSS DEPARTMENTAL RESEARCH POOL 2009-2010

A report for the Ministry for Agriculture and Forestry and the Ministry for the Environment

Prepared as part of a Ministry for Agriculture and Forestry contract (07-10413) for scientific services

by

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May 2011

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PATHWAY ATTRIBUTION

CROSS DEPARTMENTAL RESEARCH PROGRAMME 2009-2010

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Statistics New Zealand for census data, population estimates, urban rural data and travel statistics.

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SUMMARY

This report describes the work conducted by ESR on the project "*Campylobacter* in food and the environment: Examining the link with public health". The project, which began in July 2007, is a collaboration between ESR and scientists at the Ministry for Agriculture and Forestry (MAF), Ministry for the Environment (MfE), the National Institute for Water and Atmospheric Science (NIWA) and Massey University.

The overall objective for the project is to bring together approaches to risk modelling and management for pathogens that infect humans via food and environmental pathways in New Zealand. The initial focus is on *Campylobacter* spp. The project aims to provide models to help evaluate intervention strategies that can be adopted by various government departments, local authorities, and other regulatory agencies to reduce the incidence of campylobacteriosis in New Zealand.

ESR has developed models that address the relative importance of the following transmission pathways for campylobacteriosis in New Zealand:

- Food consumption and handling (chicken, beef, sheep meat, pork, offal, ducks and turkeys)
- Recreational water use
- Drinking water consumption
- Living in a rural environment (for young children 0-4 years)
- Overseas travel
- Occupation
- Pets (cats and dogs)
- Contact with other sick people

These pathways are associated with enteric zoonotic diseases in general, and campylobacteriosis in particular.

Pathway models describe how *Campylobacter* can move from sources to human exposures, and estimate what proportion of illness is attributable to each pathway. They represent an alternative approach to source attribution. Source attribution has been extensively studied in New Zealand using data on *Campylobacter* strains characterized by multi-locus sequence typing (MLST). However, people may be exposed to a single source (such as ruminant animals) via multiple pathways (e.g. red meat consumption, direct animal contact, contaminated drinking water).

Four approaches have been taken to model the pathways listed above:

(i) **Risk Factor Analysis** of notified cases of campylobacteriosis from the whole of New Zealand (overseas travel, occupation, rural environment for 0-4 year olds) and from a sentinel site in the Manawatu (Horizons Regional Council) (contact with other sick people)

(ii) **Source attribution** of *Campylobacter* using strain typing (MLST) data from a sentinel site in the Manawatu (pets);

(iii) **Exposure assessment** by estimating the number of cells ingested by humans (food consumption, recreational water use, drinking water).

(iv) **Pathway attribution**, which integrates the three approaches above, to estimate the proportion of notifications attributable to a risk factor or exposure source. This attribution leaves an unassigned remainder fraction. This remainder includes pathways that were unable to be modelled, or were not addressed.

The total number of campylobacteriosis notifications in a year is a useful annual indicator of the total burden of the disease in New Zealand. Our approach to pathway modelling involves attributing proportions of the total number of actual notified cases to specific pathways. Underlying this attribution approach is the assumption that the notified cases are representative of all cases of campylobacteriosis in the New Zealand population, particularly the cases which do not present to the health system ("community" cases).

All the risk factor and MLST data in the study comes from actual cases of illness which have been notified via the EpiSurv database. However, the risk factor data are reported for only a proportion of the notified cases, and so various adjustments are made to estimate the actual proportion of total notifications attributable to each risk factor.

Risk factor analysis provides an estimate of the number of notifications attributed to the risk factor. Exposure assessment models provide an estimate of the number of infections that occur from ingestion of *Campylobacter* in foods and water. This project has adopted a novel approach to attribution by combining these to provide an integrated overview of the transmission pathways for campylobacteriosis in New Zealand. To achieve this integration, it was necessary to calculate a scaling factor to convert estimated infections into estimated notifications. This scaling factor was calculated using data on the reduction in the number of notifications attributed to exposures from poultry over the period 2006-2008.

Pathway attribution model outputs

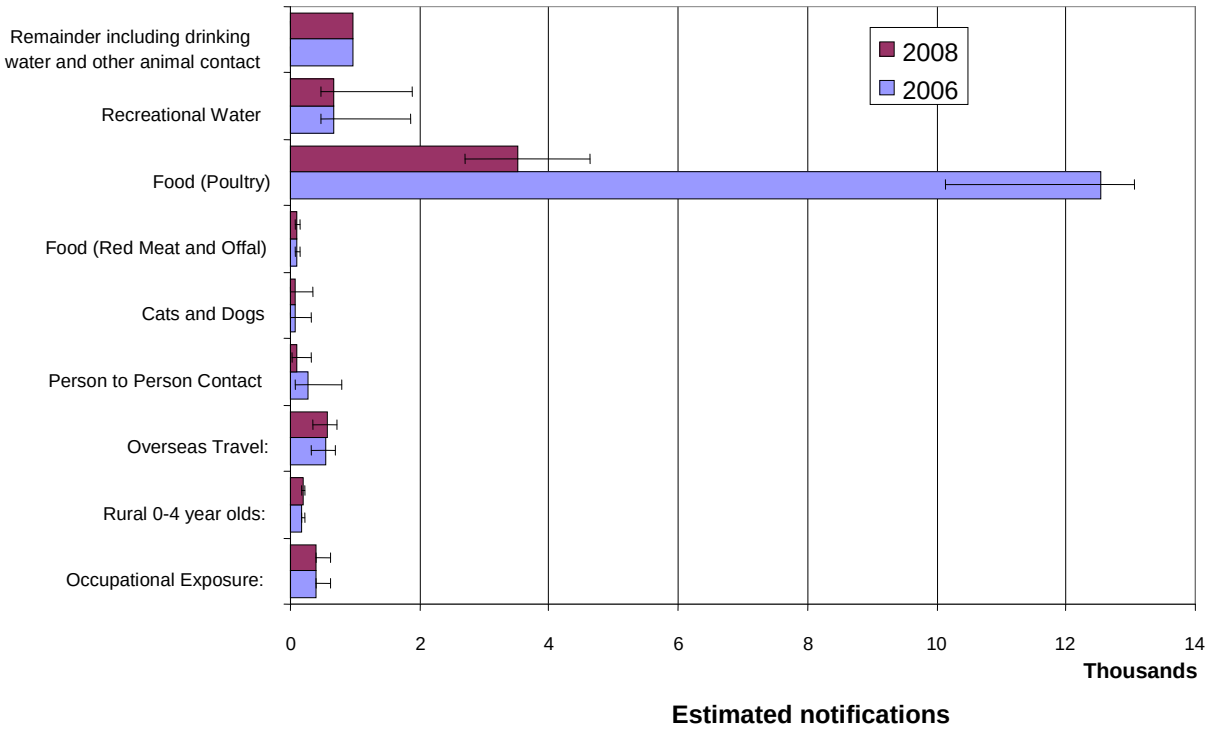
The diagram below presents the estimated relative attribution of notified campylobacteriosis cases for New Zealand in 2006 (n=15,728) and 2008 (n=6,594) to each transmission pathway. In 2007 interventions were put into place by the poultry industry to reduce *Campylobacter* in retail poultry alongside the introduction of a regulatory *Campylobacter* Performance Target.

The intervals on the attribution estimates represent plausible lower and upper bounds of the attribution estimate based on analysis of the different data sources. The different data sources mean that different approaches have been used to generate the bounds: The bounds for the risk factor analyses (occupational exposure, rural 0-4 year olds, overseas travel and person to person transmission) are from direct observation of the notification data. The bounds for the cat and dog pathways are generated using interval analysis incorporating the 95^{th} credible interval from source attribution analysis. The bounds for the exposure models (food and recreational water) are generated using interval analysis incorporating bounds on the size of exposed population and the 2.5^{th} and 97.5^{th} percentiles of the Monte Carlo simulations.

It is important to note the attribution estimate for the unassigned notifications (including drinking water and other animal contact) has been generated by difference. Plausible bounds for the number of unassigned notifications are not given in the Figures. Theoretically, the bounds could be calculated using interval analysis, accummulating the bounds from the other pathways, however combining the estimates from the different approaches in this way would produce a large interval from the extremes of the other pathway estimates.

The "remainder" includes a number of possible pathways. These include drinking water (except for rural 0-4 year olds), which was unable to be attributed by the exposure model due to data limitations. Drinking water exposure may occur from regular domestic consumption (small rural supplies are most likely to be contaminated and/or untreated), or contaminated/untreated water consumed by people when away from their domestic supplies (e.g. people visiting rural areas, campsites, tramping, etc.). Attribution for some pathways was not attempted, such as "other" animal contact (i.e. other than contact involving rural 0-4 year olds, occupation, and pets). Such contact could include keeping chickens, school activities and petting zoos. There are also some possible food exposures that could not be addressed, such as unpasteurised milk.

National pathway attribution of the campylobacteriosis notifications for 2006 and 2008. Intervals represent the lower and upper plausible bounds of the estimates, no intervals are given for the remainder pathway.



The ESR models presented in this report have been informed by models describing environmental and livestock dynamics of *Campylobacter* developed by the other science providers in this contract. Although there are gaps in the data needed to set some input parameters, the models can still be employed to estimate the effect of hypothetical intervention scenarios for some risk factors to reduce the incidence of campylobacteriosis in New Zealand.

1 INTRODUCTION

This report describes the work conducted by ESR on the project "*Campylobacter* in food and the environment: Examining the link with public health". The project, which began in July 2007, is a collaboration between ESR and scientists at the Ministry of Agriculture and Forestry (MAF), Ministry for the Environment (MfE), the National Institute for Water and Atmospheric Science (NIWA) and Massey University. It is funded through the Foundation for Research, Science and Technology (FRST) under the Cross Departmental Research Pool (CDRP) portfolio.

The overall objective for the project is to bring together approaches to risk modelling and management for pathogens that infect humans via food and environmental pathways in New Zealand. The initial focus is on *Campylobacter* spp. The project aims to deliver models to help evaluate intervention strategies that can be adopted by various government departments, local authorities and other regulatory agencies to reduce the incidence of campylobacteriosis in New Zealand.

The project has three overall objectives:

1. Improve the existing comparative exposure models.
2. Extend existing ecological/environmental models.
3. Examine the links between human exposure via different pathways and underlying ecological/environmental models by integrating all modelling activities.

This report describes the attribution models developed by ESR, which are intended to assess intervention options. The other science providers have developed the following models:

- Massey University: Source attribution models based on multi locus sequence type (MLST) data for *Campylobacter* strains; models describing the dynamics of livestock infection with *Campylobacter*; models describing the human dose-response relationship using susceptible-immune-recovering (SIR) populations;
- NIWA: Models describing the dynamics of *Campylobacter* transport through land and freshwater systems in catchments; SIR human dose-response modelling.

This report provides a detailed description of the modeling activities including background information, data analysis, and derivation of the parameters used in the models.

1.1 ESR modeling activities

ESR has developed models that address the relative importance of the following transmission pathways for campylobacteriosis in New Zealand:

- Food consumption and handling (chicken, beef, sheep meat, pork, offal, duck and turkey meat)
- Recreational water use
- Drinking water consumption
- Living in a rural environment (for young children 0-4 years)
- Overseas travel
- Occupation
- Pet (cats and dogs)

- Contact with other sick people

These pathways are associated with enteric zoonotic diseases in general, and campylobacteriosis in particular.

Pathway models describe how *Campylobacter* can move from sources to human exposures, and estimate what proportion of illness is attributable to each pathway. They represent an alternative approach to source attribution. Source attribution has been extensively studied in New Zealand using data on *Campylobacter* strains characterized by multi-locus sequence typing (MLST). However, people may be exposed to a single source (such as ruminant animals) via multiple pathways (e.g. red meat consumption, direct animal contact, contaminated drinking water). A table comparing sources and potential pathways is given in Appendix 1.

Campylobacteriosis is a notifiable disease in New Zealand. This means that health professionals and laboratories are required to inform their Medical Officer of Health of any campylobacteriosis cases they suspect or diagnose. Public health officers collate information on these notified cases into the EpiSurv database[1]. The reporting form for campylobacteriosis includes information on case management, diagnosis and risk factors. A copy of the reporting form is given in Appendix 2.

Four approaches have been taken to model the pathways listed above:

(i) **Risk Factor Analysis** of notified cases of campylobacteriosis from the whole of New Zealand (overseas travel, occupation, rural environment for 0-4 year olds) and from a sentinel site in the Manawatu (Horizons Regional Council) (contact with other sick people)

(ii) **Source attribution** of *Campylobacter* using multi locus sequence typing (MLST) data of strains of *C. jejuni* from a sentinel site in the Manawatu (pets);

(iii) **Exposure assessment** by estimating the number of cells ingested by humans (food consumption, recreational water use, drinking water).

(iv) **Pathway attribution**, which integrates the three approaches above, to estimate the proportion of notifications attributable to a risk factor or exposure source. This attribution leaves an unassigned remainder fraction. This remainder includes pathways that were unable to be modelled, or were not addressed.

The total number of campylobacteriosis notifications in a year is a useful annual indicator of the total burden of the disease in New Zealand. Our approach to pathway modelling involves attributing proportions of the total number of actual notified cases to specific pathways. Underlying this attribution approach is the assumption that the notified cases are representative of all cases of campylobacteriosis in the New Zealand population, particularly the cases which do not present to the health system ("community" cases).

All the risk factor and MLST data in the study comes from actual cases of illness which have been notified via the EpiSurv database. However, the risk factor data are reported for only a proportion of the notified cases, and so various adjustments are made to estimate the actual proportion of total notifications attributable to each risk factor.

[1] www.surv.esr.cri.nz

Four models have been developed by ESR:

1. Exposure model for food ("Food model"): This model predicts the number of human infections based on exposures to *Campylobacter* from consumption of chicken, beef, sheep meat, pork, offal, turkey and duck meat.

2. Exposure model for drinking water ("Drinking water model"): This model is designed to predict the number of human infections based on exposures to *Campylobacter* from consumption of drinking water. This model has been created, but as described later in this report there were insufficient data available to satisfactorily parameterise the model.

3. Exposure model for recreational water ("Recreational water model"): This model predicts the number of human infections based on exposures to *Campylobacter* from consumption of fresh water during recreational swimming.

4. Pathway attribution model ("Pathway model"): This model brings together attribution based on analyses of notified campylobacteriosis cases with the number of human infections predicted by the food and recreational water exposure models.

We have designed the models to allow users to vary most of the inputs. This allows evaluation of scenarios based on potential mitigations. The models describe the situation in 2008-9, using the most up to date data available when the models were developed.

The majority of cases of campylobacteriosis reported in New Zealand are caused by infection with *C. jejuni*. A small proportion of cases are infected with *C. coli* (Devane *et al.*, 2005). *C. lari* and *C. upsaliensis* are rarely identified from human cases. The available data on prevalence in sources were reviewed for information on *Campylobacter* spp., as well as individual species, although isolates of *Campylobacter* were not always identified to the species level. The data used to set parameter values in the models were chosen, where possible, to reflect the dominance of *C. jejuni* amongst human cases.

1.2 Model Worksheets

The exposure models were developed using @RISK software (Version 5.0, Palisade Corporation, 2005). The exposure models require Monte Carlo simulations to generate scenario outcomes, which are then integrated into the pathway model. The pathway model uses a Microsoft Excel spread sheet.

The pathway model is located in the Microsoft Excel 2003 workbook: *Campylobacter pathway attribution v1.2.xls*.

The exposure model for meat preparation and consumption is located in the Microsoft Excel 2003 workbook: *Food exposure model v1.xls*

The exposure models for recreational and drinking water are located in the Microsoft Excel 2003 workbooks: *Recreational Water exposure model v1.xls and Campylobacter regional drinking water model v1.1.xls*

2 PATHWAY MODEL

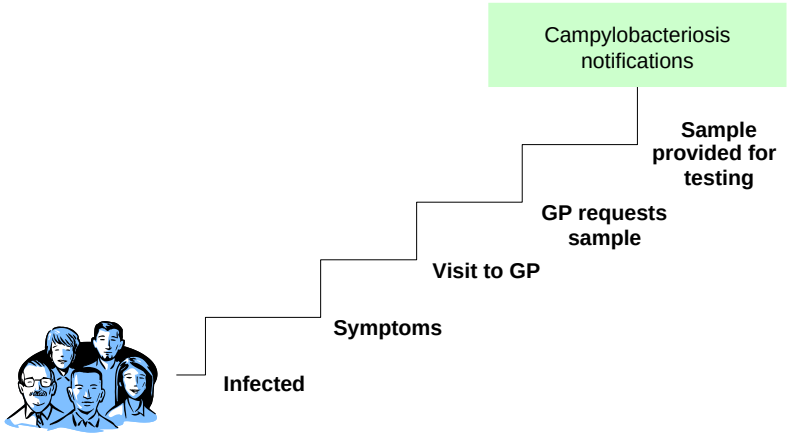
2.1 Model Structure

The objective was to develop a model that identifies the relative importance of established transmission pathways for campylobacteriosis in New Zealand (Eberhart-Phillips *et al.*, 1997; French, 2009; Lake, 2006). There is no single data type available which allows all the pathways to be modeled by the same approach. Instead information has been gathered from:

- Epidemiological and risk factor information from EpiSurv records of notified campylobacteriosis cases.
- Proportions of notified human cases associated with different sources, based on MLST typing data collected during a study based in the Manawatu.
- Data sources for calculating exposure estimates for people via food and water pathways (e.g. National Nutrition Survey, Water Information New Zealand (WINZ)).

Creating models using the multiple data types is difficult, particularly due to uncertainty regarding the relationship between reported illness (as represented by notifications) and infection (as predicted from exposure). Exposures are calculated for the whole population, whereas notification data relate only to people who visit a General Practitioner (GP) and provide a faecal sample, as shown in Figure 1.

Figure 1: The process from exposure and infection, to notification



The approach chosen was to use the best possible data available to estimate the attribution for each pathway. The quality and quantity of available data has driven the choice of attribution modelling approach for each pathway.

To combine these data we have taken the approach illustrated in Figure 2 for each of the pathways, with the aim to model the proportion of notified cases (as recorded in the database EpiSurv) attributable to different pathways. The estimate of the number of notifications in a year to each pathway was chosen to be the attribution model output for two reasons: (1) The number of notifications for previous years are known and allows the model to be grounded to a measureable value, and (2) the EpiSurv and MLST data are only related to the notified cases, not all the cases in the community.

Three different modelling approaches have been used to estimate the number of notifications attributable to pathways: risk factor analysis, MLST source attribution, and exposure assessment.

Risk factor analysis provides an estimate of the number of notifications attributed to the risk factor. Exposure assessment models provide an estimate of the number of infections that occur from ingestion of *Campylobacter* in foods and water. This project has adopted a novel approach to attribution by combining these to provide an integrated overview of the transmission pathways for campylobacteriosis in New Zealand. To achieve this integration, it was necessary to calculate a scaling factor to convert estimated infections into estimated notifications. This scaling factor was calculated using data on the reduction in the number of notifications attributed to exposures from poultry over the period 2006-2008.

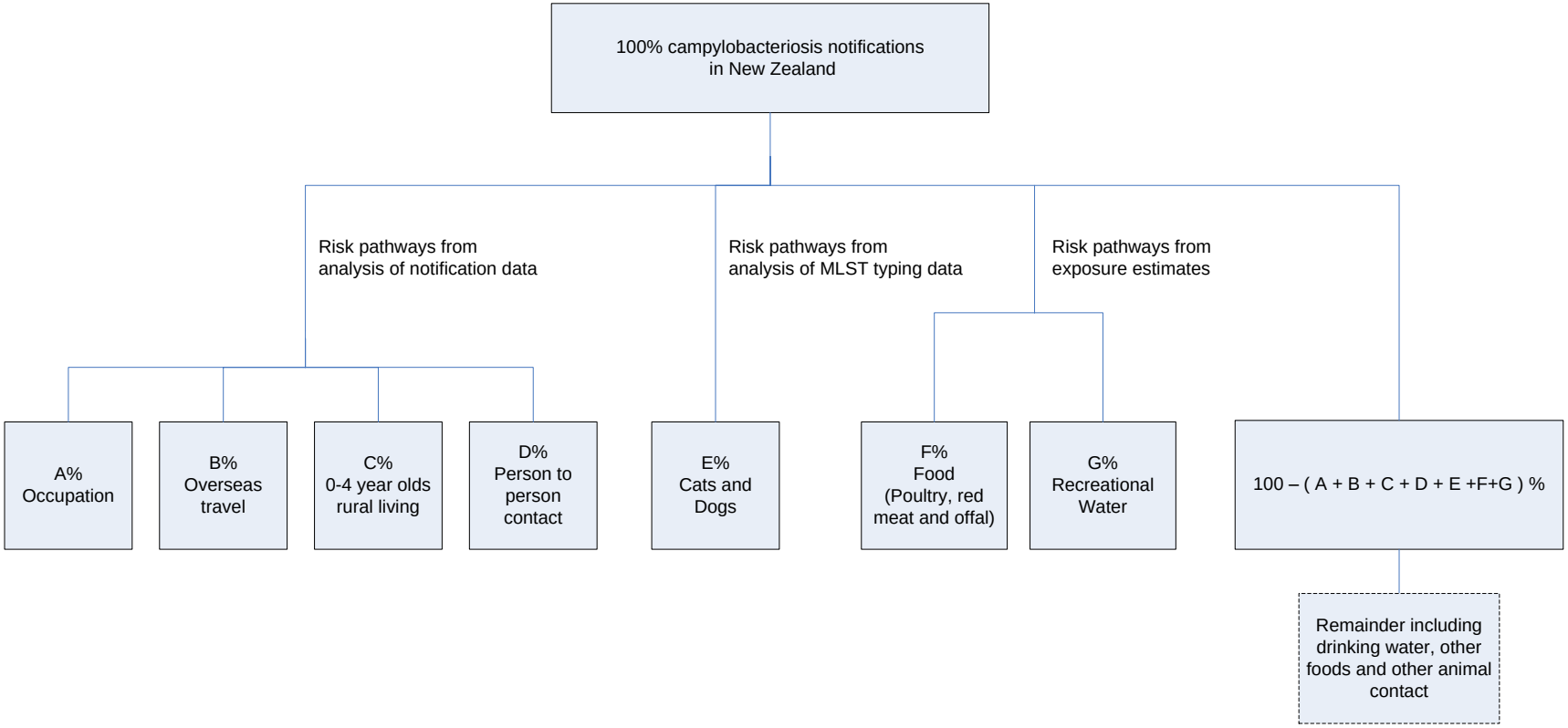
2.2 Risk Factor Analysis

Risk factor analysis estimates the proportion of notifications attributable to a pathway by analysis of risk factor information in the EpiSurv campylobacteriosis notifications dataset. The risk pathways attributed in this way are: occupation related illness, overseas travel, illness amongst young children resulting from living in a rural area, and non-occupational contact with people ill with campylobacteriosis or with symptoms of campylobacteriosis in the incubation period.

