Validation of the Nordic Disease Recording Systems for Dairy Cattle

With Special Reference to Clinical Mastitis

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Doctoral Thesis
Swedish University of Agricultural Sciences
Uppsala 2012

Acta Universitatis agriculturae Sueciae
2012:6

ISSN 1652-6880
ISBN 978-91-576-7690-0

Print: SLU Service/Repro, Uppsala 2012

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Abstract

The overall aim of the thesis was to validate the Nordic disease recording systems for dairy cattle, with a focus on mastitis.

In the first study, Nordic dairy farmers (n=580) recorded clinical disease during four months. Their registrations were compared to records in the national cattle databases. The completeness, i.e. proportion of clinical mastitis (CM) cases recorded as veterinary-attended by farmers and found in the national databases was 0.94 (DK), 0.56 (FI), 0.82 (NO) and 0.78 (SE). In FI the incidence rate (IR) in the central database (for the sampled herds) was significantly lower than the IR of veterinary-attended CM (as recorded by farmers).

The second study investigated the farmer behaviour that initiates reporting, i.e. to contact a veterinarian. A questionnaire, based on the social psychology Theory of Planned Behaviour, was distributed to dairy farmers. Focus was on cases of mild CM. Analysis of the responses (n=834) showed differences between the countries in farmers' behavioural intention, with attitude being the most important determinant.

In the third study, veterinary receipts from 112 Swedish dairy farms were compared against disease data from the Swedish Board of Agriculture (SBA) and the cattle database at the Swedish Dairy Association (SDA). The overall completeness for diagnostic events was 0.84 (SBA) and 0.75 (SDA), but varied between disease complexes, regions and veterinary employment type.

The spatial distribution of veterinary-registered CM in Sweden was described in the fourth study, and areas with significantly higher or lower probability of registered CM were identified. When compared against the distribution of herds with poor udder health (indicated by high somatic cell counts) areas with suggested under-reporting of CM could be identified.

In conclusion, the disease recording systems in DK, FI, NO and SE do not capture all events of CM. This is both due to differences in farmer threshold for contacting a veterinarian for a case of CM and to loss during the recording process.

Keywords: dairy cattle, completeness, disease recording, clinical mastitis, spatial odds, Theory of Planned Behaviour, validation, secondary data

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List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Wolff C, Espetvedt M, Lind A-K, Rintakoski S, Egenvall A, Lindberg A & Emanuelson U. Completeness of the disease recording systems for dairy cows in Denmark, Finland, Norway and Sweden with special reference to clinical mastitis. S*ubmitted manuscript*.

II Espetvedt M*, Lind A-K*, Wolff C*, Rintakoski S, Virtala A-M & Lindberg A. Nordic dairy farmers' intent to contact a veterinarian when detecting a case of mild clinical mastitis – consequences for disease recording. *Submitted manuscript*.

III Jansson Mörk M, Wolff C, Lindberg A, Vågsholm I & Egenvall A (2010). Validation of a national disease recording system for dairy cattle against veterinary practice records. *Preventive Veterinary Medicine* 93(2-3), 183-192.

IV Wolff C, Stevenson M, Emanuelson U, Egenvall A & Lindberg A (2011). Spatial patterns of recorded mastitis incidence and somatic cell counts in Swedish dairy cows: implications for surveillance. *Geospatial Health* 6(1), 117-123.

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* Equal contribution – shared first authorship

Abbreviations

CM	clinical mastitis
CODD	common disease database
DDD	dairy disease database
DK	Denmark
DNHH	Danish New Herd Health scheme
FI	Finland
FRD	farmer-recorded data
IR	incidence rate
NO	Norway
OMRS	official milk recording scheme
SCC	somatic cell count
SDA	Swedish Dairy Association
SE	Sweden
TPB	Theory of Planned Behaviour
UD score	udder disease score

1 Background

1.1 Mastitis in dairy cows

Mastitis is considered the most common disease in dairy production in developed countries. It is also associated with both direct and indirect costs for the producer, caused by e.g. reduction in milk quantity and quality, drugs, discarded milk, extra labour, veterinary services, culling of cows (Halasa *et al.*, 2007; Seegers *et al.*, 2003). Moreover, mastitis is often associated with significant pain, which means it also compromises animal welfare.