The reporting of risk factor information for notified cases is often incomplete, and varies from region to region. In particular, the completeness of reporting from the major urban centres of Auckland and Wellington is low (although reporting from Canterbury, which is another region with a high urban population, is high). Our approach involves using data from regions where reporting of the risk factor of interest is high (>50%) to estimate rates of notification for individual risk factors (e.g. infection acquired overseas, occupation). These rates are then extrapolated to the national population by using data from Statistics New Zealand for the risk factor (e.g. rates of short term travel, numbers of people employed in high risk occupations). This allows the attribution estimate, in terms of a proportion of the actual notifications, to be adjusted upwards to account for the notified cases where data are missing.

Use of Monte Carlo simulations to incorporate the variability and uncertainty in some of the risk factor variables was considered as an approach, but was not considered appropriate. Insufficient recent data were able to be analysed to describe input distributions that are required by Monte Carlo simulations. Rather than impose assumptions on the variable distributions, which may bias results, the attribution estimate with a plausible range (lower and upper bound) were calculated from direct observation of the available data. Section 4 contains details of how the lower and upper bounds on the attribution were created for each of the risk factor pathways.

Figure 2: Overview of pathway attribution approach for campylobacteriosis notifications in New Zealand



2.3 MLST source attribution

The EpiSurv database does not contain sufficient information to estimate the number of people who may be infected with *Campylobacter* due to contact with pets or their pet's faeces. In addition, not enough is known about *Campylobacter* infection rates in pets or ingestion amounts to allow this pathway to be modeled and the exposure estimated. Instead, the proportion of notified campylobacteriosis cases due to contact with cats and dogs or their faeces is estimated from source attribution modelling of *Campylobacter* MLST data collected in the Manawatu area (French, 2009) and population estimates.

The plausible range for the estimate is calculated using interval analysis, incorporating the 95% credible interval for the source attribution estimate of the percentage of notifications due to transmission from cats or dogs. This approach is explained in more detail in Section 5.

2.4 Exposure models

Exposure models use data on frequency and amount (number of cells) of *Campylobacter* ingestion combined with a dose-response relationship to predict the number of campylobacteriosis infections per day that are likely to occur for the New Zealand population. Models were constructed for food, drinking water and recreational water pathways, and these are detailed in Section 6.

The exposure models are constructed in two parts. The first part uses Monte Carlo simulations to incorporate variability into the parameters of models to estimate the probability of infection given consumption of *Campylobacter* from contaminated food or water. The second part empirically models the size of the population likely to be exposed via the pathway on any given day and uses interval analyses to create lower and upper bounds on the population estimate.

Each exposure model was split to allow easier incorporation into a standalone spreadsheet for the examination of different interventions or "what if" scenarios. The intervention spreadsheet in the pathway model contains a number of results from possible Monte Carlo simulations, allowing the spreadsheet to be used without needing to run simulations if the results of the scenario are stored in the spreadsheet.

The estimate of the lower and upper bounds of the number of infections per day is calculated using interval analyses of the bounds calculated for the size of the at risk population and the 2.5^{th} and 97.5^{th} percentiles of probability of infection from the simulations.

To convert the "infections per day" output from the exposure models to "notifications per year" as required by the overarching pathway model, a scaling factor was used. This factor relates to the difference between predicted infections for the whole population (from the exposure models), and the fraction of these that visit their GP, provide a faecal sample, and eventually become notified cases (as in the risk factor analyses).

The estimated scaling factor calculation uses data from before (2006) and after (2008) the introduction of Poultry Industry *Campylobacter* Performance Targets and makes the assumption the data on poultry contamination in the Manawatu in 2006 and 2008 is nationally representative. This approach is further discussed in Section 6.3.

During construction and calibration of the exposure models, it became evident that there were insufficient data to be able to populate the drinking water model. Data limitations concerned the size of populations served by unregistered water supplies, the types of water sources feeding these supplies, their treatment status, and frequency and concentration of *Campylobacter* contamination.

2.5 Remaining notifications

The total notifications for campylobacteriosis in a given year are known from the EpiSurv database. The models provide an estimate of the number of these that can be attributed to risk factors and exposure pathways. There are a number of notifications remaining when the assigned pathways are subtracted from the total.

The lower and upper bounds on the number of unassigned notifications are not currently calculated. Theoretically, the bounds could be calculated using interval analysis, accummulating the bounds from the other pathways, however combining the estimates from the different approaches in this way would produce a large interval from the extremes of the other pathway estimates and was not considered a sensible approach.

Creating bounds using Monte Carlo simulations were also considered to generate plausible bounds for the "remainder" pathway. However, this would require assumptions about the type and parameters of the distributions for the number of notifications associated with each risk factor pathway, which was not known.

The "remainder" includes a number of possible pathways. These include drinking water (except for rural 0-4 year olds), which was unable to be attributed by the exposure model, due to data limitations. Drinking water exposure may occur from regular domestic consumption (small rural supplies are most likely to be contaminated and/or untreated), or contaminated/untreated water consumed by people when away from their domestic supplies (e.g. people visiting rural areas, campsites, tramping etc.).

Attribution for some pathways was not attempted, such as "other" animal contact (i.e. other than contact involving rural 0-4 year olds, occupation, and pets). Such contact could include keeping chickens, school activities, and petting zoos. Visiting petting zoos was the source of greatest exposure to *Campylobacter* in an analysis conducted for the Netherlands (Evers *et al.*, 2008). Although the number of professional hunters and trappers in New Zealand (considered under occupational exposure) is small (369 according to data from the 2006 census), recreational hunting is popular, with an estimated 50,000 active big game hunters including 40,000 deer hunters based on a survey in 1988 (Fraser, 2000). Another possible outdoor recreational activity involving exposure to animal faecal sources is mountain biking (an outbreak of campylobacteriosis amongst mountain bikers thought to be caused by ingested mud has been reported (Stuart *et al.*, 2010)).

There are also some possible food exposures that could not be addressed, such as unpasteurised milk. These pathways have not been modelled at this time due to lack of descriptive data (e.g. data on consumption of raw milk).

3 EPISURV NOTIFICATION DATA

The completeness of reporting for different fields in the notification case report depends on the availability and willingness of the patient to provide this information, and the policy of public health units with respect to completing the task. In general, demographic information is completed for a very high proportion of cases (this includes the age and residential location information used in this project). However, reporting of risk factor information is more variable. Risk factor information should be interpreted with some caution as it is usually self reported by cases and no external validation of this information is undertaken. Often the cases will report several potentially important risk factors.

This project has used the following information:

- Age and residential address;
- Whether the notified case had travelled overseas during the incubation period of the disease;
- Occupation; and
- Contact with other symptomatic people during the incubation period of the disease.

The notification data has been analysed at a national and regional council level. Analysing the data at a regional level has two advantages:

1. Data from regions with more complete notification reporting can be collated and used to fill in data gaps for regions where reporting is low (defined as <50% of records with field of interest completed).
2. Identification of risk pathways of regional importance e.g. rural areas will have higher numbers of people living on farms, while urban regions have higher rates of overseas travel.

4 ATTRIBUTION USING NOTIFICATION DATA: OCCUPATION, RURAL CHILDREN 0-4 YEARS, OVERSEAS TRAVEL, SECONDARY TRANSMISSION

4.1 Occupation

Some occupations result in continuous or repeated exposure to *Campylobacter,* for example the husbandry, slaughter, processing, or veterinary care of livestock. Other occupations such as caring for sick people or small children may involve contact with human fecal material. It is generally accepted that people in such occupations get ill at the beginning of their career, and then regular exposure builds up immunity (Havelaar *et al.*, 2009).

It is not possible to estimate doses for occupational exposures, so the notification data were examined to estimate any elevated risk from being employed in specific occupations compared to the general population of working age. The following occupations were investigated:

- Health workers who are likely to have contact with people with gastrointestinal illness.
- Early childhood workers.
- Teachers at primary and secondary schools.
- Veterinary and animal welfare workers.
- Slaughter/meat processing workers.
- Farm workers with animal contact.
- Other animal/outside contact workers (e.g. hunters, forestry workers).
- Food preparation workers.
- Sewage/wastewater workers.

If the proportion of new staff entering these occupations is reasonably constant across years, considering notification data should provide an estimate of the elevated risk due to occupational contact. Considering annual notifications will account for the seasonal work patterns of some of these occupations.

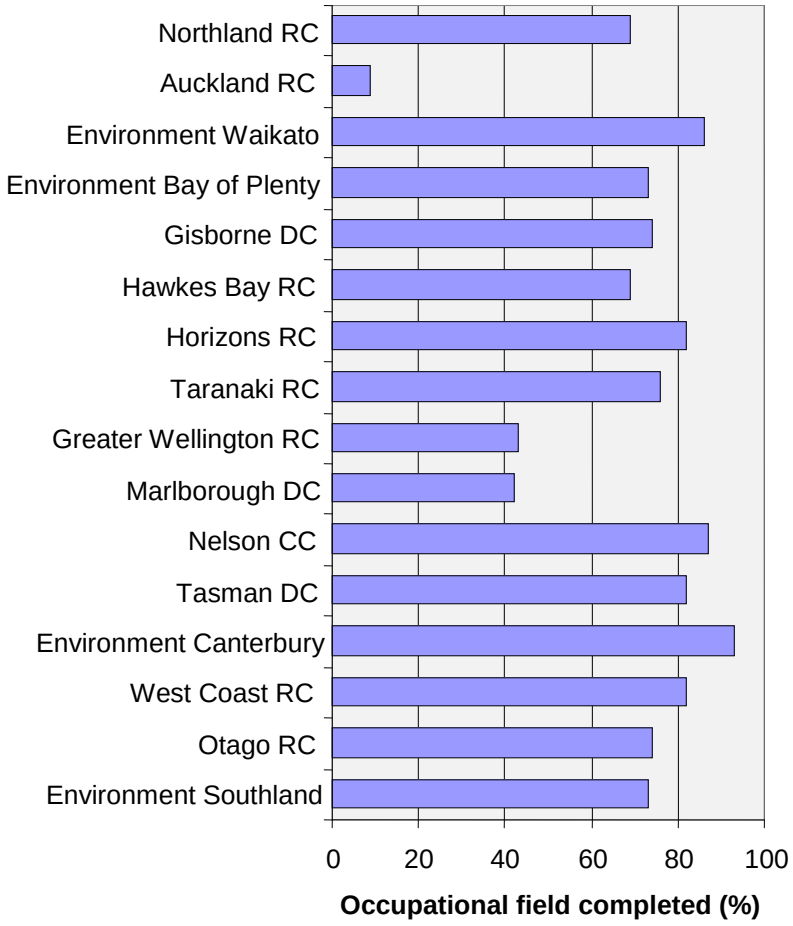
4.1.1 Completeness of notification data

The 2006 campylobacteriosis notification data for each regional council were reviewed for occupation information. This year was chosen as it was the most recent year available that was aligned with New Zealand Census data. The number of notified cases where occupation might be expected to be reported for each regional council was calculated by deducting from the total number of notifications:

- Cases aged 15 years or less
- Cases variously described as: retired, students, housewives, unemployed, beneficiary, mother, tourist as well as unknowns aged 65 years or over

The completeness of occupational information for each regional council notification dataset was calculated as the percentage of cases with a reported occupation from the number of cases where occupation might be expected to be reported. Results are shown in Figure 3. Generally there were high reporting rates (>70%) for the occupational field, however in 2006 rates below 50% were observed in the Auckland, Greater Wellington and Marlborough.

Figure 3: Percentage of notifications with occupational field completed for campylobacteriosis cases expected to have an occupation in 2006.



RC = Regional Council, DC=District Council, CC=City Council

4.1.2 Census data occupation populations

A custom dataset was ordered from Statistics New Zealand that segmented the number of usually resident people employed in each regional council according to the NZSC099 V1.0 occupational categories for census night in 2006.

The occupational groups listed in Section 4.1 are comprised of a number of specific occupations from the NZSC099 categories, as shown in Table 1. The number of people employed in these categories was collated for each regional council, as shown in Table 2. Some occupational groups such as sewage/waste water, health, vet/animal welfare, and food preparation workers had similar rates per 1,000 people aged 15 years or over across all regions. In contrast, there were large regional variations for slaughter/meat processing and farm workers with animal contact.

Table 1: NZSC099 Occupational Categories included in specific occupation groups

	Health – likely contact with infected people
22211	General Practitioner
22312	Registered Nurse
22315	Public Health and District Nurse
32311	Enrolled Nurse
51311	Hospital Orderly
51312	Health Assistant
51314	Nurse Aid

	Vet and animal welfare
22231	Veterinarian
32241	Veterinary Assistant
61441	Animal Welfare Worker (Zoo, shelters etc)

	Farm – animals
61211	Dairy Farmer, Dairy Farm Worker
61212	Sheep Farmer, Sheep Farm Worker
61213	Cattle Farmer, Cattle Farm Worker
61214	Pig Farmer, Pig Farm Worker
61215	Goat Farmer, Goat Farm Worker
61216	Deer Farmer, Deer Farm Worker
61217	Stud Racehorse Breeder, Stud Worker
61218	Other Livestock Farmer, Other Livestock Farm Worker
61221	Mixed Livestock Farmer, Mixed Livestock Farm Worker
61231	Poultry Farmer and Poultry Farm Worker
61251	Crop and Livestock Farmer, Worker
61261	Shepherd or Musterer
61262	Shearing Contractor/Shearer
61263	Wool Classer
61264	Shearing Shed Hand
61265	Horse Trainer, Groom or Stable Hand

	Early Childhood
22314	Plunket Nurse
23321	Early Childhood Teacher
23322	Kohanga Reo Teacher
32312	Karitane Nurse
51421	Child Care Worker

	Teaching
23211	Secondary School Teacher
23311	Primary School Teacher
23411	Special Education Teacher
23412	Speech-Language Therapist
33422	Teacher Aid

	Slaughter / Meat Processing
31512	Meat Inspector
74111	Butcher
74112	Meat Grader
82712	Slaughterer
82717	Meat Processing Worker

	Sewage / Waste Water
71231	Plumber
84111	Drain Layer
81522	Water Treatment Plant Operator

	Animal / Outside Contact
33162	Livestock Buyer
33164	Wool Buyer / Merchant
33811	Acclimatisation Field Officer
33812	National Park Ranger
61431	Hunter and Trapper
61311	Logger
61312	Forest Hand
61111	Field Crop Grower and Related Worker
61112	Market Gardener and Related Worker
61121	Fruit Grower, Worker
61122	Grape Grower and or Wine Maker, Worker
61131	Nursery Grower, Nursery Worker
61132	Landscape Gardener
61133	Grounds or Green Keeper
61134	Gardener
83311	Farm Machinery Operator

	Food Preparation
51221	Chef
51222	Cook
51234	Catering counter assistant
51235	Kitchen hand

Table 2: Census 2006 occupational rates per 1,000 people aged 15 years or over*

Area	Health	Vet / Animal Welfare	Slaughter / Process	Farm - animals	Food Preparation[1]	Sewage / Waste Water
Northland Regional Council	13.8	1.8	4.0	44.8	12.2	2.8
Auckland Regional Council	12.7	1.1	1.6	3.5	13.7	2.5
Environment Waikato	13.9	2.0	6.4	57.3	14.9	2.8
Environment Bay of Plenty	14.7	1.2	3.6	17.1	14.1	2.9
Gisborne District Council	14.6	1.4	6.6	42.4	13.1	2.5
Hawkes Bay Regional Council	13.6	1.4	18.4	32.9	14.6	2.6
Horizons Regional Council	15.4	2.0	11.0	50.3	14.8	2.7
Taranaki Regional Council	14.1	1.9	13.4	72.6	13.8	2.2
Greater Wellington Regional Council	13.2	1.3	2.2	7.0	16.3	2.9
Marlborough District Council	12.0	1.8	4.3	28.2	15.8	2.7
Nelson City Council	16.3	1.6	4.0	2.3	18.2	2.7
Tasman District Council	13.2	2.1	3.4	38.0	14.8	2.9
Environment Canterbury	16.9	1.6	8.2	29.4	16.9	2.1
West Coast Regional Council	17.3	1.9	8.1	55.1	18.7	2.3
Otago Regional Council	15.5	1.4	10.3	34.2	20.2	3.3
Environment Southland	13.8	2.3	34.3	94.2	14.2	2.3

* Excludes groups later found not to have elevated risk. See Section 4.1.3.

[1] Food preparation / food handler / café worker; excludes people in these professions who do not have contact with food.

4.1.3 National estimate of risk from occupational exposure

The regional rates of occupation field completion for 2006 were greater than 50% for regions other than Auckland, Greater Wellington, and Marlborough. For all of the 13 council regions where occupation was reported for 50% or more of notified cases expected to have an occupation, the notifications were reviewed to find cases identified as being in the nine occupational groups given in Table 1. The rates of notified cases in each occupational group were expressed per 1000 workers in that group. These rates were compared against the rate for a control group consisting of employed people aged over 15 years old excluding people in the nine occupation groups. Column 4 of Table 3 shows the estimated notification rates across all 13 regions and the control group rate (background).

To investigate any regional differences, the notification rates were calculated for each of the regional council areas. Due to the relatively small number of notifications for each of the occupations the investigated regions were amalgamated into six geographical areas:

1. Northland and Waikato
2. Bay of Plenty, Gisborne and Hawke's Bay
3. Manawatu-Wanganui (Horizons) and Taranaki
4. West Coast, Nelson and Tasman
5. Canterbury
6. Southland and Otago

The fifth column of Table 3 lists the number of geographical areas where the occupation related notification rate was greater than the control (background) notification rate.

Table 3: 2006 Notifications and rates of notification per 1,000 workers for all regions of New Zealand (excluding data from Auckland, Greater Wellington, and Marlborough)

Occupational group	Number of workers in specified regions of New Zealand	Number of notifications reporting occupation	Notification rate per 1,000 workers	Number of areas with greater than background rates	Estimated national notifications due to occupation
Slaughter/process	18,852	224	13.7	All	191
Sewage/wastewater	8,274	31	6.8	All	26
Health	44,460	163	6.2	5 out of 6	115
Veterinary	4,677	15	5.0	4 out of 6	7
Food preparation	47,544	117	4.3	4 out of 6	33
Farm-animals	79,626	279	3.9	4 out of 6	24
Teacher	63,738	122	3.3	2 out of 6	-
Early childhood	22,803	36	2.9	1 out of 6	-
Animal/outside contact	49,182	71	2.0	1 out of 6	-
Background:	**1,523,000**	**5455**	**3.6**		Total: 396

Table 3 indicates elevated rates of illness above background for the following occupational groups:

- Slaughter/meat processing workers
- Sewage/wastewater workers
- Health workers with likely contact with people with gastrointestinal illness
- Veterinary and animal welfare workers
- Food preparation workers
- Farm workers with animal contact

From the notification data, there appears to be no extra risk to people in teaching occupations or those involved on working on the land (this category is quite broad).

A national overview of the number of cases which might be caused by occupational exposure was considered for each group. The elevated notification rate minus background rate was multiplied by the number of workers in the occupational group across the whole of New Zealand (i.e. effectively filling in for the regions where data are incomplete). An estimated 396 notifications were due to occupational exposure in 2006. The estimated number of occupational related notifications for each occupation group is given in the last column of Table 3.

The estimated number of notified cases in 2006 due to being employed as veterinarians or animal welfare workers was 7 out of 4,677 employed people. So while the occupational risk is elevated for this group, the effect on the notifications will be small. Conversely, farm workers with animal contact have only a slightly higher risk than the general population, but they are also the largest occupational group considered with an estimated number of people in this occupation of over 79,000.

Fifteen percent of the sub-national (excluding Auckland, Wellington and Marlborough) notified cases in the 15+ possibly employed group did not have their occupation recorded. If these cases are allocated by assuming the distribution of occupations and unemployed is the same as the completed records, the notification rates amongst the elevated risk occupation workers are increased. Using the increased rates, the estimate of national notifications associated with occupational exposure rises to 614. This is likely to be an upper bound, as some of the missing data may be due to the person not in employment and field being left blank. In addition occupations perceived as being of high risk may be more likely to be recorded. This estimate is used in the spreadsheet as the upper bound on expected number of notifications due to occupational exposure.

Because no information is available on how the working population has changed since 2006, the notifications due to occupational exposure for 2008 in the pathway model have been estimated from the 2006 data.

4.1.4 Regional estimates of risk from occupational exposure

For the pathway model, at a regional level the number of occupationally related cases was considered too small to generate a reliable rate estimate, so a national rate was calculated. The national rate per 1,000 workers of notifications due to different occupations was assumed to be consistent across different regional council areas.

4.2 Rural children 0-4 years old

4.2.1 Introduction

Exposure to *Campylobacter* for rural dwelling people may occur via contact with animals and/or environmental contamination. Studies in Denmark (Ethelberg *et al.*, 2005) have examined the association between campylobacteriosis and population density. The risk of illness was significantly higher amongst younger people (0-4 years: Odds Ratio (OR) 2.23, 5-14 years, OR 1.41) living in areas with low population density (1-25 people per km^2) compared to those living in areas with high population density (>2,000 people per km^2). Elevated risks were also found for the next highest category of population density (26-250 people per $km^{2)}$: 0-4 years OR 1.59, 5-14 years OR 1.34. The risk for older people (>14 years old), although elevated in some instances, was not statistically significant. This is biologically plausible, whereby an initial exposure causes illness and repeated exposures maintain immunity, as has been suggested for occupationally exposed people.

A similar effect can be demonstrated in New Zealand, and has been used to attribute a proportion of the incidence of campylobacteriosis to rurality. An elevated rate of reported campylobacteriosis in the under 15 rural population in New Zealand has been noted previously (Baker *et al.*, 2007).

For a variety of reasons, young children with campylobacteriosis have a higher rate of notification than older age groups. Some of these reasons (e.g. parental concern) are likely to be common across urban/rural regions. Our analysis has shown there is a higher rate of campylobacteriosis notification for young children in rural areas compared to those in urban regions. The increase in notification rate amongst 0-4 year olds in rural areas relative to those in urban areas is used to estimate the size of this elevated risk, and this is applied to the rural 0-4 year old population.

4.2.2 Census data for defining urban and rural populations

Statistics New Zealand uses seven definitions to define urban and rural New Zealand. These categories are based on a variety of criteria, and location of employment address as well as residential address is considered. This has the advantage of linking rural occupation to rural location. The categories are:

- Main urban areas
- Satellite urban communities
- Independent urban communities
- Rural areas with high urban influence
- Rural areas with moderate urban influence
- Rural areas with low urban influence
- Highly rural/remote areas.

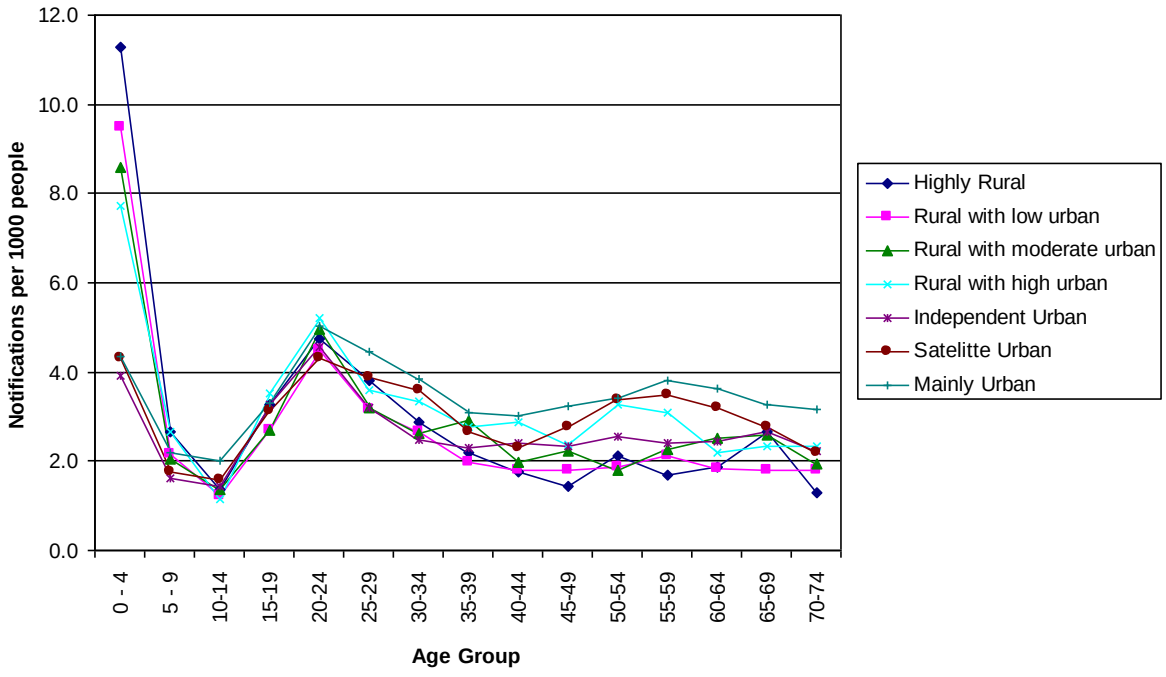
The census data for 2001 and 2006 has been analysed by Statistics New Zealand to provide population estimates for these urban/rural categories by age group. Regional population estimates for 2007 to 2009 are based on the 2006 urban/rural 0-4 year old population adjusted by a factor equal to the estimated change in numbers of 0-4 year olds in each regional council area, as estimated by Statistics New Zealand.

4.2.3 National estimate of risk due to a rural early childhood

Each EpiSurv notification for campylobacteriosis was assigned to one of the above urban/rural categories, based on the case address meshblock[2], and linkage of the meshblock to one of the urban/rural categories. The age of the cases were then used to determine rates for five year age groups in each of the urban/rural categories. The rates of notified campylobacteriosis (per 1,000 population) for each urban/rural category, for amalgamated data from 2001, 2002, 2003 and 2006 are shown in Figure 4. These were the years that urban/rural population estimates were available at the time the analysis was completed.

Cases in the 0-4 year age group had the greatest difference in campylobacteriosis rate between urban and rural cases. In Table 4 the rates of illness (per 1,000 population) amongst 0-4 year olds are shown, for each of the rural/urban categories for each of the years 2001, 2002, 2003 and 2006, and since the rates appeared relatively static, the overall rate was calculated from the amalgamated dataset.

Figure 4: Notified campylobacteriosis rates (per 1,000 population) for all seven rural/urban categories for 5 year age ranges; amalgamated data for 2001-2003, and 2006



[2] A meshblock is the smallest geographic unit for which statistical data is collected by Statistics New Zealand. Meshblocks vary in size from part of a city block to large areas of rural land. Each meshblock abuts another to cover all of New Zealand, extending out to the 200-mile economic zone (approximately 320 kilometers). Meshblocks aggregate to build larger geographic areas, such as area units, territorial authorities, and regional councils.

Table 4: Rate of notified campylobacteriosis cases (per 1,000 population) in 0-4 year olds in rural/urban categories

Year	Highly rural	Rural with low urban	Rural with moderate urban	Rural with high urban	Independent urban	Satellite urban	Main urban area
2001	12.2	9.3	8.4	6.5	3.5	3.2	3.6
2002	12.6	10.4	10.3	10.1	3.9	5.6	4.3
2003	9.1	9.4	8.4	6.1	3.8	4.0	4.6
2006	11.2	8.7	7.3	8.1	4.5	4.4	5.0
Combined	**11.3**	**9.5**	**8.6**	**7.7**	**3.9**	**4.3**	**4.4**

To estimate the contribution of the elevated risk for 0-4 year old rural children in the overall epidemiology of campylobacteriosis in New Zealand, the following approach was taken:

- The elevation of risk was calculated from the difference between the combined notification rate per 1,000 population (Table 4) separately for each of the four categories with some rural character, and the rate for the mainly urban 0-4 year old population;
- The differences in notification rates were multiplied by the number of children living in each of the four categories with some rural character to generate a predicted number of the notifications due to 0-4 year olds living in a rural environment.

Some of the illness in rural 0-4 year olds will be due to environmental or animal contact and some could be due to exposure to untreated water supplies. To avoid duplicating the attribution for rural 0-4 year olds in the drinking water exposure estimates model, the exposed populations in the drinking water categories excludes the 0-4 year old population.

4.2.4 Regional estimates of risk from early childhood in rural areas

The national rate of notifications due to early childhood in rural areas was assumed to be consistent across different regional council areas. At a regional level, the number of such cases was considered too small to generate a reliable region specific rate estimate.

The 2008 estimates for proportion of notifications attributable to 0-4 year old rural children due to living in a rural environment are given in Table 5. The lower and upper bounds on the proportion of notifications are calculated using the minimum and maximum observed rates over the four years (2001-2003, 2006) for each of the urban-rural classifications

Population data for urban-rural categories by Regional Council are given in Table 6 for 0-4 year olds, and the total population in Table 7. The urban/rural regions are shown in Figure 5.

Table 5: Estimate of the proportion of annual notifications in 2008 likely to be due to 0-4 year olds living in a rural environment.

Area	Number of notifications per year likely to be due to rural 0-4 year olds.		
	Estimate	Lower bound	Upper bound
New Zealand	192	171	227
Northland Regional Council	24	22	28
Auckland Regional Council	14	11	19
Environment Waikato	33	31	38
Environment Bay of Plenty	15	14	19
Gisborne District Council	5	5	6
Hawkes Bay Regional Council	7	6	8
Horizons Regional Council	14	12	16
Taranaki Regional Council	10	9	11
Greater Wellington Regional Council	4	4	6
Marlborough District Council	3	3	3
Nelson City Council	0	0	0
Tasman District Council	6	5	7
Environment Canterbury	26	23	31
West Coast Regional Council	5	4	5
Otago Regional Council	14	12	16
Environment Southland	11	10	13

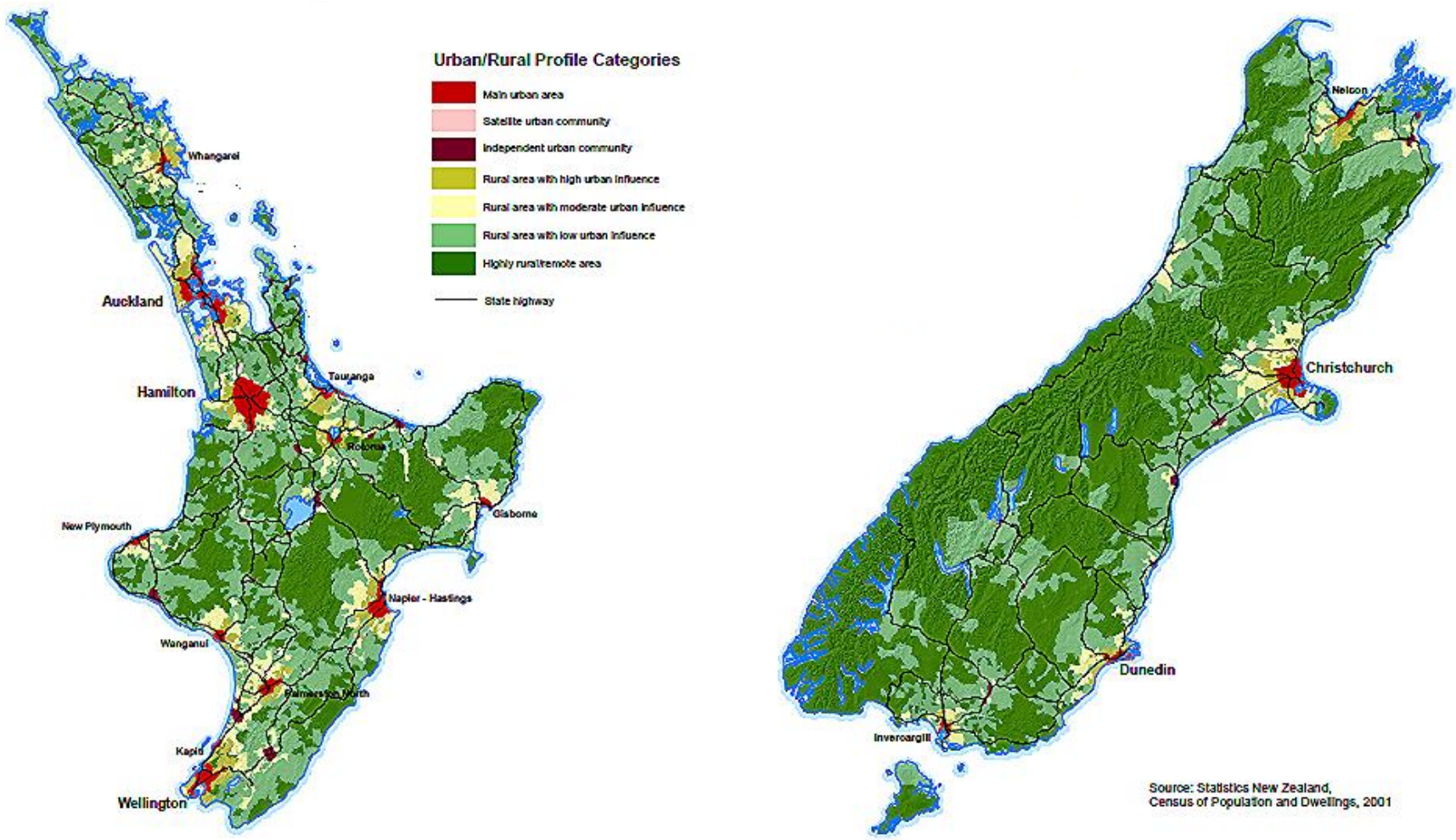
Table 6: Urban/rural populations of 0-4 year old children in 2006, estimated from the 2006 census data (Statistics New Zealand).

Area	Highly rural	Rural with low urban	Rural with moderate urban	Rural with high urban	Independent urban	Satellite urban	Main urban area
New Zealand	4902	15240	10227	8256	28263	9489	198684
Northland Regional Council	453	2508	972	828	2046	0	3462
Auckland Regional Council	48	300	1008	2073	525	2664	87282
Environment Waikato	537	3474	1812	783	6144	1425	13494
Environment Bay of Plenty	135	1167	1083	993	2931	468	11496
Gisborne District Council	294	261	315	147	0	0	2631
Hawkes Bay Regional Council	180	549	363	264	771	0	8313
Horizons Regional Council	321	1104	870	585	2916	1422	7539
Taranaki Regional Council	303	801	516	240	1464	642	2895
Greater Wellington Regional Council	39	273	357	330	1659	492	27225
Marlborough District Council	63	306	171	0	1827	0	0
Nelson City Council	0	0	0	63	0	0	2463
Tasman District Council	108	408	492	168	498	330	894
Environment Canterbury	879	1599	1416	1263	3141	1866	22296
West Coast Regional Council	321	360	144	0	1074	0	0
Otago Regional Council	540	1245	399	360	2439	0	5652
Environment Southland	639	885	309	162	828	180	3036

Table 7: Urban/rural resident populations in 2006, estimated from the 2006 census data (Statistics New Zealand).

Area	Highly rural	Rural with low urban	Rural with moderate urban	Rural with high urban	Independent urban	Satellite urban	Main urban area
New Zealand	65,350	226,620	159,440	128,050	454,310	132,370	3,016,800
Northland Regional Council	6,680	39,300	14,900	13,650	27,500	0	50,500
Auckland Regional Council	1,060	5,210	17,250	31,300	8,430	34,700	1,272,800
Environment Waikato	7,270	47,900	26,900	9,940	94,300	17,100	191,700
Environment Bay of Plenty	1,600	15,600	18,000	15,750	39,300	7,330	167,700
Gisborne District Council	3,250	3,380	3,790	1,920	0	0	33,600
Hawkes Bay Regional Council	2,310	8,140	5,420	3,790	10,450	0	121,900
Horizons Regional Council	4,110	15,450	14,500	9,480	44,800	22,000	119,000
Taranaki Regional Council	3,340	10,250	7,230	3,790	22,100	9,710	50,800
Greater Wellington Regional Council	610	4,140	6,030	5,820	27,600	8,050	413,900
Marlborough District Council	1,440	5,710	2,960	20	33,400	0	0
Nelson City Council	0	0	0	900	0	0	43,400
Tasman District Council	1,810	7,020	7,240	2,780	8,480	3,780	14,700
Environment Canterbury	12,250	25,300	21,800	20,500	59,300	26,300	374,500
West Coast Regional Council	4,360	6,770	2,480	0	18,500	0	0
Otago Regional Council	7,500	19,800	6,380	5,490	46,200	0	114,400
Environment Southland	7,760	12,650	4,560	2,920	13,950	3,400	47,900

Figure 5: Urban/rural regions of New Zealand



4.3 Overseas travel

It is important for policy makers in New Zealand to be able to differentiate domestically acquired cases that are potentially preventable through measures taken in New Zealand, from cases infected while overseas. In the UK for the year ended April 2001 it was estimated that 20% of English and Welsh cases could be have been infected during overseas travel (*Campylobacter* Sentinel Surveillance Scheme, 2003). In Sweden, data from 1997 to 2003 suggested that 54% of Swedish cases were overseas travel related, at a rate of 0.423 per 1,000 overseas trips (Ekdahl and Andersson, 2004).

It is not feasible to estimate the dose and probability of exposure during travel overseas. Therefore the travel risk factor information recorded in the EpiSurv database was used to estimate the risk associated with travelling overseas.

4.3.1 Data

Overseas travel fields are part of the risk factor component of the EpiSurv notification database. The information recorded includes:

- If the case was overseas during the incubation period, defined as 2-5 days (range 1-10 days) (Heymann, 2008).
- The date the case arrived back in New Zealand.
- The last three countries the case visited and the dates of the visits.
- The date of onset of symptoms.

To estimate the proportion of the overall incidence attributable to this risk factor the EpiSurv database was examined to find the number of confirmed cases of *Campylobacter* that reported travel overseas during the incubation period.

The results are summarised in Table 8 for the period 1998 to 2008 and show that overseas travel information is available for only 30-60% of notified cases with the percentage completion decreasing over time. Over the eleven years from 1998 to 2008, 41% of case reports had the overseas travel section completed and of these, 7.6% were overseas during the incubation period.

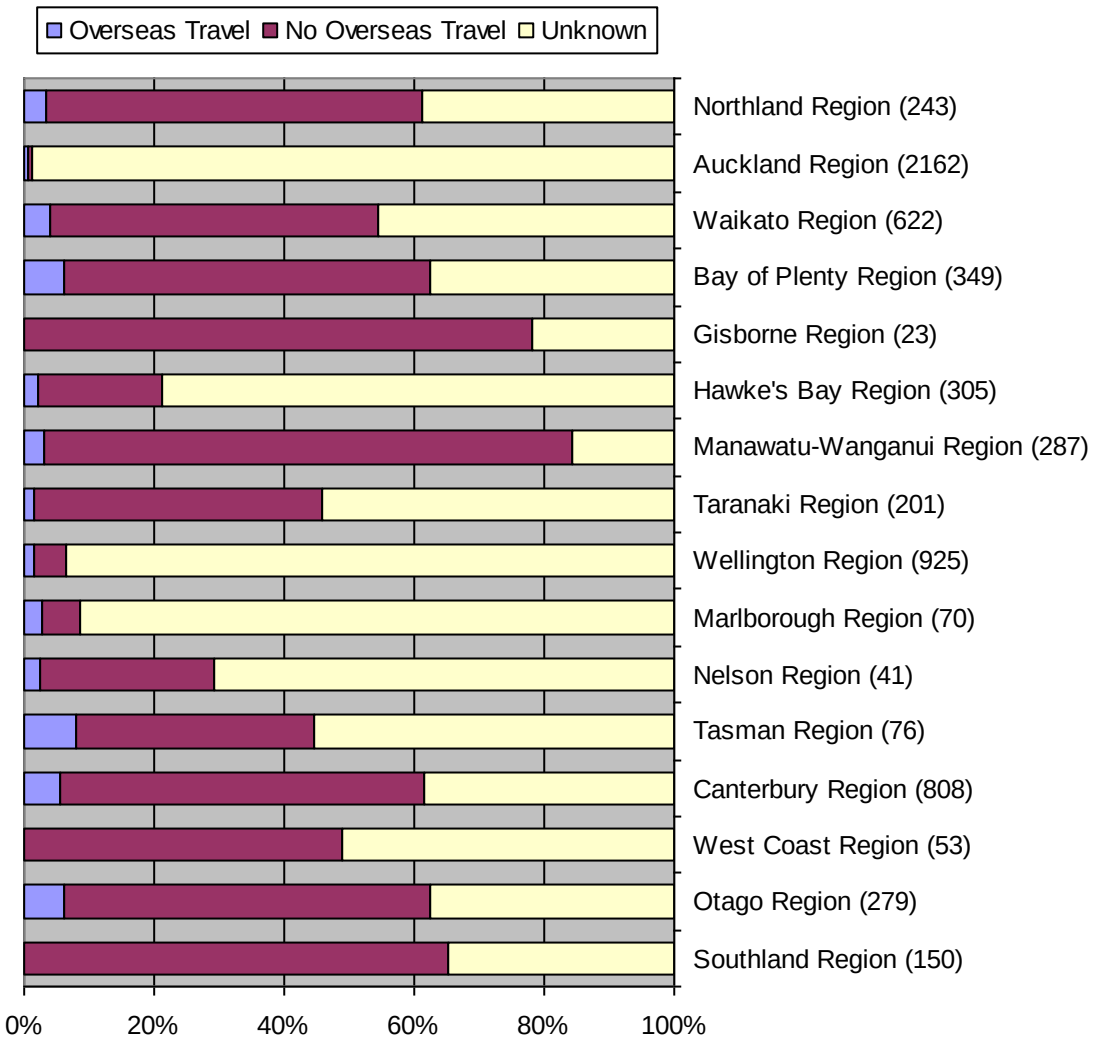
Table 8: Summary of EpiSurv data for *Campylobacter* cases and overseas travel for period 1998 to 2008

Year	All New Zealand confirmed cases	EpiSurv Question: Was the case overseas during the incubation period?			
		Number who answered question	Percentage who answered question (%)	Number who answered YES	Percentage of YES answers from completed responses (%)
1998	11572	6907	59.7	566	8.2
1999	8161	4592	56.3	528	11.5
2000	8418	4587	54.5	386	8.4
2001	10146	5049	49.8	383	7.6
2002	12494	4886	39.1	360	7.4
2003	14789	5458	36.9	353	6.5
2004	12215	3939	32.2	287	7.3
2005	13836	4880	35.3	279	5.7
2006	15873	5056	31.9	304	6
2007	12776	4174	32.7	283	6.8
2008	6594	2054	31.1	172	8.4
All years	126874	51582	40.7	3901	7.6

The data were examined in more detail at the regional council level for the years 2005 to 2008.
Figure 6 graphically shows the proportion of notifications with the overseas travel section completed and the proportion of notifications overseas during the incubation period for 2008. Similar trends were observed for 2005, 2006 and 2007.

The overseas travel data show that regions vary considerably in their completeness of reporting travel as a risk factor. Overseas travel information is absent principally for notifications from the Auckland, Greater Wellington, Hawkes Bay, Marlborough and Nelson regions in 2008.

Figure 6: Percentage of overseas travel risk factor responses for confirmed campylobacteriosis cases by region in 2008. Figures in brackets indicate the total number of confirmed cases notified for each regional council area in 2008



4.3.2 National and Regional Travel Habits

Data on short term overseas travel for the population in each region were obtained from Statistics New Zealand and are shown in columns two and three of Table 9. Short term means a travel period of less than 12 months. There are regional differences in average travel rates per person for a region, with the highest rates occurring in the main urban centers of Auckland and Wellington.