Clinical mastitis (CM) is defined as an inflammation in the udder characterised by visible abnormalities in the milk and/or udder. The severity of clinical cases can be described as mild, moderate or severe. Mild clinical mastitis (MCM) is defined as observable abnormalities in the milk, generally clots or flakes with little or no signs of swelling of the mammary gland or systemic illness. Subclinical mastitis is not detected by physical examination of the cow but the diagnosis requires an additional diagnostic test (International Dairy Federation, 1999).

Mastitis is a disease with multiple causes and is in modern dairy production regarded as a production-related disease. It is most commonly caused by bacteria that manage to invade the udder and evoke an immune response. However, not all bacterial infections will result in clinical manifestation (Sandholm *et al.*, 1995). The outcome of the infection depends on the immune status of the cow, pathogen characteristics and the infectious dose. A milk sample may be taken from the affected quarter or all quarters and analysed, most commonly, by bacteriological culturing to investigate the microbial aetiology of the mastitis. However, negative results do not rule out a microbial cause of inflammation. Negative bacteriological results may be due to too few bacteria for detection or that the immune defence of the cow has already cleared the infection (Sandholm *et al.*, 1995). In the Nordic countries CM is treated with prescription drugs, e.g. NSAID and/or antibiotics for intra-mammary or parenteral use.

The somatic cell count (SCC) is the concentration of cells, predominantly inflammatory cells, in the milk. To measure the SCC is the most commonly used method to diagnose subclinical mastitis (Pyörälä, 2003). There is a well-documented relationship between an increase in SCC and increase in the incidence of CM (Beaudeau *et al.*, 1998; Philipsson *et al.*, 1995; Harmon, 1994; Dohoo *et al.*, 1984). In the Nordic countries, SCC in individual cows is recorded at test milking. In the Swedish cattle database, SCC from the 3 last test-days are included in an index based on a rolling geometric average; the udder disease score (UD score). This parameter is a measure of how likely a cow is to have an intra-mammary infection. The scale ranges from 0 to 9, where 6-9 indicates a high probability of infection.

1.2 Secondary data in epidemiological studies

Secondary data are defined as data that were not collected with the current use as the primary purpose. Examples of secondary data are medical records, insurance claims and administrative data, when used for another purpose, such as research. This means that the user, in this case the researcher, had no control over the process that generated the data, e.g. inclusion criteria or recording methods. However, data collection is usually time consuming and hence, a costly part of field studies. One major advantage with secondary data is that they already exist – the researcher does not have to gather the information him-/herself. Another advantage with secondary data is that they may include a large proportion of the population of interest which potentially reduces bias. To ensure that the quality of data is sufficient for the intended usage the database should be validated (Sorensen *et al.*, 1996).

There are various types of databases that include medical records, such as hospital databases (Lofthus *et al.*, 2005), national and regional databases for general disease (e.g. the General Practitioners Database) (Hjerpe *et al.*, 2010; Devine *et al.*, 2008) or databases including only certain diagnoses, e.g. end-stage renal disease (Hommel *et al.*, 2010). Administrative databases may be available that link medical records data with for example birth and death registrations (Preen *et al.*, 2004). In human medicine there are numerous examples of research based on secondary data and the Scandinavian countries have a strong record in such register-based research. Recent examples include Räisänen *et al.* (2011) who used data from the Finnish Medical Birth Register covering the whole Finnish population of women who gave birth during a ten-year period to evaluate risk factors for episiotomy, Sørensen *et al.* (2011) where information from The Danish National Hospital register was combined with The Danish Psychiatric Central Register to a large cohort to evaluate if prepartum maternal iron-deficiency increases the offspring risk of schizophrenia and Holmberg *et al.* (2011) who used the cancer registers in England, Norway and Sweden to compare survival.