The total counts for short-term arrivals and departures of New Zealand residents are actual counts of travelers, not an estimate for a population, and so are not subject to sampling errors.

Table 9: Adjusted overseas travel attribution for 2008

Region	Rate of short term overseas travel[1] in 2008 (trips per 1000 population)	Number of short term arrivals	Rate of notifications per trip using adjusted[2] number of cases	Estimated number of overseas travel notifications adjusted using rate of illness per trip from most complete datasets
Northland	***294***	***45,558***	***0.000286***	***13***
Auckland	620	877,557	NC	254
Waikato	***321***	***128,926***	***0.000356***	***37***
Bay of Plenty	***362***	***97,804***	***0.000344***	***28***
Gisborne	***215***	***9,893***	***0***	***3***
Hawke's Bay	289	44,106	NC	13
Horizons	***269***	***61683***	***0.000173***	***18***
Taranaki	324	34,779	NC	10
Wellington	500	236,959	NC	68
Marlborough	377	16,758	NC	5
Nelson	418	18,675	NC	5
Tasman	276	12,814	NC	4
Canterbury	***444***	***245,514***	***0.000291***	***71***
West Coast	257	8,312	0	2
Otago	***366***	***74,398***	***0.000366***	***22***
Southland	***287***	***26,661***	***0***	***8***
New Zealand			0.00029	570

1. Short term overseas travel is less than 12 months, NC means rate has not been calculated due to missing data.
2. Adjusted to account for travel data with no address of residence and incomplete EpiSurv overseas travel fields.

Although for a returning traveler carrying an infection the period overseas is not important, Statistics New Zealand data on the length of stay overseas for 2006 and 2007 were reviewed. Statistics New Zealand data for period of short term travel for both years were almost identical:

Up to 2 weeks:	62% of travelers
2-3 weeks:	14% of travelers
3-4 weeks:	7% of travelers
1-6 months:	16% of travelers
6-12 months:	1% of travelers

Thus short term travel is predominantly for a period of less than 4 weeks.

4.3.3 Modelling

Figure 6Figure 6 shows that reporting of overseas travel amongst reported cases of campylobacteriosis is low for a number of regions. One way of filling the data gaps is to estimate for each region the total number of travel related cases amongst the notifications, using the prevalence amongst the cases for which this factor is reported. If the neighbouring regional rates are used for Auckland, Wellington, Hawkes Bay and Marlborough, this calculation generates a national total of 8.7% of notified cases due to overseas travel. While it is possible that the national travel related notifications is this high, it was possible that the data is skewed by this risk factor being more likely to be reported as "yes" when it occurs, but not reported as "no" when it does not occur. This would over-emphasise the risk factor.

To fill the data gaps for regions where travel reporting was low, data from regions where reporting was more complete (>50%) was used to calculate the rate of notifications per overseas trip. The rate was adjusted to take into account:

- Returning travelers who did not have a recorded address that could be linked to a regional council, and
- The number of notifications in the more complete regional datasets that did not have the overseas travel fields filled in.

In 2008, there were eight regional councils where the overseas travel field was completed greater than 50% of the time. The rate per trip (699343 short term trips in those regions) was calculated by combining data from each of these regions to provide an estimate of 0.00029 notifications per trip (Table 9). This rate was then applied across all travelers and regions, yielding a national estimate of 570 notifications, which is 8.5% of the total in 2008. This is very similar to the percentage calculated directly from notifications in 2008 but gives greater confidence in the result.

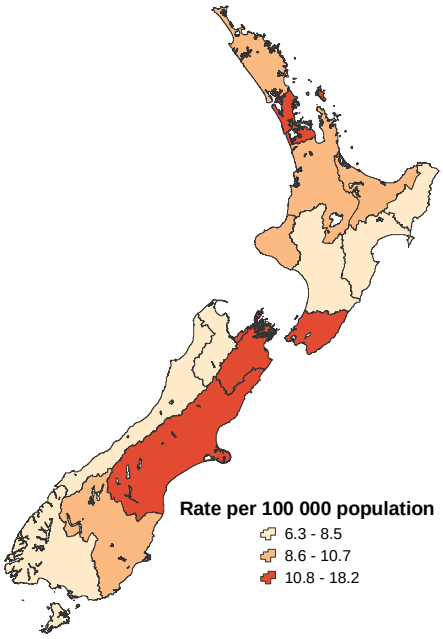
The same calculations were performed for 2005 (using 2006 regional population data as data for 2005 could not be located), 2006 and 2007. These calculations provided estimates of 7.1%, 5.7% and 7.3% of notifications for 2005, 2006 and 2007 respectively.

The lower and upper bounds on the estimate of the proportion of notifications due to overseas travel are defined by observed variability in adjusted rates in regional council areas with greater than 50% completion of the overseas travel field. The minimum and maximum observed rates were 0.00017 and 0.00037 notifications per overseas trip. Based on these rates, the national estimated number of notifications due to overseas travel in 2008 ranged from 340 to 727.

The estimated rate of notifications per 100,000 population for regional councils in New Zealand for 2008 is shown in Figure 7.

The application of rates based only on certain regions (with higher reporting) to the national population makes the assumption that people in different parts of the country and over different years have similar travel habits in terms of where they are likely to travel to.

Figure 7: Estimate of the campylobacteriosis notifications per 100,000 population in each regional council area due to overseas travel in 2008.



4.3.4 Travel destination of notifications

Of the notified cases who reported overseas travel during the incubation period, most also reported a destination, as the data for 2005-2007 show:

2005: 263 of 272 cases (96.7%) reported a destination.
2006: 282 of 299 cases (94.3%) reported a destination.
2007: 247 of 274 cases (90.1%) reported a destination.

The reported destinations were consolidated, and compared with reported destinations for short term travelers for the same years obtained from the Statistics New Zealand website. The results are shown in Table 10.

These comparisons show that India, Asia (excluding China and India), and Central and South America, are consistently high risk destinations across these three years (i.e. the destination as a percentage of notifications is higher than the percentage of that destination amongst short term travelers).

Table 10: Comparison of destinations for 2005-2007 notified campylobacteriosis cases reporting overseas travel during the incubation period, and short term departure destinations for New Zealand travelers

Destination	2005		2006		2007	
	Amongst Notifications (%)	Amongst Travellers (%)	Amongst Notifications (%)	Amongst Travellers (%)	Amongst Notifications (%)	Amongst Travellers (%)
Australia	32.0	50.8	36.8	49.9	35.0	49.8
Pacific Islands	17.3	11.1	13.4	11.9	13.1	12.1
Asia (excluding China and India)	25.7	7.9	19.1	8.7	21.9	7.8
China	2.2	2.7	2.0	2.7	1.8	2.8
India	2.9	1.0	7.0	1.1	4.4	1.3
Central and South America*	1.8	0.5	2.0	0.5	4.0	0.6
USA and Canada	7.0	6.1	2.0	5.6	3.3	5.0
UK/Europe	5.5	7.6	8.4	8.4	8.4	8.7
Africa	2.2	ND	3.7	ND	0.7	ND

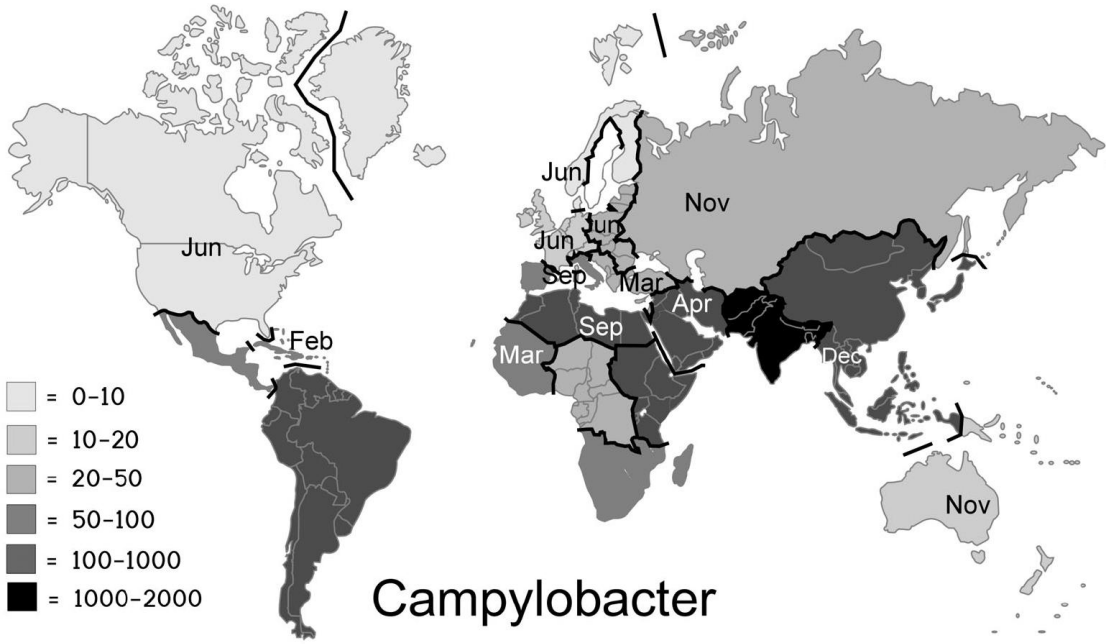
*Calculated as Americas minus USA and Canada

ND: There is a travel destination "Others" in the Statistics New Zealand data, which includes South Africa but may also include non-African countries. It represents 10.3% of travelers in 2006.

Studies done in the UK (*Campylobacter* Sentinel Surveillance Scheme, 2003) and Sweden (Ekdahl and Andersson, 2004) have also shown the risk of infection acquired during overseas travel is dependent on the country to which they travel. The risk to Swedish travellers visiting 19 different regions of the world was found to be highest for the Indian subcontinent, followed by East Asia, East and North Africa and South America (see Figure 8). They also noted seasonality in the risk in the temperate regions with notification peaks in the summer.

The UK study also found the highest risk destinations to be the Indian subcontinent and East Asia area, with elevated risk also associated with Central and Southern America and Africa. A study of Japanese travellers "showed that *C. jejuni* enteritis was more common in travellers to the Indian subcontinent than other countries in Far East" (Taylor and Echeverria, 1986).

Figure 8: Map showing campylobacteriosis risk per 100,000 returning travellers to Sweden from different regions of the world.



In regions with a distinct seasonality, the month with the highest risk (OR) is given. © 2004 Ekdahl and Anderson (http://creativecommons.org/licenses/by/2.0)

A model outline that using data on travel to specific destinations was developed as part of this project (see Appendix 3) but was not further pursued.

4.4 Contact with sick people (person-to-person)

4.4.1 Introduction

Person-to-person transmission of *Campylobacter* is considered to be unusual (Olson *et al.*, 2008) and this pathway has been recorded as low risk in notification data records in New Zealand, Australia (Olson *et al.*, 2008) and Canada (Michaud *et al.*, 2004). A New Zealand case-control study (Eberhart-Phillips *et al.*, 1997) identified a slightly elevated risk of becoming ill with *Campylobacter* infection given contact with a person having a similar illness in the home.

Person-to-person transmission is not amenable to the exposure assessment approach. Notification data provides information that enables an estimate of how often person-to-person transmission may be occurring.

4.4.2 Data

Although it is considered a minor pathway for campylobacteriosis, the number of notifications attributed to person-to-person transmission has been modelled by examining the frequency of this risk factor (contact with other people with gastroenteritis) amongst a dataset of notifications with complete reporting.

The 2008 and 2009 notification data for the Horizons Regional Council area (Manawatu-Wanganui) were examined for evidence of person-to-person transfer of *Campylobacter*. This regional council was examined because the council area had been part of a sentinel surveillance study (French, 2008) and extra care had been taken to ensure notification records were completed as fully as possible.

The notification records were filtered to only keep cases;

- recording contact with other people with gastrointestinal illness, AND
- with symptom onset between 2 and 10 days after contact with symptomatic people, or cases gaining symptoms after looking after sick people, AND
- who had not contracted the infection overseas, AND
- who were not listed as having an occupation in slaughter houses, occupationally looking after patients with gastrointestinal illness or having contact with sewage in the incubation period.

This filtering produced a subset of 32 notifications out of a total of 638 recorded cases with earliest onset dates over the period January 2008 to end of December 2009. Many of the cases had other possible risk factors as well, as shown in Table 11. For example, two cases also drank untreated drinking water and unpasteurised milk, and had contact with both farm animals and a symptomatic person during the incubation period.

Table 11: Risk factors associated with 32 notified campylobacteriosis cases who possibly became ill through person-to-person transmission in Horizons Regional Council 2008 to 2009.

Risk Factor	Risk factor recorded in notification								
Person to person	◢	◢	◢	◢	◢	◢	◢	◢	◢
Food*	◢	◢	◢	◢	◢	◢	◢	◢	◢
Drinking Untreated Water		◢			◢		◢	◢	◢
Recreational Water			◢		◢	◢	◢		
Animal contact				◢		◢	◢	◢	◢
Unpasteurised milk									◢
Number of notifications	**7**	**8**	**4**	**2**	**1**	**1**	**3**	**4**	**2**

* It was assumed all cases would have food consumption as a risk factor for their infection.

4.4.3 Modelling

The person-to-person pathway is dependent on the number of cases in a population. The more people who become ill, the more likely person-to-person transmission will occur in the population. Therefore the total number of annual notifications for an area will scale the number of person-to-person related infections. We modelled an estimate of the number of notifications attributable to person-to-person transmission, as a rate per notification in the population.

The estimate of the rate of person-to-person transfer per notification was calculated using a weighted sum of the number of notifications listing person-to-person contact as a risk factor, based on the notified cases listed in Table 11. Although these cases were filtered to choose those most likely to be caused by person-to-person contact, other risk factors also occur, and could not be ruled out.

The weights depend on how many risk factors each notification has associated with it. There was no information regarding the relative likelihood of a case becoming infected from the different pathways, so the different pathways were treated equally. For example, there were 14 cases which had three possible risk factors shown in Table 11 (columns 3, 4 and 5). Because there are three risk factors with assumed equal possibility of causing illness the weight given to these notifications was 1/3 for each pathway. Therefore, of these 14 possible notifications due to person-to person transfer, 14/3 or 4.7 notifications were estimated to be caused by the person to person transfer pathway.

Taking into account all the data in Table 11, the estimated rate is calculated:

$$\frac{\left(\sum_{i=2}^{5} \frac{\text{Number of notifications with } i \text{ risk factors}}{i}\right)}{\text{Total notifications in 2008-9}}$$

$$= \frac{\left(\frac{7}{2} + \frac{14}{3} + \frac{6}{4} + \frac{5}{5}\right)}{638} = 0.017$$

(i = the number of reported risk factors)

Estimates of the lower and upper bounds for and the estimate of the rate of person-to-person transfer per notification have been calculated as given below:

- The lower bound on the rate of person-to-person transfers per notification is calculated using the proportion of the 32 notifications with only personal contact listed as a risk factor (7) and assuming half these notifications are due to a food pathway.

$$\frac{\text{Number of notifications (symptomatic person, food)}}{\text{Total notifications in 2008-9}} = \frac{7/2}{638} = 0.005$$

- The upper bound on the rate of person-to-person transfers per notification is calculated using all the notifications with person-to-person contact listed as one of the risk factors (32), assuming that person-to-person was the transmission route for all these cases.

$$\frac{\text{Number of notifications including contact with symptomatic person}}{\text{Total notifications in 2008-9}} = \frac{32}{638} = 0.050$$

Applying these rates suggests nationally in 2008 that 110 (range 36 to 331) notifications out of a total of 6594 could be due to person-to-person contact with an infected person.

5 ATTRIBUTION USING MLST TYPING DATA: PETS

5.1 Introduction

Ownership of pets has been investigated as a risk factor for campylobacteriosis in a number of case-control studies, including one from New Zealand (Eberhart-Phillips *et al.*, 1997). Although ownership of pets was not a significant risk pathway for campylobacteriosis in New Zealand, significantly elevated risks were found for ownership of a puppy (<6 months), pets in the home with diarrhoea, and ownership of three or more caged birds.

Surveys reporting the carriage rate of *Campylobacter* cats and dogs are comparatively uncommon and provide mixed results, with some studies reporting relatively high prevalence, principally of *C. upsaliensis* (Baker *et al.*, 1999; Lake, 2006). There is some debate about the importance of *C. upsaliensis* as a cause of human illness. Studies in Thailand, Canada, England and Wales have isolated *C. upsaliensis* from less than 1% of faecal samples from diarrhoea cases. In contrast, studies in South Africa using the "Cape Town" microbiological protocol have isolated this species in faecal samples from up to 25% of cases (Lastovica and Allos, 2008). Procedures suitable for detecting *C. coli* and *C. jejuni* may not detect *C. upsaliensis* (Hald *et al.*, 2004; Moreno *et al.*, 1993).

Studies of New Zealand community and hospital laboratories testing faecal specimens (King *et al.*, 2007; Nicol *et al.*, 2010) found that laboratories were using a variety of testing methods to isolate *Campylobacter*, many of which favored *C. jejuni* and *C. coli* over other species.

In a longitudinal study (Hald *et al.*, 2004) it was found that young pet dogs in Denmark excreted *Campylobacter* during the majority of their puppyhood and adolescence (up to 24 months). In total 76.2% of faecal samples were positive, and positivity was unrelated to gastrointestinal health. *C. upsaliensis* strains were most commonly excreted (30-80% of samples depending on age) with *C. jejuni* the next most common. Prevalence decreased with age of the animal for *C. jejuni*.

5.2 Data

The Hopkirk Institute at Massey University has conducted a survey of cat and dog faeces for *Campylobacter* in Palmerston North. Dog faecal material was collected from ten dog bins around Palmerston North and cat faecal material was collected from a small animal clinic at the University. Statistical modeling tools have been used on data collected from a molecular genotyping technique called Multi-locus Sequence Typing (MLST).

From the samples analysed it was estimated that 1.2% (95% Confidence Interval 0-4.8%) of human cases in the Manawatu could have pets as their source of *Campylobacter* (French, 2009).

5.3 Modelling

The national rate of cat and dog related notifications per 1,000 people was estimated from the Manawatu region as follows:

- In 2008 and 2009 (the period during which Massey University's samples were taken), the number of annual notifications with reporting dates in 2008 and 2009 was 287 and 380 respectively.
- Using the estimate above, that 1.2% of these notifications are caused by infection from cats and dogs, this represents 3.4 and 4.6 notifications in the Manawatu in 2008 and 2009 respectively.
- The population estimates for the Manawatu in 2008 and 2009 are 229,200 and 230,200.
- The average rate of cat and dog related notifications per 1,000 people in the Manawatu across the two years is calculated at 0.0174.
- This rate was then applied to national and regional populations.

The lower and upper bounds on this rate estimate were calculated using the 95% confidence interval (0-4.8%) for the percentage of notifications in the Manawatu region likely to be due to cat and dog sources.

It was estimated that in 2008, 74 (range: 0-338) of the notifications across New Zealand could be due to contact with cats and dogs. This assumes the number of pets per person is the same over the different regional council areas and *Campylobacter* infection rates in cats and dogs are consistent throughout the country.

6 ATTRIBUTION USING EXPOSURE MODELS: FOOD, RECREATIONAL WATER, DRINKING WATER

6.1 Introduction

Three models have been created which estimate infections based on data on the consumption and contamination of food and water, and the dose-response relationship. The pathways considered are:

- Food (chicken, duck and turkey meat, beef, sheep meat, pork, and offal).
- Recreational water (swimming in waterways and the ocean).
- Drinking water.

Figure 9 shows the structure of the exposure models and a summary of the data inputs used for the food and drinking water pathways. The exposure model for recreational water is based on ingestion of water during freshwater swimming in surface waters, and has a similar structure to that of the drinking water exposure model. The dashed boxes on the drinking water column of Figure 9 highlight inputs for which very few *Campylobacter* specific data are available. Because of the data gaps there is large uncertainty around water contamination and therefore the resulting infection rates for drinking and recreational water.

Although an exposure model for drinking water was constructed, it was not used in the final pathway summary model as the input parameters based on the limited data available were not considered reliable.

The models for this project have been constructed to simulate the exposure of a hypothetical New Zealander on a single day e.g. data on the probability of consumption of food or water on any given day are used. These models are similar to those generated overseas which have estimated daily intake of *Campylobacter* (Evers *et al.*, 2008).

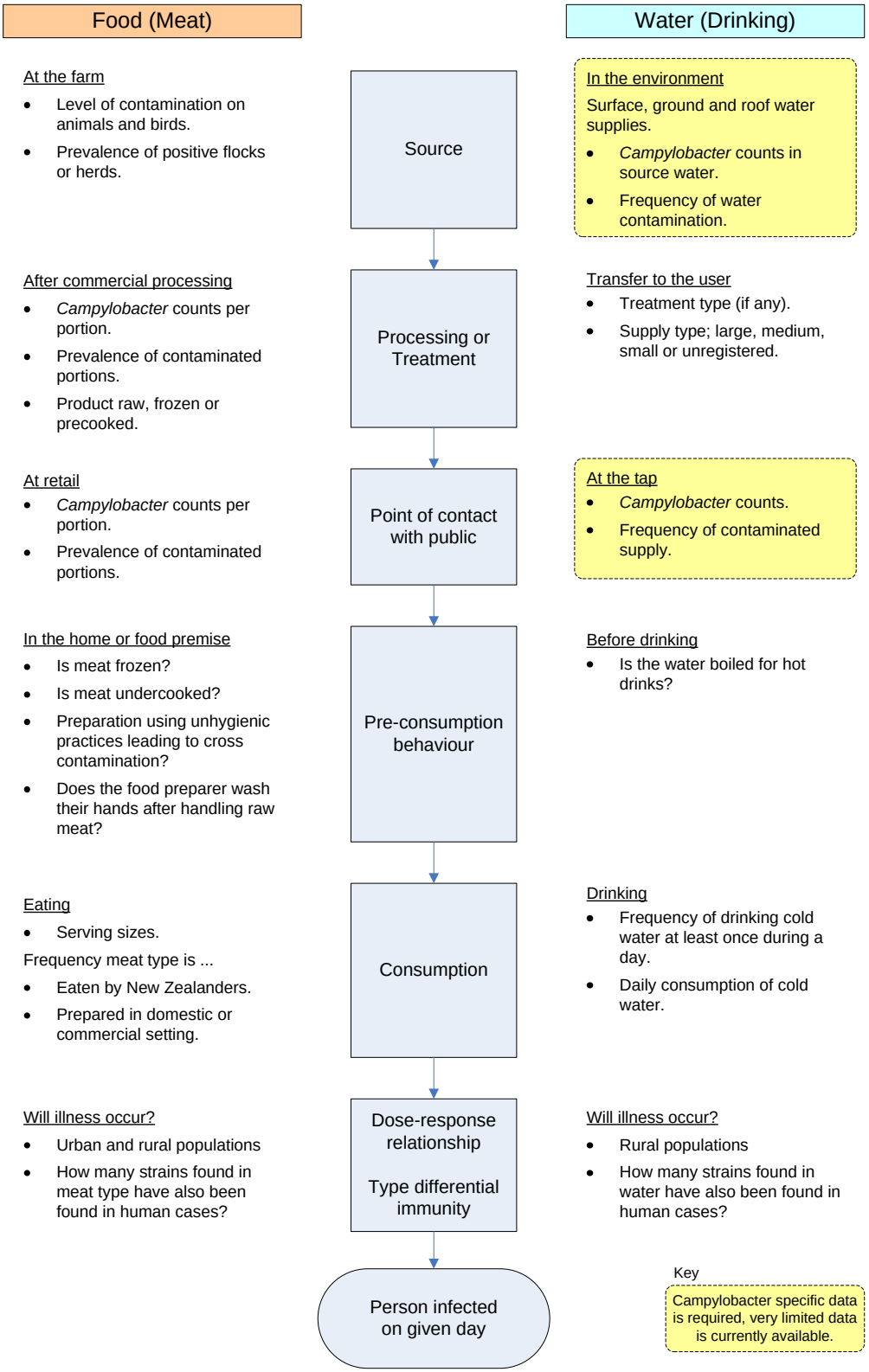
The exposure models are split into two parts. The first part uses Monte Carlo simulations to estimate the probability of infection given consumption of a food or water source which is contaminated with *Campylobacter*. The second part estimates the size of the population at risk from these pathways. Combining these estimates provides an estimate for the number of campylobacteriosis infections that occur in New Zealand on any given day.

The exposure model was split into two parts to allow the worksheets to be used to examine some of the possible interventions, without the need to rerun Monte Carlo simulations each time a new scenario is considered.

The lower and upper bounds on the infection rate are calculated using interval analysis to combine the 2.5% to 97.5% intervals from the Monte Carlo simulation results with empirical and sampling intervals used to determine at risk population sizes. The Monte Carlo simulations were conducted using the @RISK software combined with an Excel workbook.

To incorporate the exposure estimates for infections per day to notifications per year used in the pathway attribution model, a scaling factor was used. The derivation of the scaling factor is discussed in section 6.3.

Figure 9: Exposure model structure, with input types for the food and drinking water pathways.



6.2 Differential infectivity and dose-response

Although strain differences are not clearly understood, it appears that some strains of each *Campylobacter* species are more likely to infect humans than others. A factor has been included in each exposure model to adjust for this differential infectivity. This factor is based on the proportion of *Campylobacter* MLST strain types which are found in food and water sources and are also found in human cases (Professor Nigel French, Massey University, pers. comm., April 2010). These data come from studies in the Manawatu region.

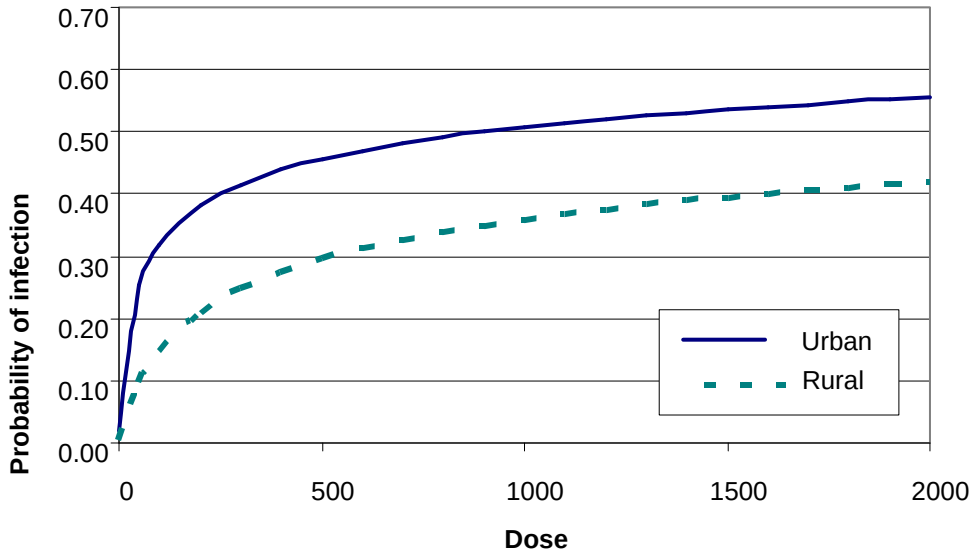
Dose-response relationships describe the probability that a given number of ingested cells will cause infection and/or illness. The food and water comparative exposure models contain such calculations based on an equation which predicts a probability of infection given ingestion by an individual of a number of *Campylobacter* cells, and this probability is then used in a binomial trial to determine whether infection occurs or not. The equation to calculate the probability includes two parameters (alpha and beta) which can be changed in the models to reflect the immune status of the person or population consuming the cells.

The recommended parameters in this model are:

- For populations without inherent immunity: α=0.145 β=8.007
- For populations with immunity maintained by regular exposure: α=0.145 β=50

Examples of the latter population could be rural dwelling people who are exposed to *Campylobacter* regularly via contaminated water, environment, or through contact with animals, particularly livestock. Figure 10 shows the two dose-response relationships using parameters derived from an analysis by scientists at NIWA and Massey University (McBride and French, 2006).

Figure 10: Dose-response relationships for *C. jejuni* based on equations using parameters for urban (α=0.145 β=8.007) and rural (α=0.145 β=50) populations.



6.3 Combining the notification risk factor and exposure estimate attribution

During 2007/08 there was a noticeable drop in confirmed campylobacteriosis notifications (15,728 in 2006 to 6594 in 2008) which coincided with the introduction of a regulatory *Campylobacter* Performance Target for poultry. A review of notification and hospitalisation data has provided evidence that this change in notifications was indeed linked to reductions in *Campylobacter* contamination of poultry (Sears *et al.*, 2011). The large change in total annual notifications for campylobacteriosis between 2006 and 2008, with only one known driver, allows a factor for converting predicted infections per day into predicted notifications per year to be calculated by solving two simultaneous equations.

In the pathway attribution model there are small changes in attribution estimates for the different risk factor and cats and dogs pathways between 2006 and 2008. If we assume there has been no change in risk due to unspecified (remainder) exposures, then the remainder of the difference should be due to changes in poultry contamination.

The predicted number of infections from poultry in the Manawatu region (Horizons Regional Council) using the food exposure model was estimated from prevalence and concentration data from both 2006 and 2008 (see Section 7.4). Using the outputs from the exposure model provides an estimate of 10.1 notifications per year from every infection per day predicted in the Manawatu.

Applying this ratio allows the proportion of notifications due to poultry in the Manawatu to be calculated (67% in 2006, 36% in 2008).

The ratio of predicted infections per day to notifications per year is expected to vary regionally due to a variety of factors, including differences in access to health services. In order to generate a national overview of the attribution, the same approach to calculating a conversion factor was taken for the national population. The data on poultry contamination in the Manawatu in 2006 and 2008 was assumed to be nationally representative.

This produced a national level factor of 17.8 notifications per year for every infection per day estimated. This factor was used to estimate the proportion of the notifications nationally attributable to all food and recreational water exposures, derived from the predicted number of infections from the exposure models.

The extrapolation of the factor derived from Manawatu data makes the assumption that the changes in poultry contamination in that region between 2006 and 2008 apply across New Zealand. This may not be the case, although all three major suppliers were sampled in the Manawatu data. A general reduction in poultry contamination could be inferred from the fact that all regions in New Zealand have shown a decline in notifications over that period, and the proportional decline has been the greatest in predominantly urban regions. Nevertheless, the reduction in notifications between 2006 and 2008 varies between regions.

The factor of 17.8 to convert infections per day from the exposure models to notifications per year is in the range of other published data. Two studies provide the following ratio estimates;

- ratio of 1:7.6 reported:total cases of campylobacteriosis (i.e. multiple of the notifications that represents the total number of illness cases) found in a prospective UK study (Wheeler *et al.*, 1999)
- ratio of 1:0.33 of infections:illness (i.e. proportion of people who are infected who develop symptoms) (FAO/WHO, 2009).

Combining these ratios and converting from per day to per year, leads to an infections per day to notifications per year factor of 16 (infections per day/3 = illnesses per day, illnesses per day x 365 = illnesses per year, illnesses per year/7.6 = notifications per year).

6.4 Exposures from food

The food pathway exposure model starts at the point of retail sale to domestic customers or wholesalers to food service providers. Work prior to this project developed models for the primary and secondary processing of chickens which informed the modeling in this project (Lake *et al.*, 2008; Lake *et al.*, 2007).

The food options are those frequently identified as being contaminated with *Campylobacter*: chicken, beef, sheep meat, pork, offal, duck and turkey meat.

The model calculates exposures and the risk of infection from *Campylobacter* from the following exposure channels:

- Consumption of poultry or red meat with residual bacteria following undercooking
- Consumption of other (ready-to-eat, RTE) foods cross-contaminated by raw poultry/meat during meal preparation
- Intake from contamination on domestic food preparer's hands.

A consistent set of parameters have been collated and applied in a generic model. Where possible, the most recent data (2007-2008) have been used. Some of these parameters are used to calculate the exposure to cells of *Campylobacter*, while others are used to calculate the size of the exposed population, which may be further split into urban and rural populations. Some parameters are universal for all foods, due to a shortage of data specific to the type of food.

Data to calculate exposures includes:

- Amounts of food consumed, e.g. serving size.
- Concentration of *Campylobacter* contamination.
- Any changes in the concentration of *Campylobacter* on food caused by processing e.g. freezing, cooking.

The exposures (i.e. cells of *Campylobacter*) are applied to a dose-response relationship to calculate probability of infection given exposure (Section 6.2).

Data to calculate the size of the exposed population includes:

- Probabilities of behaviours that create risk of infection e.g. undercooking, unhygienic food handling, not washing hands.
- Probability that a particular food is consumed on a given day.
- Probability of food consumption in a domestic or commercial environment (separate calculations are performed for each environment)[3].
- Prevalence of meat contamination with *Campylobacter* types likely to infect people; and,
- Usually resident population of region of interest (rural/urban, regional council).

By multiplying the average probability of infection by the exposed population, the number of daily predicted infections is obtained

6.4.1 Parameters common to all foods

For calculating probability of infection given exposure to contaminated food via different mechanisms:

- Reduction in $\log_{10}$ cfu count if frozen = 2 (Solow *et al.*, 2003; Zhao *et al.*, 2003)
- Probability of meal including RTE food: 0.21 (from review of NNS records for meals including chicken)
- Reduction in $\log_{10}$ cfu counts even if undercooked: 2 (estimate)
- % Transfer to surface: RiskLognorm(2.0216,4.2935,RiskTruncate(0,23.9)) (fitting to data in (Luber *et al.*, 2006) as reported in (Lake and Bayne, 2007)
- % Transfer to RTE food: RiskExpon(14.536,RiskTruncate(0,62.5)) (fitting to data in (Luber *et al.*, 2006) as reported in (Lake and Bayne, 2007)
- % Transfer to hand: RiskLognorm(3.9984,9.0361,RiskShift(0.1036),RiskTruncate(0,100)) (fitting to data in (Luber *et al.*, 2006) as reported in (Lake *et al.*, 2007))
- % Transfer to mouth: RiskLognorm(3.9984,9.0361,RiskShift(0.1036),RiskTruncate(0,100)) (fitting to data in (Luber *et al.*, 2006) as reported in (Lake *et al.*, 2007))

For calculating exposed populations:

- Probability of cooking method prone to undercooking: 0.12 (95% CI 0.09 – 0.16) (based on data for poultry in (Gilbert *et al.*, 2007))
- Probability of undercooking: RiskUniform(0.01,0.1) (based on data for poultry in (Gilbert *et al.*, 2007))
- Probability of behaviours causing cross contamination: 0.174 (95% CI 0.136-0.22) (based on data in (Gilbert *et al.*, 2007))

[3] The remaining proportion of consumption is pre-cooked by industry before retail sale. We have assumed these industry cooking steps are effective in eliminating *Campylobacter*.

- Probability of failure to wash hands: 0.13 (95% CI 0.10 – 0.17) based on data in (Gilbert *et al.*, 2007))

6.4.2 Food specific parameters and sources

These parameters and their sources are summarized in Table 12.

Analyses of records from the National Nutrition Survey (conducted in 1997) (Russell *et al.*, 1999) and the Child Nutrition Survey (conducted in 2002) (Ministry of Health, 2003) were used to generate the data for the daily probability of consumption of the meat types considered in this model. The estimate for chicken consumption from the surveys (26.1%) was adjusted upwards to reflect trends in consumption since the time of the survey. According to data on the PIANZ website, since 1998 the poultry consumption has increased from 26.1 kg per person in 1998 to 32.5 kg per person in year ending September 2009. Although it is possible that some of this increase represent poultry consumers eating larger portions, we have used these data to adjust the probability of a chicken meal on a given day from 26.1% in 1998 to 33.3% in 2008.

6.4.3 Notification estimates

It is estimated in 2008 that out of a total of 6594 notifications:

- 3510 (Range 2704 to 4635) notifications could be due to pathways associated with poultry meat.
- 98 (Range 68 to 148) notifications could be due to red meat and offal.

The estimate for poultry includes both chicken and duck and turkey meat. However, due to low consumption frequency, the number of estimated notifications attributed to duck and turkey meat is very low, between 22 and 26 notifications a year.

Table 12: Food specific parameters for exposure and exposed population calculations

Food	Chicken	Beef	Sheep	Pork	Offal (liver)	Duck and turkey meat
Exposure						
Percentage food is contaminated	50[1] (2008)	5.3[1]	1.4[1]	9.1[2]	80[3]	85[4]
Count on contaminated food unit	=RiskNormal (2.62,1.13, RiskTruncate(0,8))[5] (log_{10} cfu/per carcass) (2008)	Bins (cfu/g)[2]	Bins (cfu/g)[2]	Bins (cfu/g)[2]	=RiskLognorm (2.795,1.641)[3] (log_{10} cfu/g)	=RiskWeibull (1.6598,1.5051, RiskShift(2.2484))[4] (log10 cfu/carcass)
Probability of freezing	0.63[6]	0.57[6]	0.57[6]	0.57[6]	0.05[7]	0.9[7]
Serving size[8]	=RiskInvgauss (121.77,304.26,RiskShift(-30.47),RiskTruncate(30.47,600))	=RiskLognorm(75.15, 86.9, RiskTruncate(0, 684))	=RiskLognorm(62.42, 80.71, RiskTruncate(0, 560))	=RiskLognorm(40.84, 57.27, RiskTruncate(0, 639))	=RiskInvgauss (62.96,21.48, RiskTruncate(0,300))	=RiskInvgauss (121.77,304.26, RiskShift(-30.47), RiskTruncate(30.47,600))[9]
Exposed population						
Probability of eating food on day[8]	33.3	51	16.3	38.1	1.6	0.1
Proportion of food consumed domestically	0.479[11]	Assume same as chicken	Assume same as chicken	Assume same as chicken	0.215[12]	0.215[12]
Proportion of food consumed commercially	0.379[11]	Assume same as chicken	Assume same as chicken	Assume same as chicken	0.645[12]	0.645[12]

1 (French, 2008), Manawatu, whole chicken carcasses and red meat mince, *C. jejuni*, 2 (Wong *et al.*, 2007)

3 Based on consolidated data for sheep liver (Cornelius *et al.*, 2005), chicken livers (Whyte *et al.*, 2006), and beef and sheep livers (Hudson, 1997). Counts from fitting to data in (Whyte *et al.*, 2006)

4 Based on data from surveys by ESR and Massey University, and fitting to log cfu/carcass concentration data

5 Fitting to 2006 Massey data from Manawatu, 6 Data for red meat and poultry reported in (Gilbert *et al.*, 2007)

7 Estimated based on discussion with Dr Teck Lok Wong, ESR, 8 Data extracted from NNS and CNS, weighted for population in each age range; as given in (Cressey *et al.*, 2006)

9 Insufficient servings to estimate; assumed same as chicken

10 Adjusted from National and Child Nutrition Survey data (see text), 11 Poultry industry data on secondary processing of poultry in (Lake *et al.*, 2008)

12 Opinion after discussion with Dr Teck Lok Wong, ESR, assume same proportion precooked by industry as for chicken.

6.5 Exposure from recreational water activities

This model estimated potential exposure from surface water swallowed during fresh water swimming (rivers, lakes etc.). There are a number of other recreational activities which may involve ingestion of untreated fresh water (e.g. boating, water skiing). It was considered that swimming represented the activity most likely to result in ingestion.

Potential doses are calculated from data on the prevalence and concentration of *Campylobacter* in surface waters found in the Manawatu and Freshwater Microbiology Programme (FMP) studies (French, 2008; McBride *et al.*, 2002). The volume of water consumed is calculated from data on consumption (swallowing) rates per hour and estimated duration of each swim. The dose is applied to the dose-response relationship.

The size of the potentially exposed population is calculated from data on the number of New Zealanders who swim in surface waters, the estimated numbers of swims per year, and the probability that the water is contaminated with *Campylobacter*.

The following model inputs were used:

- Proportion of the New Zealand population that swim in fresh water (excluding swimming pools):

  0.063 (= 1/16 of the population)

This is based on the FMP report (McBride *et al.*, 2002), which states (page 23) that about 250,000 people go for at least one swim at a freshwater site each year (McBride *et al.*, 1996; MfE, 1998). The 250,000 people are assumed to be $1/16^{th}$ of total New Zealand population of approximately 4 million.

- Number of swims per year in freshwater for a swimmer:

  Uniform (1,20) (estimation)

Intake of freshwater during a swim is based on duration of the swim and ingestion rate for water as used by the FMP report (McBride *et al.*, 2002) which cites a claim by Schernewski and Julich (2001) that 10-100 ml are ingested during swimming based on Johl *et al.*, 1995.

- Duration of swim (hours):

  BetaPert (minimum, mode, maximum) = BetaPert (0.25,0.5,2)

- Ingestion rate (ml) per hour:

  BetaPert (minimum, mode, maximum) = BetaPert (10,50,100)

A "differential infectivity factor" is included in the model to account for the fact that only a proportion of *C. jejuni* types found in surface water samples in the Manawatu also appear in human cases (Section 6.2). This makes the assumption that the types of *C. jejuni* found in surface water in the Manawatu (mostly associated with wildlife, with some ruminant types) are representative of those found in other regions of New Zealand (French, 2008).

In 2008 it is estimated that 675 (Range 476 – 1885) of the 6594 notifications could be due to recreational water contact.

This attribution estimate is high in comparison to consumption of red meat and offal, However, recreational water exposures do not contain any contamination reduction steps such as freezing, or cooking.

The attribution of notifications to the recreational water use pathway is dependent on the number of swimming sites that are contaminated and at what concentration. New data or the NIWA catchment models could be used to further inform this model and evaluate the effect of potential interventions due to changes in water quality.

6.6 Exposures from drinking water supplies

Exposure to *Campylobacter* from drinking water supplies may occur through two different scenarios:

1. Drinking water from untreated and contaminated supplies consumed by urban resident people away from their normal (uncontaminated) supply, on a temporary basis. For example, water consumed during visits to camp grounds or rural areas with untreated water supplies.
2. Drinking water from a normal supply which is untreated and contaminated. This would be expected to apply mostly to small rural supplies.

An exposure model of the first scenario was not attempted, due to a lack of data on the frequency of such exposures. However, a New Zealand case-control study of campylobacteriosis identified an adjusted odds ratio of 1.43 (95% CI 1.08-2.63) for non-city water outside of the home, which was estimated to contribute 5% of the population attributable risk in 1994/5 (Eberhart-Phillips *et al.*, 1997).

Campylobacteriosis notification records for 2006 and 2008 were examined to identify cases that reported consuming untreated source water as a risk factor. Data were extracted for seven regions where reporting was more complete (>50%, Bay of Plenty, Canterbury, Gisborne, Horizons, Northland, Otago, Southland Regional Councils). The number of cases located in the three Statistics New Zealand regional categories with the most urban character (main urban areas, satellite urban areas, independent urban communities) and which reported consumption of untreated water were:

2006: 208/4246 case notifications (4.9%)
2008: 94/1276 case notifications (7.4%)

The presumption would be that these people consumed the untreated water away from their normal urban supply. The number of urban notifications listing untreated drinking water as a risk factor will provide an upper bound to the attribution estimate for this scenario, as many of the cases will have been exposed to other risk pathways at the same time.

An exposure model was developed to describe the second scenario. Only drinking cold water from the tap is considered in the model. While people may consume tap water from other

activities such as teeth brushing or showering, the amounts are considered minor (and soap or toothpaste may be bactericidal).

The structure of the drinking water exposure model is shown in Figure 9. As for the food exposure models, the attribution is based on estimating the probability of infection given exposure to contaminated drinking water and the size of the "at risk" populations.

The probability of infection from consumption of drinking water is estimated on the basis of frequency and concentration of contamination by *C. jejuni* by type of water source, the probability of treatment, and the daily volume of water consumed. The model is intended to use Monte Carlo simulation from distributions of various stochastic inputs.

Following review of the available data for inputs to the drinking water exposure model as described in Appendix 4, it was decided that the data were insufficient to allow the model to generate outputs for attribution. In particular there were very few data on unregistered supplies, which could be expected to be the greatest contributors to human exposure to *Campylobacter*. The shortage of data concerned the size of the population using unregistered supplies, the types of source waters used, treatment status, and prevalence and concentration of contamination (particularly for roof water supplies).