In veterinary medicine, secondary data have been more sparsely used compared to the human medical field, most likely because the number of available databases is more limited. One example from North America is the Veterinary Medical Database which gathers medical record information from up to 26 veterinary schools (Bartlett *et al.*, 2010). The Agria insurance database in Sweden includes a large proportion of the Swedish dog, horse and cat populations and has been used to describe morbidity and mortality for various disorders (see e.g. Bonnett *et al.* (2005), Egenvall *et al.* (2010), Egenvall *et al.* (2006) and Bergström *et al.* (2006)). Disease data from the Agria database have also been combined with radiographic assessments for hip status from the Swedish Kennel Club database to study morbidity related to hip-dysplasia (Malm *et al.*, 2010).

The Nordic countries have extensive disease recording systems for dairy cattle. Data from these have been used for numerous studies; for instance on genetic evaluation (Carlen *et al.*, 2005), clinical mastitis (Sato *et al.*, 2008; Nyman *et al.*, 2007; Whist & Østerås, 2007; Gröhn *et al.*, 1990), organic farming (Fall & Emanuelson, 2009; Valle *et al.*, 2007), animal welfare (Sandgren *et al.*, 2009) and risk factors for various other disease conditions (Thomsen & Sørensen, 2009; Hultgren *et al.*, 2004; Schnier *et al.*, 2004).

1.3 Veterinary data for disease monitoring and surveillance

The Nordic dairy disease data are used for monitoring of disease at the herd level but also on a national level. The focus in herd management is, for cows, mainly on production disorders where herds in milk recording receive regular reports on the health status of their herd, benchmarked against other herds. On a national level, disease statistics are presented annually.

Another type of surveillance is for exotic or emerging diseases. Clinical observations from field veterinarians are often the first signal of a new disease, or increase in incidence, and several countries have investigated the feasibility of information systems where enrolled field veterinarians report atypical cases of disease (Robertson *et al.*, 2011; Vourc'h *et al.*, 2006). Medical records contain diagnoses and clinical observations and can, if they are part of a disease recording system, i.e. routinely collected in a database, be used for surveillance purposes. If the coverage - i.e. the proportion of the population of interest that is covered by the recording system - is good, emerging diagnoses or clinical signs/syndromes deviating from what is normally seen may be brought to attention. The completeness of the disease recording system, i.e. the proportion of observations that are recorded in the database, is important for the usefulness of the disease data from a surveillance perspective. The fact that field diagnoses may be fairly unspecific should be of less concern. False positive cases based on clinical observations can be confirmed by further investigation e.g. by laboratory tests.

When monitoring endemic disease there is a need for quantitative data on the 'normal' level of occurrence; a baseline including for example seasonal variation. Further, updated knowledge about the population of interest, e.g. number of livestock, locations and age distributions, is needed to interpret changes in disease occurrence. The disease recording systems in the Nordic countries, with registrations on the individual animal level, fulfil these criteria but the completeness of the disease recording systems is not known.

1.4 Disease recording for dairy cattle in the Nordic countries

Disease recording systems for dairy cattle are in place in (DK), Finland (FI), Norway (NO) and Sweden (SE). The unique feature of these disease recording systems is the possibility to combine disease information with production data for the individual animal. In NO disease recording started already in the mid-seventies (Østerås *et al.*, 2007). A Swedish recording system including the entire country was started in 1984 after a decade of only regional implementation (Emanuelson, 1988). In FI a nation-wide recording system started in 1982 (Gröhn *et al.*, 1986) and in DK in 1991 (Bartlett *et al.*, 2001). The main purpose of the disease recording systems is to monitor endemic disease occurrence, mainly in individual animals. This is done by routinely registering information from disease records in a national central cattle database. The information in the central cattle databases are used by the farmers, by extension personnel (including veterinarians), for statistics, in research and for genetic evaluation.