While missing data currently prevents the drinking water exposure model being used to estimate attribution of campylobacteriosis to the drinking water pathway, the spreadsheets can be used to explore the effects on public health risk of different "what if" scenarios where the hypothetical data and interventions are used to fill in for the missing data.

7 COMPARISON OF THE ESR PATHWAY MODEL WITH THE MASSEY UNIVERSITY MANAWATU SURVEILLANCE PROJECT AND NOTIFICATION DATA

7.1 Introduction

The Hopkirk Institute at Massey University developed source attribution models for human infection based on MLST data for *Campylobacter* strains taken from human, animal and environmental samples in the Manawatu (French, 2008).

This section compares the results from the source modeling in the Manawatu and EpiSurv notification data for the region, with the estimates generated from the pathway attribution model for the Horizons Regional Council area. As mentioned earlier, the notifications dataset from this region is almost complete, and population data specific for this region (e.g. occupations) can be extracted from Statistics New Zealand information.

Data from before (2006) and after (2008-9) the introduction of the *Campylobacter* Performance Target were used to help calibrate the poultry pathway of the model. Over this time period there was a drop in the number of confirmed notifications from 564 to 287 in the Horizons Regional Council area.

7.2 Comparison of pathway model estimates with notification data

The pathway model estimates of the number of notifications in the Horizons Regional Council Area are given alongside numbers from directly analysing the notifications data directly for the years 2006 and 2008 in Table 13.

The pathway model provides a close estimate of the notifications associated with rural pre-school children. Overseas travel illness is reported in the notification data at a rate lower than the national average per trip and hence the notification data has slighter lower numbers associated with overseas travel than predicted by the pathway model.

The person-to-person contact is calculated from the data from this region so the pathway model estimates will be consistent with notification data.

The biggest difference between the pathway model and the notification data is in the predictions for the occupational categories. The pathway model over-predicts the number of notifications from slaughter house/meat processing staff in 2006 and 2008, and health workers in 2008.

If improved regional estimates of occupational infections were required, regional models may need to differentiate between populations employed in poultry processing as opposed to red meat processing. This level of detail is not available from census data, although industry may be able to provide these numbers.

The drop in health workers risk between 2006 and 2008 may be due to the general drop in notifications and in future development this occupation could be linked to the proportion of cases by taking a similar approach to the person-to-person contact pathway.

Table 13: Comparison of risk factor and MLST pathway model estimates with the analysed notification data.

Occupation	2006 estimates		2008 estimates	
	Pathway model	**Notifications**	**Pathway model**	**Notifications**
Health – GI[1] person contact	7	6	7	0
Vet / Animal welfare	1	1	1	1
Slaughter / Meat processing	19	6	19	6
Livestock farms	3	5	3	5
Food Preparation	2	0	2	0
Sewage / Waste water	2	1	2	0
Total	**33 (33-50)**	**19**	**33 (33-50)**	**12**
Rural 0-4 year olds	14 (12-16)	13	14 (12-16)	13
Overseas Travel	18 (11-23)	14	18 (11-23)	11
Person-to-person contact	9 (3 -28)	ND[2]	5 (2-14)	5
Cats and Dogs	4 (0 –18)	ND	4 (0 -18)	ND

1. GI, Gastrointestinal illness.
2. ND, no data.

7.3 Poultry and water exposure model estimates

Whole fresh poultry carcasses were sampled from retail outlets in Palmerston North (French, 2008). The prevalence of contaminated carcasses and the counts of *Campylobacter* obtained from rinsing these carcasses were summarised for; before introduction of the *Campylobacter* Performance Target (2006-October 2007) and following the target as represented by the year of 2008. The results are in Table 14 and show a reduction in both prevalence of contaminated carcasses and rinsate counts.

Table 14: Prevalence of *C. jejuni* and rinsate counts from fresh retail poultry carcasses sampled from the Palmerston North.

Sampling Period	Prevalence of contaminated carcasses (%)	Mean log counts of contaminated carcass rinsates (log_{10} cfu/rinse)	Standard deviation of counts of contaminated carcass rinsates (log_{10} cfu/rinse)
2006 to Oct 2007	60	3.41	1.36
2008	50	2.62	1.13

Using these data as inputs to the poultry exposure model produces estimates of 37 infections a day in 2006 and 10 infections per day in 2008. The recreational water exposure model predicts there could be 2 infections per day related to recreational water, using Manawatu regional population data. There are no data that demonstrate any change in source water contamination with *Campylobacter* between 2006 and 2008. If the drop in frequency of *Campylobacter* in flocks from poultry farms is not affecting the frequency of contamination in freshwater, the number of infections due to drinking and recreational water can be assumed to be the same in 2006 and 2008.

Combining the results from the exposure model and analysis of the notifications gives the results in Figure 11. The pathway model predicts that in 2006, 378 notified cases were due to poultry consumption (67%), compared to 103 (36%) in 2008. The recreational water exposure model accounts for 20 notifications each year.

There was also a slight drop in poultry production from 2006 to 2008, suggesting the probability of a person eating chicken on a day may have reduced from 0.35 to 0.33.

The source attribution models from the Manawatu surveillance project predicted a proportion of human cases attributable to poultry sources as opposed to bovine, ovine and environmental sources (French *et al.*, 2010). The model estimates that 77% (95% credible interval: 61%-90%) of notified cases were associated with a poultry source in 2006 and 25% (95% credible interval: 5%-49%) of notified cases in 2008.

Figure 12 compares the percentage of notifications attributable to poultry as a food, as predicted by the source attribution model (French *et al.*, 2010) and the pathway attribution model developed in this project. The interval given for the source attribution model represents the 95% credible intervals produced by the Hald source attribution model. The intervals for the pathway attribution are the upper and lower bounds that have been calculated as discussed in Section 6.

Figure 11: Estimated attribution of different pathway notifications for Horizons Regional council area in 2006 and 2008.

Pathway	2006		2008	
	Estimated Attribution of Notifications to Pathways for the year		Estimated Attribution of Notifications to Pathways for the year	
Occupation	33		33	
Rural 0-4 year	14		14	
Overseas	18		18	
Person to Person	9		5	
Cats and dogs	4		4	
		Estimated infections per day		Estimated infections per day
Poultry	378	37	103	10
Red Meat	3	0	3	0
Recreational Water	20	2	20	2
Remainder including drinking water and other animal contact, other foods and recreational exposure	87		87	
Total Reported Notifications	564		287	

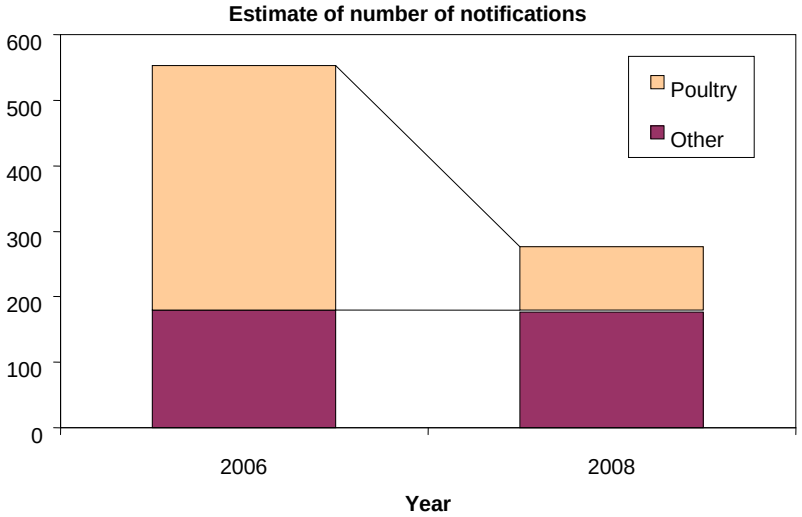
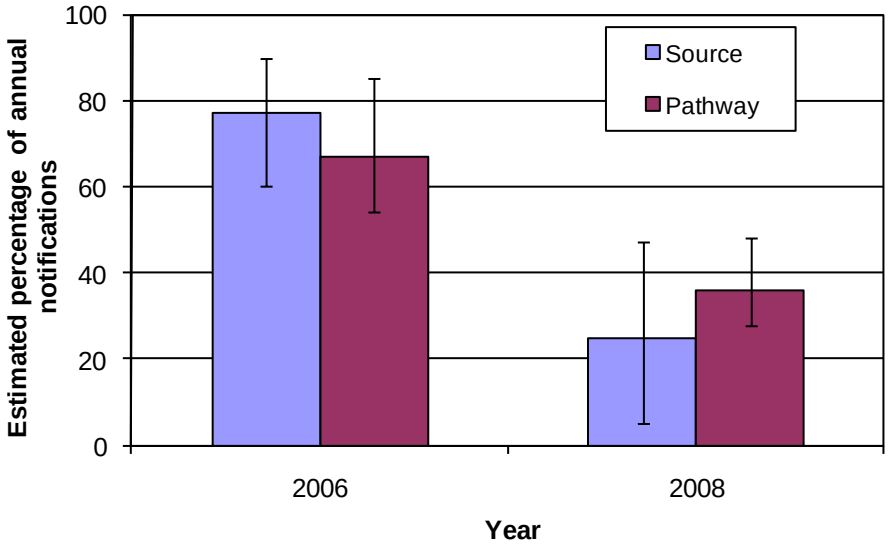


Figure 12: Attribution by source attribution for poultry and by pathway attribution for poultry as a food displayed as the estimated percentage of notified human campylobacteriosis cases in 2006 and 2008 in the Manawatu.



8 CONCLUSIONS

A national overview of the pathway attribution of campylobacteriosis notifications generated by the modeling described in this report is shown in Figure 13. The pathway attribution for the Manawatu region is shown in Figure 14.

The intervals on the attribution estimates represent plausible lower and upper bounds of the attribution estimate based on analysis of the different data sources. The different data sources mean that different approaches have been used to generate the bounds: The bounds for the risk factor analyses (occupational exposure, rural 0-4 year olds, overseas travel and person to person transmission) are from direct observation of the notification data. The bounds for the cat and dog pathways are generated using interval analysis incorporating the 95^{th} credible interval from source attribution analysis. The bounds for the exposure models (food and recreational water) are generated using interval analysis incorporating bounds on the size of exposed population and the 2.5^{th} and 97.5^{th} percentiles of the Monte Carlo simulations.

It is important to note the attribution estimate for the unassigned notifications (including drinking water and other animal contact) has been generated by difference. Plausible bounds for the number of unassigned notifications are not given in the Figures. Theoretically, the bounds could be calculated using interval analysis, accummulating the bounds from the other pathways, however combining the estimates from the different approaches in this way would produce a large interval from the extremes of the other pathway estimates.

Between 2006 and 2008 the attribution to poultry has declined markedly, and since person-to-person transmission model attribution depends on the total number of cases this has also declined. Overseas travel has increased slightly due to an increase in international travel rates. Attribution for rural 0-4 year olds and recreational water also increased slightly due to increasing populations. Occupation did not change due to the modeling approach, which fixed the number of people employed in occupations as that recorded in the 2006 census.

It is worth noting that in the Manawatu in 2008, attribution to the unassigned pathway is approaching that for poultry, while there is a greater difference when the data are presented nationally. This is plausible for a largely rural area.

Some of the estimates in this analysis can be compared with other studies. As discussed in Section 7, the exposure assessment approach for exposures to *Campylobacter* in chicken for 2008 is broadly in agreement with the source attribution analyses using strain typing for the Manawatu region which show that poultry is an important source (approximately 25% of cases attributed to poultry associated types in 2008) (French *et al.*, 2010).

Figure 13: National pathway attribution of the campylobacteriosis notifications for 2006 and 2008. Intervals represent the lower and upper plausible bounds of the estimates, no intervals are given for the remainder pathway.

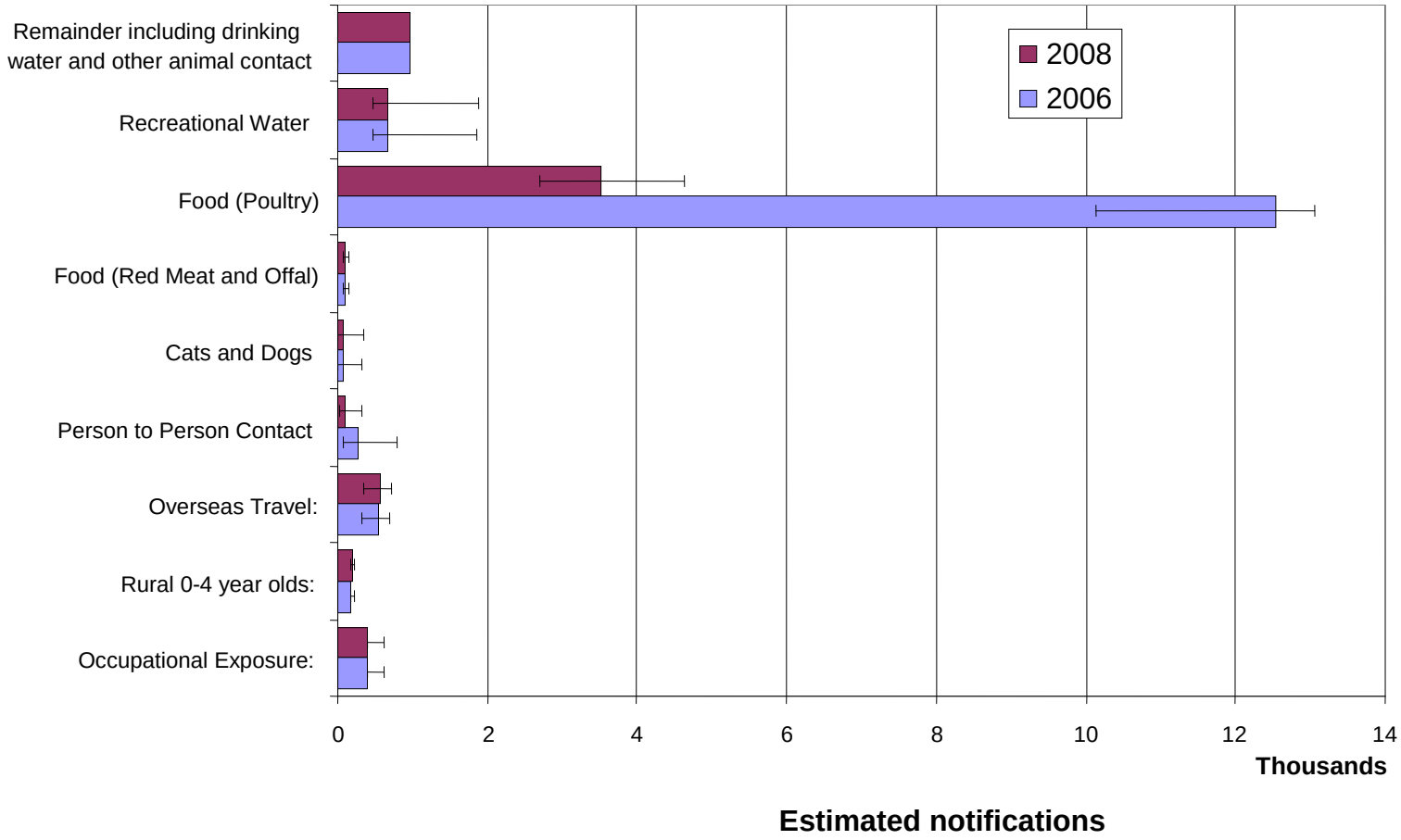
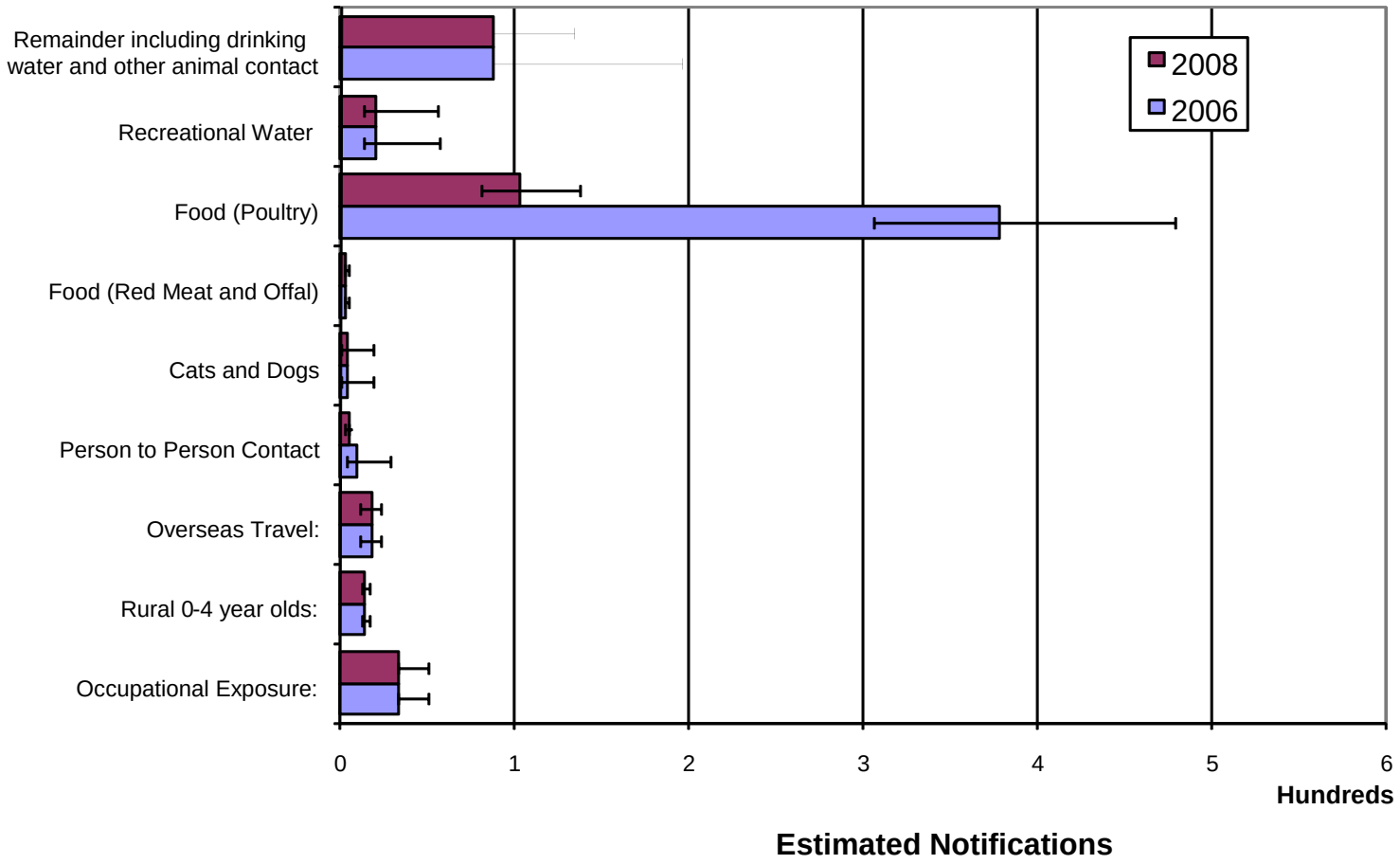


Figure 14: Pathway attribution of campylobacteriosis notifications in the Manawatu for 2006 and 2008. Intervals represent the lower and upper plausible bounds of the estimates, no intervals are given for the remainder pathway.



The source attribution analyses have also found that cases in rural areas were more likely to be infected with ruminant associated types than urban areas (Mullner *et al.*, 2010b). Approximately 67% of cases in the Manawatu have been attributed to ruminant (cattle, sheep) associated types in 2008 (French *et al.*, 2010). Given the apparently low prevalence of contamination of ruminant derived foods (beef and sheep meat) at retail (French, 2008; Wong *et al.*, 2007), and low consumption of more frequently contaminated ruminant derived foods (offal) (Cressey *et al.*, 2006) there is a question about the transmission routes for these source types. Transmission pathways involving animal contact and contaminated water are plausible routes for such exposures, and the combination of attribution in the Manawatu for the remainder (including drinking water), recreational water, occupation, and rural children pathways would exceed that for poultry.

The use of a factor to convert numbers of infection predicted by the exposure models into notification was driven by the differing outputs of the model types. Calculating this factor involves assuming that the recent decline in campylobacteriosis notifications is due to changes in the poultry food supply. The pathway model is very sensitive to the size of this factor. Nevertheless, the value of the factor estimate (Section 6.3) and attribution results are plausible, when reviewed alongside other data.

The analysis presented in this report represents an alternative approach to understanding the transmission of campylobacteriosis in New Zealand. This topic has to date been investigated by case-control studies (Eberhart-Phillips *et al.*, 1997; Ikram *et al.*, 1994) and source attribution using strain typing (Mullner *et al.*, 2010a; Mullner *et al.*, 2009), as well as analysis of notification and hospitalisation data (Baker *et al.*, 2007).

Our approach attempts to combine analysis of notification data with exposure assessment models. The latter have not been extensively used to examine exposures to *Campylobacter*; we are aware of only one report from the Netherlands (Evers *et al.*, 2008). However, exposure assessment models represent a useful tool for investigating the effect of potential interventions that affect specific pathways.

Notification data is incomplete and potentially subject to selection bias amongst those who are notified from the totality of community cases, and bias in reporting of the data on these cases by public health sources. Our use of notification data involves geographical location and age of cases (for urban/rural analyses), occupation, and overseas travel associated with illness. Occupation and overseas travel in particular are subject to incomplete reporting.

National data from Statistics New Zealand sources (urban/rural populations, overseas travel rates, number of people employed in occupations) have been employed to compensate for incomplete reporting. Nevertheless, there remains the potential for bias in the notification data e.g. occupations at higher risk of infection may be more likely to be reported than others. Cases of campylobacteriosis potentially related to occupations where there is a risk of further transmission (e.g. food workers, health care workers) are more likely to be investigated, according to a recent study of diagnostic and public health practices (Nicol *et al.*, 2010). It is possible that such bias would lead to an overestimation of occupational risk, when data from notifications are used, and this is consistent with the results from the Manawatu, as shown in Table 13.

8.1 Data Gaps

There are numerous data gaps in the information available to estimate parameters for these models. The two most important areas that would improve the estimates are:

- More complete reporting of risk factor information for notified cases of campylobacteriosis; and,
- Better data on the populations served by unregistered drinking water supplies, the water sources feeding these supplies and treatment status along with the prevalence and concentration of *Campylobacter* contamination of drinking water sources.

Other data gaps that would improve our ability to understand the epidemiology of campylobacteriosis are the lack of information on carriage of *Campylobacter* by pets, and traits that affect the infectivity of different strains.

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10 APPENDIX 1: Comparison of sources with pathways

Sources are the habitats in which *Campylobacter* can survive and possibly grow. The pathway is the route by which *Campylobacter* transfers to a person in order for infection of the person to occur. Table 15 gives examples of possible relationships between example sources and pathways.

It is clear from Table 15 there are multiple possible pathways to human infection from the different sources. There is no simple relationship between the sources and the pathways.

Overseas travel is kept as a separate source and pathway, as the *Campylobacter* strains are generally different from those typically isolated in New Zealand and the cases were overseas during the incubation period. It is possible some of these notifications were infected on their return to New Zealand (e.g. on an airline or in the first couple of days following their return).

Table 15: Sources and pathways for human *Campylobacter* attribution modelling

		PATHWAY							
		Food Eating / Preparation	Drinking Water	Recreational Water	Rural Pre- school children	Occupation	Animal Contact	Faecal Contact	Overseas Travel
SOURCE	Pets			X		X	X	X	
	Poultry	X			X	X	X	X	
	Cows/Sheep/Pigs	X	X	X	X	X	X	X	
	Wild Animals / Birds		X	X	X			X	
	Environmental		X	X	X	X		X	
	Human	X	X	X		X		X	
	Overseas								X

11 APPENDIX 2: EpiSurv Enteric disease report form

CASE REPORT FORM **Enteric Disease**

Enteric Disease EpiSurv No.

Disease Name

○ Gastroenteritis - unknown cause ○ Gastroenteritis/foodborne intoxication - specify

○ Campylobacteriosis ○ Cholera ○ Cryptosporidiosis ○ Giardiasis

○ Paratyphoid fever ○ Salmonellosis ○ Shigellosis ○ Typhoid fever ○ Yersiniosis

Reporting Authority

Name of Public Health Officer responsible for case

Notifier Identification

Reporting source* ○ General Practitioner ○ Hospital-based Practitioner ○ Laboratory

○ Self-notification ○ Outbreak Investigation ○ Other

Name of reporting source **Organisation**

Date reported* **Contact phone**

Usual GP **Practice** **GP phone**

GP/Practice address Number Street Suburb

Town/City Post Code ☐ GeoCode

Case Identification

Name of case* Surname Given Name(s)

NHI number* **Email**

Current address* Number Street Suburb

Town/City Post Code ☐ GeoCode

Phone (home) **Phone (work)** **Phone (other)**

Case Demography

Location **TA*** **DHB***

Date of birth* **OR** **Age** ○ Days ○ Months ○ Years

Sex* ○ Male ○ Female ○ Indeterminate ○ Unknown

Occupation*

Occupation location ○ Place of Work ○ School ○ Pre-school

Name

Address Number Street Suburb

Town/City Post Code ☐ GeoCode

Alternative location ○ Place of Work ○ School ○ Pre-school

Name

Address Number Street Suburb

Town/City Post Code ☐ GeoCode

Ethnic group case belongs to* (tick all that apply)

☐ NZ European ☐ Maori ☐ Samoan ☐ Cook Island Maori

☐ Niuean ☐ Chinese ☐ Indian ☐ Tongan

☐ Other (such as Dutch, Japanese, Tokelauan) *(specify)

Enteric Disease EpiSurv No. _____

Basis of Diagnosis

CLINICAL CRITERIA

Fits clinical description* ○ Yes ○ No ○ Unknown

LABORATORY CRITERIA (refer to case definition)

Meets laboratory criteria* ○ Yes ○ No ○ Unknown

Organism / toxin / antigen / oocysts / cysts / trophozoites isolated or detected from body site* ○ Yes ○ No ○ Not Done ○ Awaiting Results

Specify site* ○ Faeces ○ Blood ○ Other site (*specify) _____

Organism / toxin isolated or detected from linked food or water* ○ Yes ○ No ○ Not Done ○ Awaiting Results

EPIDEMIOLOGICAL CRITERIA

Contact with a confirmed case of the same disease* ○ Yes ○ No ○ Unknown
(If yes also record details in risk factors section)

Part of an identified common source outbreak* ○ Yes ○ No ○ Unknown
(If yes also record details in outbreak section and risk factors section)

STATUS* ○ Under Investigation ○ Probable ○ Confirmed ○ Not a case

ADDITIONAL LABORATORY DETAILS

Organism species/serotype/phage toxin etc* _____

ESR Updated ☐ Laboratory _____

Date result updated _____ Sample Number _____

ASSOCIATED FOOD/WATER/ENVIRONMENTAL SAMPLES

Were there any food, water or environmental samples associated with this case? ○ Yes ○ No ○ Unknown

If yes, specify type(s) and results

Sample Type	Sample Number	Result

Clinical Course and Outcome

Date of onset* _____ ☐ Approximate ☐ Unknown

Hospitalised* ○ Yes ○ No ○ Unknown

Date hospitalised* _____ ☐ Unknown

Hospital* _____

Died* ○ Yes ○ No ○ Unknown

Date died* _____ ☐ Unknown

Was this disease the primary cause of death?* ○ Yes ○ No ○ Unknown

***If no, specify the primary cause of death**

_____

Outbreak Details

Is this case part of an outbreak (i.e. known to be linked to one or more other cases of the same disease)?*

☐ Yes **If yes, specify Outbreak No.*** _____

Enteric Disease EpiSurv No.

Risk Factors

FOOD PREMISES

Did the case consume food from a food premises during the incubation period?~ ○ Yes ○ No ○ Unknown

If yes, specify

1. Name of premises

Address Number Street Suburb

Town/City Post Code ☐ GeoCode

Foods eaten **Date consumed**

Comments **Status** ○ Suspected ○ Confirmed ○ Exonerated

2. Name of premises

Address Number Street Suburb

Town/City Post Code ☐ GeoCode

Foods eaten **Date consumed**

Comments **Status** ○ Suspected ○ Confirmed ○ Exonerated

3. Name of premises

Address Number Street Suburb

Town/City Post Code ☐ GeoCode

Foods eaten **Date consumed**

Comments **Status** ○ Suspected ○ Confirmed ○ Exonerated

DRINKING WATER

Current address* water supply code or specify

Work/school/pre-school* water supply code or specify

Did the case consume water other than regular supply (home or work / school / pre-school) during the incubation period?~ ○ Yes ○ No ○ Unknown

If yes, specify address* Water supply code

Water supply code

Did the case consume untreated surface water, bore water or rain water during the incubation period?~ ○ Yes ○ **No** ○ **Unknown**

If yes, specify water source:~

RECREATIONAL WATER CONTACT

Did the case have recreational contact with water during the incubation period?~ ○ Yes ○ No ○ Unknown

If yes, nature of contact

☐ **Swimming in public swimming pool, spa pool or in other pool (e.g. school, hospital, motel, private pool)**

1. Name of pool

Address Number Street Suburb

Town/City Post Code ☐ GeoCode

Comments Date of exposure

2. Name of pool

Address Number Street Suburb

Town/City Post Code ☐ GeoCode

Comments Date of exposure

Enteric Disease EpiSurv No. _____

3. Name of pool _____

Address Number _____ Street _____ Suburb _____

Town/City _____ Post Code _____ ☐ GeoCode ____

Comments _____ Date of exposure _____

☐ **Swimming in streams, rivers, sea etc**

1. Name of stream/river/beach _____

Address Number _____ Street _____ Suburb _____

Town/City _____ Post Code _____ ☐ GeoCode ____

Comments _____ Date of exposure _____

2. Name of stream/river/beach _____

Address Number _____ Street _____ Suburb _____

Town/City _____ Post Code _____ ☐ GeoCode ____

Comments _____ Date of exposure _____

3. Name of stream/river/beach _____

Address Number _____ Street _____ Suburb _____

Town/City _____ Post Code _____ ☐ GeoCode ____

Comments _____ Date of exposure _____

☐ Other recreational contact with water specify _____ Date of exposure _____

Location of other recreational contact with water _____

HUMAN CONTACT

Attendance at school, preschool or childcare~ ○ Yes ○ No ○ Unknown

Did the case have contact with other symptomatic people during the incubation period?~ ○ Yes ○ No ○ Unknown

If yes, specify type of contact _____

If yes, give names of people _____

Did the case have contact with children in nappies, sewage or other types of faecal matter or vomit during the incubation period?~ ○ Yes ○ No ○ Unknown

If yes, specify what they had contact with _____

ANIMAL CONTACT

Did the case have contact with farm animals during the incubation period?~ ○ Yes ○ No ○ Unknown

If yes, specify type of animal _____

Did the case have contact with sick animals during the incubation period?~ ○ Yes ○ No ○ Unknown

If yes, specify type of animal and illness _____

OVERSEAS TRAVEL

Was the case overseas during the incubation period for this disease* ○ Yes ○ No ○ Unknown

If yes, date arrived in New Zealand* _____

Specify countries visited*	Country	Date Entered	Date Departed
Last (most recent):*			
Second last:*			
Third last:*			

Enteric Disease EpiSurv No.

Risk Factors continued

If the case has not been overseas recently, is there any prior history of overseas travel that might account for this infection?* ○ Yes ○ No ○ Unknown

If yes, specify*

OTHER

Other risk factor for disease (specify)~

Source

Was a source confirmed by*

a) Epidemiological evidence* ○ Yes ○ No ○ Unknown

e.g. part of an identified common source outbreak (also record in outbreak section) or person to person contact with a known case

b) Laboratory evidence* ○ Yes ○ No ○ Unknown

e.g. organism or toxin of same type identified in food or drink consumed by case

Specify confirmed source(s)*

☐ From consumption of contaminated food or drink, specify food or drink

☐ From consumption of contaminated drinking water, specify supply

☐ From contact with infected animal, specify type of animal

☐ Person to person contact with another case, specify relationship to case

☐ From other confirmed source, specify source

If not, were any probable sources identified?*

Specify probable source(s)* ○ Yes ○ No ○ Unknown

☐ From consumption of contaminated food or drink, specify food or drink

☐ From consumption of contaminated drinking water, specify supply

☐ From contact with infected animal, specify type of animal

☐ Person to person contact with another case, specify relationship to case

☐ From other probable source, specify source

Management

CASE MANAGEMENT

Case excluded from work or school/preschool/childcare until well? ○ Yes ○ No ○ NA ○ Unknown

Does the case fit any of the following high risk categories?

Early childhood centre work	○ Yes	○ No		○ Unknown
Food handler	○ Yes	○ No		○ Unknown
Water supply worker	○ Yes	○ No		○ Unknown
Intellectually/physically impaired	○ Yes	○ No		○ Unknown
Healthcare/rest-home worker	○ Yes	○ No		○ Unknown
If yes, to any of the above, was the case excluded from work until microbiological clearance achieved?	○ Yes	○ No	○ NA	○ Unknown

CONTACT MANAGEMENT

Number of contacts identified

Number of contacts followed up according to national or local protocols

Enteric Disease EpiSurv No. _____

Comments*

Food Premises

4. Name of premises _____

Address Number _____ Street _____ Suburb _____

Town/City _____ Post Code _____ ☐ GeoCode____

Foods eaten _____ **Date consumed** _____

Comments _____ **Status** ○ Suspected ○ Confirmed ○ Exonerated

5. Name of premises _____

Address Number _____ Street _____ Suburb _____

Town/City _____ Post Code _____ ☐ GeoCode____

Foods eaten _____ **Date consumed** _____

Comments _____ **Status** ○ Suspected ○ Confirmed ○ Exonerated

6. Name of premises _____

Address Number _____ Street _____ Suburb _____

Town/City _____ Post Code _____ ☐ GeoCode____

Foods eaten _____ **Date consumed** _____

Comments _____ **Status** ○ Suspected ○ Confirmed ○ Exonerated

7. Name of premises _____

Address Number _____ Street _____ Suburb _____

Town/City _____ Post Code _____ ☐ GeoCode____

Foods eaten _____ **Date consumed** _____

Comments _____ **Status** ○ Suspected ○ Confirmed ○ Exonerated

8. Name of premises _____

Address Number _____ Street _____ Suburb _____

Town/City _____ Post Code _____ ☐ GeoCode____

Foods eaten _____ **Date consumed** _____

Comments _____ **Status** ○ Suspected ○ Confirmed ○ Exonerated

Version 3rd August 2007 * **core surveillance data, ~ optional data**

12 APPENDIX 3: A travel destination specific model

Further examination of travel and EpiSurv data may provide data to allow a model to be produced based on the association between campylobacteriosis and the number of travellers to different regions of the world.

Intuitively, the number of overseas travel related campylobacteriosis cases should be related to the number of travellers visiting high risk areas. While some people will become ill from *Campylobacter* infection from regions not classed as high risk areas, it would be expected that most had travelled to high risk areas. This could be represented by an equation of the form,

$$\mathbf{Prob(\ C_{ill} \mid T\ ) = Prob(\ C_{ill} \mid AHR, T\ ) Prob(\ AHR \mid T\ ) + Prob(\ C_{ill} \mid AO, T\ ) Prob(\ AO \mid T\ )} \quad \textbf{(1)}$$

where,

C_{ill} : Person with Campylobacteriosis.
AHR : Arrived from High Risk region (See Table 10).
AO : Arrived from Other than a high risk region.
T : Travelled overseas during incubation period for *Campylobacter*.

The probability of arriving from a high risk region given that people are travelling overseas during the incubation period, Prob(AHR|T), and the probability of arriving from other than a high risk region given travelling overseas, Prob(AO|T) can be found from the Statistics New Zealand migration data, whereby Prob(AO|T) = 1 - Prob(AHR|T).

The probability of people becoming ill from *Campylobacter* given they have travelled during the incubation period, Prob(C_{ill}|T), can be calculated from the relationship

$$\mathbf{Prob(\ C_{ill} \mid T\ ) = Prob(\ T \mid C_{ill}\ ) Prob(\ C_{ill}\ ) \ /\ Prob(\ T\ )} \quad \textbf{(2)}$$

where Prob(T | C_{ill}) and Prob(C_{ill}) can be estimated in terms of notified cases from the EpiSurv data, and Prob(T) can be determined from Statistics New Zealand migration data.

Equation 1 has two remaining unknowns Prob(C_{ill} | AHR, T) and Prob(C_{ill} | AO,T). These may be able to be determined from looking at travel and notification data for a number of different years.

Using such a model would allow the estimate of overseas travel associated notifications to be sensitive to changes in the travel destination habits of New Zealanders. Further extraction of detailed data from Statistics New Zealand will be required to investigate this. Project time constraints meant this approach was not further investigated at this time, but could be in the future.

13 APPENDIX 4: Data analysis toward parameters for the drinking water exposure model

13.1 Drinking water exposure model

There are a number of different drinking water sources in New Zealand:

- Ground water (bores, springs, aquifers and wells).
- Surface water (water races, rivers, lakes and dams).
- Roof water.

These sources provide water to reticulated supplies, serving populations of various sizes, and where necessary are treated to control microbial contamination. Most of these supplies are required to be registered under the New Zealand Drinking Water Standards i.e. a "community drinking water supply" that serves more than 25 people for at least 60 days a year (Ministry of Health, 2008).

The drinking water model estimates exposure to *Campylobacter* from eight types of water supply, categorised by the type of source water, and the size of the population served.

- Large (>10,000 population).
- Medium (500 to 10,000 population).
- Small (<500 population), sourced from surface water
- Small (<500 population), sourced from ground water
- Small (<500 population), sourced from roof water
- Unregistered, sourced from surface water
- Unregistered, sourced from ground water
- Unregistered, sourced from roof water

The potentially exposed population calculation is based on the number of people served by each type of water supply (excluding children aged 0-4 years, see Section 4.2), segregated by source water. These populations are then multiplied by three factors:

1. The probability the type of water source for these supplies is contaminated with *C. jejuni* (and its concentration).
2. The probability the type of *C. jejuni* is likely to cause infection in people (an "infectivity" factor).
3. The probability the water supply is not treated in some way which will eliminate bacteria.

The exposure model is sensitive to the number of supplies which are effectively treated, as effective treatment eliminates the risk of campylobacteriosis. However, there are few data available on how many unregistered supplies are treated across New Zealand.

13.2 Populations on different types of water supplies

The proportion of people on registered residential supplies can be estimated from data held by the Water Information New Zealand (WINZ) database[4] which stores information on drinking water supplies. WINZ collates information on location, supply type, treatment status and estimate of population served by the supply.

Some New Zealanders derive their drinking water from supplies which are not required to be registered. This population was of particular interest for modelling exposure, as it was expected that these supplies were most likely to be contaminated and untreated.

An annual report is prepared by ESR for the Ministry of Health on drinking water quality in New Zealand derived from data held by the WINZ database. This includes an estimate of the size of the New Zealand population on unregistered drinking water supplies (9% in the 2007-2008 report, 11% in the 2008-2009 report). These estimates are obtained from the difference between reported populations on registered drinking water supplies, and the total population of New Zealand.

To provide data for the drinking water model for this project, the WINZ data were analysed on a regional council basis, to remove double counting by excluding non-residential registered water supplies (schools, factories etc.). As described below, this resulted in a slightly higher estimate of the population on unregistered supplies (14%), since the non-residential registered supplies are no longer counted towards the total population on registered supplies. However, as the estimates of populations served by registered supplies provided to the WINZ database may not be fully updated, these estimates should be treated with caution.

The 2007 Register of Community Drinking Water Supplies in New Zealand includes 2,303 distribution zones and 2,247 water treatment plants that cover an estimated 92% of the New Zealand population (Ball *et al.*, 2007). Approximately 30% of these supplies (serving 95% of the approximately 3.6 million people covered by registered supplies) fall under the jurisdiction or control of a Local Authority (District Council, City Council etc.). The remaining registered supplies are under the control of a variety of organisations (e.g. marae, schools, camping grounds).

The registration for each supply includes an estimate of the population served. The most recent estimates (2007-2008) were extracted from the data held by the WINZ database (administered by ESR for the Ministry of Health). This included 2302 registered water supplies.

Supplies were categorized on the basis of size of population served: large (>10,000), medium (501 – 10,000) and small (≤500). Note that this represents a simplification of the supplies as categorized by WINZ, which uses the categories: large (>10,000), medium (5,001 – 10,000), minor (501 – 5,000), small (101 – 500) and neighbourhood (25 – 100).

In order to avoid double counting of populations, supplies were reviewed by category. The registered populations of those supplies considered to be non-residential were excluded. This

[4] http://www.moh.govt.nz/moh.nsf/indexmh/drinking-water-publications

covered all supplies identified in the "description" field as: Department of Conservation (DOC), Hospitality, Private (the names of these supplies showed them to be mostly large factories), and Schools.

Specific non-Local Authority supplies serving residential populations ("Communal") were included. One example is the Doubtless Bay Water Supply Company serving 2,000 people in the Northland Regional Council. Two large "Private" supplies were retained as residential; these were for Massey and Lincoln Universities which were considered to have at least a partially residential population (halls of residence).

Statistics New Zealand population estimates for June 2008 were used as comparators (the June 2008 estimate is extrapolated from the 2006 census results) to the data held by WINZ. The data was first aggregated by regional council area. Then, the population served by registered supplies in each regional council was compared to the Statistics New Zealand population estimates. The remainder of the population in the regional council was assumed to represent those people using an unregistered supply. The results of this analysis are shown in Table 16.

The data in Table 16 must be considered indicative only. The estimates of the population served by drinking water supplies are not always updated each year and are likely to have considerable uncertainty and/or have been estimated by different methods. A particular example is Christchurch City (part of Canterbury Regional Council), where the reported population served by the water supplies is some 38,000 (11%) greater than the estimated city population. The populations served by registered water supplies in a few other regions were also greater than the actual populations, albeit by much smaller amounts (<3000). For the purposes of this analysis, negative differences for unregistered supplies in sub-populations of regional councils were set to zero. Consequently the population on unregistered supplies may be an underestimate, particularly in Canterbury.

An alternative approach to estimating the size of the population that may be on unregistered residential supplies is to consider the urban/rural categories, as defined by Statistics New Zealand (section 4.2.2). These data, for the regional councils, are shown in Table 17. To compare with the estimates from WINZ data, the percentage population sum in four, three and two categories with rural character are shown in Table 18. This suggests the percentage population served by unregistered supplies in Auckland and Wellington are overestimated when the WINZ data are used. Conversely, the populations served by registered water supplies based on WINZ data appear to be overestimated for the West Coast.

Possible bounds for the model would be 14% of the New Zealand population on unregistered supplies estimated from WINZ data as the upper bound. The lower bound could be set to 7.4%, based on the populations of the two most rural categories from Statistics New Zealand data.

Table 16: Estimated populations on different residential drinking water supplies in each regional council area in New Zealand 2007-8

Regional Council/ Unitary Authority	Population (2008 estimate)	Percentage of population on large supplies (>10,000)	Percentage of population on medium supplies (501 – 10,000)	Percentage of population on small supplies (≤500)	Percentage of population unregistered supplies
Northland	154700	31	29	7	33
Auckland	1414700	85	4	0	10
Waikato	402200	43	31	3	23
Bay of Plenty	296900	63	23	2	12
Gisborne	46000	67	1	1	31
Hawkes Bay	152800	70	11	2	16
Manawatu-Wanganui	229200	53	32	4	14
Taranaki	107500	33	41	3	23
Wellington	473800	66	22	1	12
Marlborough	44500	54	22	4	20
Nelson City	44700	96	0	0	4
Tasman	46500	23	16	8	54
Canterbury[1]	552900	80	15	5	7
West Coast	32400	0	57	19	24
Otago	203500	45	38	7	14
Southland	93000	51	22	3	24
Total[2]	**4268300**	**67**	**18**	**2**	**14**

1 Estimated making assumptions that no Kaikoura District Council, Hurunui District Council, or Christchurch City Council residents are on unregistered supplies (see text).
2 Excludes Chatham Islands.

Table 17: Percentage of regional populations in each of the Statistics New Zealand seven urban/rural categories (June 2006)

Regional Council/ Unitary Authority	Main urban area (%)	Satellite urban area (%)	Independent urban community (%)	Rural area with high urban influence (%)	Rural area with moderate urban influence (%)	Rural area with low urban influence (%)	Highly rural/remote area (%)
Northland	33.1	0.0	18.0	12.3	4.3	31.2	1.0
Auckland	92.8	2.5	0.6	2.1	1.3	0.5	0.1
Waikato	48.5	4.3	23.9	2.7	6.0	14.5	0.2
Bay of Plenty	63.2	2.8	14.8	6.8	6.4	5.9	0.1
Gisborne	73.0	0.0	0.0	0.8	11.6	6.6	7.8
Hawkes Bay	80.1	0.0	6.9	3.7	1.1	7.4	0.7
Manawatu-Wanganui	51.9	9.6	19.5	4.5	6.4	7.4	0.7
Taranaki	47.3	9.0	20.6	3.2	6.9	11.2	1.6
Wellington	88.8	1.7	5.9	1.2	1.3	1.1	0.0
Marlborough	0.0	0.0	76.6	0.0	0.0	21.1	2.1
Nelson City	98.0	0.0	0.0	2.0	0.0	0.0	0.0
Tasman	32.1	8.3	18.5	0.1	16.1	22.5	2.5
Canterbury	69.4	4.9	11.0	4.1	4.4	4.8	1.4
West Coast	0.0	0.0	57.6	0.0	5.1	23.9	13.5
Otago	57.3	0.0	23.1	3.0	0.8	12.4	3.3
Southland	51.4	3.6	15.0	2.9	2.9	15.5	8.7
Total	**72.1**	**3.2**	**10.9**	**3.2**	**3.3**	**6.4**	**1.0**

Table 18: Summation of percentage of populations in rural categories, and comparison with estimates from WINZ data

Regional Council/ Unitary Authority	Sum of population in four categories[1] with rural character (%)	Sum of population in three categories[2] with most rural character (%)	Sum of population in two categories[3] with most rural character (%)	Population on unregistered supplies (%, based on WINZ data)
Northland	48.8	36.5	32.3	33
Auckland	4.0	1.9	0.6	10
Waikato	23.3	20.6	14.6	23
Bay of Plenty	19.2	12.4	6.0	12
Gisborne	26.8	26.0	14.4	31
Hawkes Bay	12.9	9.3	8.1	16
Manawatu-Wanganui	19.0	14.5	8.1	14
Taranaki	22.9	19.7	12.8	23
Wellington	3.6	2.4	1.1	12
Marlborough	23.2	23.2	23.2	20
Nelson City	2.0	0.0	0.0	4
Tasman	41.2	41.0	25.0	54
Canterbury	14.8	10.7	6.2	7
West Coast	42.4	42.4	37.4	24
Otago	19.6	16.6	15.8	14
Southland	29.9	27.0	24.2	24
Total	**13.9**	**10.7**	**7.4**	**14**

1 Highly rural areas, and rural areas with low, moderate and high urban influence.
2 Highly rural areas, and rural areas with low and moderate urban influence.
3 Highly rural areas, and rural areas with low urban influence.

To attempt to characterise source waters that may be relevant to unregistered supplies, data on registered small water supplies were analysed. Small water systems have been defined as those that supply water to less than 500 people (Ministry of Health, 2008). The WINZ database of registered drinking water supplies for 2007-2008 was interrogated to extract all supplies fitting this category.

All registered small water supplies (residential and non-residential) were also aggregated according to source water type (surface, ground or roof). Many water supplies had more than one type of water source. When there were multiple water sources for a supply, the supply was associated with the source type with the highest risk of *Campylobacter* contamination (Surface > Ground > Roof). The results are shown in Table 19 and Table 20.

The registered small supply data indicate that ground and surface water supplies predominate, both in terms of numbers of supplies and people served. Roof water supplies serve approximately 5% of the population on residential small registered supplies, and these are apparently concentrated in the Northland region (the Far North District Council website[5] states: "Collection of rainwater for drinking and household use is common in Northland, especially in more rural settings.".

The absence of small residential registered roof water supplies in several regions is unlikely to also be correct for unregistered supplies. The Ministry of Health Draft Guidelines for Drinking-water Quality Management for New Zealand, October 2005 Chapter 19 on Small Individual and Roof Water Supplies[6] states "In New Zealand more than 10 percent of the population are on roof-collected rainwater systems,…". A study of essential supplies for Housing New Zealand[7] indicated that roof water supplies were common in Northland, East Cape, and Bay of Plenty. This is consistent with the data in Table 19 registered small water supplies for Northland, but not for East Cape (Gisborne) and Bay of Plenty. The above information for one of the water source types shows that it would not be appropriate in an exposure model to use the proportion of small registered supply types as a surrogate for the small unregistered supplies.

The remaining population are on medium and large supplies. These two categories could be used for evaluating special event risks like heavy rainfall, and are included in the model, but populations served by these supplies will not usually be at risk.

13.3 Probability and volume of consumption of cold drinking water

These data have been extracted from the National Nutrition Survey and the Child Nutrition Survey and have been set at p=0.666 and RiskLognorm(796.31,868.47,RiskTruncate(2,6000)) respectively. The distribution describing water consumption is based on New Zealand nutritional surveys, and includes cold water and drinks made with cold water, while excluding hot drinks and bottled water (Cressey *et al.*, 2006). Water consumption combined with contamination data provides an estimate of dose, which is used in the dose response relationship for a rural population to provide a probability of infection (Section 6.2).

[5] http://www.fndc.govt.nz/services/water-wastewater-and-refuse/water-supply/rain-water-tanks
[6] http://www.moh.govt.nz/moh.nsf/0/5A25BF765B400911CC25708F0002B5A8/$File/19smallsupplies.pdf
[7] http://www.hnzc.co.nz/hnzc/web/research-&-policy/housing-research-&-evaluation/summaries-of-reports/necbop.htm

Table 19: Populations on registered residential small water supplies aggregated according to source water type.

Region	Surface[1]	Ground[2]	Roof[3]	Total
Northland	4536	2747	3745	11028
Auckland	975	2126	192	3293
Waikato	8306	3203	69	11578
Bay of Plenty	2099	3601	0	5700
Gisborne	546	10	14	570
Hawkes Bay	940	2623	225	3788
Manawatu-Wanganui	3988	4087	395	8470
Taranaki	2765	670	50	3485
Wellington	572	1342	0	1914
Marlborough	1247	440	0	1687
Nelson	120	0	0	120
Tasman	1100	2600	0	3700
Canterbury	9801	13943	0	23744
West Coast	4341	1823	400	6564
Otago	9516	4429	0	13945
Southland	1291	1397	0	2688
Total	**52143**	**45041**	**5090**	**102274**

1: Supplies which include a surface water source. 2: Supplies which include a ground water supply with or without a roof water supply (no surface water source). 3. Supplies with only a roof water source.

Table 20: Number of small water supplies (residential and non-residential) aggregated according to source water type

Region	Surface[1]	Ground[2]	Roof[3]	Total
Northland	77	92	109	278
Auckland	16	116	110	242
Waikato	59	113	14	186
Bay of Plenty	42	78	2	122
Gisborne	4	17	33	54
Hawkes Bay	18	105	21	144
Manawatu-Wanganui	23	54	55	132
Taranaki	17	23	21	61
Wellington	16	38	6	60
Marlborough	50	21	2	73
Nelson	1	0	1	2
Tasman	18	33	3	54
Canterbury	99	147	3	249
West Coast	31	30	10	71
Otago	74	57	9	140
Southland	10	27	11	48
Total	**555**	**951**	**410**	**1916**

1: Supplies which include a surface water source. 2: Supplies which include a ground water supply with or without a roof water supply (no surface water source). 3. Supplies with only a roof water source

Table 21: Prevalence data for contamination of surface and groundwaters

References	Details	Number of samples	Positive for *Campylobacter* spp.	%	Positive for *C. jejuni* only	%	Concentration method and limit of detection
Surface water							
(McBride *et al.*, 2002)	National sampling at 25 sites over 15 months	726	432	59.5	207	28.5[1]	MPN 0.3 MPN/100ml
(Eyles *et al.*, 2003) winter	Taieri river, Otago	80	73	91.2	NA	NA	MPN 0.12 MPN/100ml
(Eyles *et al.*, 2003) spring	Taieri river, Otago	60	51	85	NA	NA	MPN 0.12 MPN/100ml
(Eyles *et al.*, 2003) summer	Taieri river, Otago	70	59	84.3	NA	NA	MPN 0.12 MPN/100ml
(Eyles *et al.*, 2003) autumn	Taieri river, Otago	60	33	55	NA	NA	MPN 0.12 MPN/100ml
(Bigwood and Hudson, 2009)	Canterbury region, summer 2007-2008	53	45	84.9	42	79.2	MPN 0.3 MPN/100 ml
(French, 2008)	Manawatu, six sites over 3 years	335	140	41.8	82	32.2[2]	NA
Total		1384	833	60.2	331	NA	
Ground water							
(Close *et al.*, 2008)	Canterbury, border irrigation diary farming	126	16	12.7	11	8.7	MPN 0.6 MPN/L
Roof water							
(Simmons *et al.*, 2001)	Auckland	115	0	0	0	0	NA
ESR[3]		75	3	4	NA	NA	NA

NA = not available

1: Lower bound, does not include unknown species, some of which may have been *C. jejuni*., 2: % of samples speciated, 3:Roof water samples submitted to ESR Auckland and Christchurch Public Health Laboratories as part of gastrointestinal illness investigations 2001-2009

13.4 Probability and concentration of contamination

No data were found on the frequency of *Campylobacter* contamination in medium and large supplies. It was considered that contamination in these monitored supplies would be rare, especially as they are usually treated in ways that would eliminate *Campylobacter*. No attempt was made to derive input parameters for these types of supply. However, the exposure model could be used to estimate the possible number of infections given a hypothetical contamination episode for these supplies.

A number of unregistered supplies will store water in tanks before use. It is possible that this would reduce the concentration of *Campylobacter* from the concentrations found in source waters, although the effect may be modest. For *Campylobacter* added as an inoculum in effluent in tanks the time to 90% inactivation (D time, at 14°C) in river water in darkness was 82.6 hours and in sunlight (depending on the season) 0.8-1.6 hours (Sinton *et al.*, 2007). This effect was not included in the exposure model as the extent of tank use is unknown.

Available data on the probability of contamination of "at risk" water supply sources were reviewed, as shown in Table 21.

It is important to note that model calculations using the parameter settings for probability of contamination, based on *Campylobacter jejuni* prevalence data for each water source type, also involve a "differential infectivity factor". This factor allows the model to incorporate the observation that *C. jejuni* found in water samples are often MLST types associated with wild birds that are not found amongst isolates from human cases. The factor settings in the model is derived from human and water isolates collected in the Manawatu (surface and ground water 0.31, roof water 0.5) (Jonathan Marshall, Massey University, pers. comm., 2 February 2010).

Concentration in surface water sources:

The concentration of contamination in surface water samples has been reported by the Freshwater Microbiological Programme (FMP) using a binning procedure for most probable number (MPN) results as previously described (see (McBride *et al.*, 2002)). These concentration data are for *Campylobacter* spp.; separate data for *C. jejuni* are not available.

N.B. The binning procedure described in the reference includes a Bin 0 which represents MPN results of <0.3 MPN/100ml (no tubes positive). This Bin is not included in the concentration calculations in the model; instead all concentration estimates are obtained from Bins 1-5. The reason for this is that MPN results of <0.3 are treated as zero, and thus allow calculation of the prevalence i.e. probability of contamination, as above. The option of ignoring prevalence and basing calculations solely on the Bins was explored and including Bin 0 made a very small (2%) difference in predicted infections. While it is arguable that an MPN result of <0.3 MPN/100ml should be treated as a result in the range 0 – 0.3, it was considered that the model would be more useful if a prevalence parameter was included (to calculate potentially exposed populations), to allow assessment of interventions that affect prevalence.

Concentration in groundwater sources:

From (Close *et al.*, 2008), 11/126 samples were positive for *C. jejuni*; 0.3 MPN/L (9 samples), 6.2 MPN/L (2 samples).

Concentration in roof water sources:

No concentration data were located on the concentration of *C. jejuni* in roof water supplies. Such data would need to be collected to incorporate this water source into an exposure model.

13.5 Water treatment

Available data on water treatment was reviewed. Two sources were identified.

Dr Stan Abbott at the Institute of Food Nutrition and Human Health, Massey University was contacted in relation to a recent publication (Abbott *et al.*, 2006) on the microbiological quality of roof water. Alongside the data concerning roof-water based supplies, data on a number of supplies with other water sources were collected. Most of the supplies were in the lower North Island. The information regarding water treatment is given in Table 22. The information from these supplies was relevant to unregistered supplies in the model.

Table 22: Water treatment in private home water supplies in the lower North Island

Source water	Number of supplies	Number with treatment (%)	Number with treatment in addition to filtering[1] (%)
Surface water (creek/river/stream)	21	8 (38)	8 (38)
Groundwater (bore/spring/well)	173	32 (18)	6 (3)
Roof	278	85 (31)	45 (16)

[1] Excludes supplies that are only filtered; the study (Abbott et al., 2006) found that 71% of filtered roof water supplies were contaminated with *E. coli*.

Unpublished results from a PhD study (Andrew Ball, ESR, pers. comm., 2010) provided information from 297 schoolchildren who were served by private (unregistered) water supplies in several regions of New Zealand. Data from these children indicated that 38% of their water supplies had some form of water treatment.

Water treatment data in the WINZ database of registered supplies were also reviewed. The results are given in Table 23. The primary categories are for disinfection treatments, but secure groundwater sources and membrane filter treatments (but not slow sand filters) were also considered appropriate for removal of *Campylobacter* in the absence of disinfection treatments.

Small water supplies were then examined to review the probability of treatment, based on source water categories (see Table 24). Untreated supplies were those without disinfection, secure sources or membrane filter treatment.

Table 23: Water treatment on small, medium and large water supplies in New Zealand 2007-2008

Type	Size	Cl	Cl Oz	ClUV	No disinfection or other	No disinfection but secure groundwater	No disinfection but membrane filter	No disinfection but slow sand filter	Oz	Oz UV	UV
Communal	Small	17	0	2	77	0	3	0	1	0	18
	Medium	0	0	0	2	0	0	0	0	0	2
	Large	0	0	0	0	0	0	0	0	0	0
Contractor	Small	0	0	0	1				0	0	0
	Medium	3	0	0	0	0	0	0	0	0	0
	Large	0	0	0	0				0	0	0
DOC	Small	8	0	0	24	0	1	0	0	0	17
	Medium	0	0	0	0	0	0	0	0	0	0
	Large	0	0	0	0	0	0	0	0	0	0
Government	Small	3	0	2	1	1	0	0	0	0	1
	Medium	8	0	0	0	1	0	0	0	0	1
	Large	0	0	0	0	0	0	0	0	0	0
Health	Small	2	0	0	1	1	0	0	0	0	0
	Medium	1	0	0	1	2	0	0	0	0	0
	Large	0	0	0	0	0	0	0	0	0	0
Hospitality	Small	33	1	3	151	0	19	0	4	1	123
	Medium	0	0	0	0	0	0	0	0	0	1
	Large	0	0	0	0	0	0	0	0	0	0
LATE	Small	0	0	0	0	0	0	0	0	0	0
	Medium	60	0	0	0	0	0	0	0	0	0
	Large	7	0	0	0	0	0	0	0	0	0
Local Authority	Small	198	0	13	106	15	2	0	0	0	22
	Medium	178	5	17	40	13	0	0	0	0	13
	Large	38	1	51	3	11	0	0	0	0	0

Marae	Small	0	0	0	119	0	1	0	0	0	41
	Medium	0	0	0	1	0	0	0	0	0	0
	Large	0	0	0	0	0	0	0	0	0	0
Private	Small	52	1	12	138	0	20	0	1	0	70
	Medium	8	0	0	6	0	0	0	0	0	0
	Large	0	0	0	0	0	0	0	0	0	0
Regional	Small	6	0	0	4	0	0	0	0	0	5
	Medium	0	0	0	0	0	0	0	0	0	0
	Large	0	0	0	0	0	0	0	0	0	0
School	Small	25	0	4	162	0	27	1	9	0	357
	Medium	0	0	0	2	0	0	0	0	0	1
	Large	0	0	0	0	0	0	0	0	0	0
Totals											
Non-residential	Small	118	2	19	475	0	67	1	14	1	567
	Medium	8	0	0	8	0	0	0	0	0	2
	Large	0	0	0	0	0	0	0	0	0	0
Residential	Small	226	0	17	309	17	6	0	1	0	87
	Medium	225	6	21	47	26	0	0	0	0	16
	Large	9	0	1	1	2	0	0	0	0	0

Small = 0 – 500, Medium = 501 – 10000, Large = >10000 population served
Cl = chlorine disinfection
ClOz = chlorine and ozone disinfection
ClUV = chlorine and ultraviolet disinfection
Oz = ozone disinfection
OzUV = ozone and ultraviolet disinfection
UV = ultraviolet disinfection
No disinfection or other = disinfection field in database reported as “no” or “other”
DOC = Department of Conservation
LATE = Local authority trading enterprise (equivalent to local authority control for these WINZ data)

Table 24: Regional populations on <u>residential</u> small water supplies aggregated according to source water type and presence/absence of disinfection.

Region	Surface		Ground		Roof		Total
	Disinfected	Not disinfected (proportion)	Disinfected	Not disinfected (proportion)	Disinfected	Not disinfected (proportion)	
Northland	1892	2644 (0.583)	1065	1682 (0.612)	1375	2370 (0.633)	11028
Auckland	975	0 (0)	1557	569 (0.268)	92	100 (0.521)	3293
Waikato	6283	2023 (0.244)	840	2363 (0.738)	0	69 (1.0)	11578
Bay of Plenty	1040	1059 (0.505)	860	2741 (0.761)	0	0	5700
Gisborne	546	0 (0)	0	10 (1.0)	0	14 (1.0)	570
Hawkes Bay	390	550 (0.585)	1985	638 (0.243)	0	225 (1.0)	3788
Manawatu-Wanganui	3938	50 (0.013)	3173	914 (0.224)	0	395 (1.0)	8470
Taranaki	2340	425 (0.154)	570	100 (0.149)	0	50 (1.0)	3485
Wellington	572	0 (0.0)	834	508 (0.379)	0	0	1914
Marlborough	210	1037 (0.832)	320	120 (0.273)	0	0	1687
Nelson	120	0 (0.0)	0	0	0	0	120
Tasman	905	195 (0.177)	1580	1020 (0.392)	0	0	3700
Canterbury	7592	2209 (0.225)	8702	5241 (0.376)	0	0	23744
West Coast	2734	1607 (0.37)	527	1296 (0.711)	0	400 (1.0)	6564
Otago	8296	1220 (0.128)	1860	2569 (0.58)	0	0	13945
Southland	1291	0 (0.0)	1097	300 (0.215)	0	0	2688
Total	**39124**	**13019 (0.25)**	**24970**	**20071 (0.446)**	**1467**	**3623 (0.712)**	**102274**

13.6 Other data on drinking water supplies

Two surveys of treated drinking water supplies (Nokes *et al.*, 2004; Nokes and Kikkert, 2007), did not detect *Campylobacter* in samples from distribution zones, and in only two (0.5%) of the samples taken immediately after treatment (both samples were from a small ultraviolet treated supply). Neither was contamination detected after heavy rain conditions. However, 16% of source waters were contaminated. Overall, this survey took 549 samples from 31 supplies over 12 months. Half of the supplies were chosen on the basis of other information which indicated that *Campylobacter* was likely to be present.

An earlier study (Savill *et al.*, 2001) tested a small number of drinking water samples from four towns. Of these samples, 7/24 (29.2%) were positive for *Campylobacter*, although it was stated that most of the isolates were *C. lari*, not *C. jejuni*. *C. lari* is rarely identified from human cases of campylobacteriosis. The maximum concentration detected in these samples was 0.3 MPN/100ml.

However, *C. lari* may not be identified from human isolates because some laboratories do not routinely identify isolates to species level, and others may not identify species other than *C. jejuni* and *C. coli*.

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These two results support the assumption that for treated drinking water in New Zealand, the prevalence and concentration of *C. jejuni* at the tap is very low.

The Annual Review of Drinking Water for 2007 (Ball *et al.*, 2007) indicates that 5% of the population is served by registered supplies which are non-compliant for bacteriological reasons, including:

- unacceptable levels of the water quality indicator bacteria, *E. coli* (2%)
- water suppliers failed to take appropriate compliant action once *E. coli* had been found (0.7%)
- *E. coli* monitoring was not carried out or data were not available (2%)
- compliance testing was performed by a non-registered laboratory (0.2%).

The above data are percentages calculated across an 18 month period for water distribution zones, which may include more than one treatment plant.

An alternative approach is to consider the number of samples taken which actually contained *E. coli*, since contamination would be expected to be intermittent. Analysis of WINZ data from 2006-2007 concerning the 2% of supplies that were non-compliant is shown in Table 25. Data from inadequately monitored zones (e.g. zones which were non-compliant for reasons such as taking insufficient samples) showed that no samples contained *E. coli*.

Table 25: Prevalence of non-compliant drinking water samples by size of supply; percentage of samples that contained *E. coli*

Non compliant Zone type (2% of total zones)	Percentage of samples positive for *E. coli*
Large zones (>10,000 population)	0.35
Medium zones (500-10,000 population) administered by local authorities	4.04
Medium zones (500-10,000 population) not administered by local authorities	9.12
Small zones (<500 population) administered by local authorities	18.29
Small zones (<500 population) not administered by local authorities	27.44

The data in Table 25 indicate that *E. coli* contamination is more likely at the tap in small drinking water supplies, and this supports including such supplies for specific exposure estimation in the model. However, the presence of *E. coli* is not necessarily an indicator of the presence of *Campylobacter*. In surface waters in New Zealand, *E. coli* has been detected in almost 100% of samples, while the prevalence of *C. jejuni* in the same samples was only 28.5% (McBride *et al.*, 2002). We have no data on the relative prevalence of these two organisms in water at the tap.