The disease recording systems in DK, FI and NO are linked to the herd's participation in the national official milk recording schemes (OMRS) and therefore have the same coverage as the OMRS, except in FI (details below). In SE disease recording for cattle is mandatory for the veterinarian and the system has thus, in principle, a complete coverage of dairy cattle. The data are reported to the Swedish Board of Agriculture and transferred regularly to the central cattle database at SDA where it is linked to the OMRS data. In the OMRS, data on monthly test milkings, slaughter, culling, calvings, artificial inseminations (AI), fertility treatments and hoof trimming are also collected. Further, information on animal entries and removals, other than birth and culling, is also available. The OMRS and the central cattle databases are managed by the farmer-owned dairy organisations; the Danish Cattle Federation, The Finnish Agricultural Data processing Centre, TINE SA and the Swedish Dairy Association (SDA) (Olsson *et al.*, 2001).

The Nordic dairy farmers, with the exceptions described below, do not write disease records themselves; instead, the disease recording systems are based on veterinary recording. Moreover, Nordic dairy farmers have very limited access to prescription drugs such as antibiotics. For example, to prescribe antibiotics for a case of CM, a veterinarian must first physically examine the animal and establish a diagnosis. Follow-up treatment may be performed by the farmer with drugs from the veterinarian or prescribed by the veterinarian. Below follows some country-specific features of the disease recording systems that are also important for the objectives of this thesis.

In DK, submission to the database is either done by the veterinarian or by the farmer (Figure 1). A dairy producer must have signed a herd health contract with their veterinarian to be allowed to administer follow-up treatments. For farms with a herd health contract, the veterinarian should make 12 scheduled herd health visits annually. However, one type of herd health contract introduced in 2006 allows dairy farmers to initiate treatments for some disorders without contact with, or a visit and clinical examination by, a veterinarian. Treatment is only allowed with certain drugs and the criteria for treatment are defined in the contract. The responsible herd veterinarian makes scheduled visits to the herd. The frequency of such visits is weekly to fortnightly depending on the size of the herd and its health status. During a visit, all recently calved cows and cows just before dry-off should be examined. Throughout the thesis, this type of herd health contract is referred to as the Danish New Herd Health (DNHH). In 2008, approximately 8% of the Danish dairy herds participated in DNHH (Committee for Food, Agriculture and Fisheries, 2008). Starting in year 2010 all dairy herds with >100 cows should have herd health contracts, but not necessarily the DNHH (Danish Veterinary and Food Administration, 2011). Farmers participating in the DNHH write disease records themselves. The coverage of the Danish disease recording system was about 90% of the dairy herds in 2008.

For Finnish dairy producers, participation in the milk recording system is voluntary. Approximately 80% of the dairy herds were members in 2008, and of these about 90% also participated in the health surveillance system, i.e. the disease recording system. The veterinarian records the diagnosis and treatment on the cow's health card and the AI technician submits the information when he or she visits the herd (Figure 1). Cases of CM where the cow is not severely ill are not always visited by a veterinarian. Instead, the common practice is for the farmer to take a milk sample and send for bacteriological analysis. When the results are ready the farmer contacts the veterinarian who decides if antibiotic treatment is relevant. In case treatment is prescribed, the farmer should note the diagnosis and treatment on the cow's health card. The information is transferred by the AI technician in the same way as are diagnoses recorded by the veterinarian. The proportion of CM cases treated by phone prescription drugs has been estimated to two thirds of all cases (Saloniemi, 1980). Drugs prescribed over phone may only be for local use, i.e. intra-mammary tubes. If systemic treatment is needed the veterinarian should visit the herd and examine the cow.

In NO the animal owner is responsible by law to ensure that every disease event and treatment of an animal is recorded on the health card of the cow. In practice, the visiting veterinarian fills in the health card of each individual cow (Figure 1). This information is submitted to the central cattle database by the herd advisor (who receives a summary record from the farmer) or farmer. Submission is usually done on a monthly basis but since June 2008, the attending veterinarian can submit the information him-/herself to the central cattle database. The coverage of the disease recording system, i.e. herds participating in milk recording, was 97% in 2008.

In SE, disease recording is compulsory for all veterinarians. For all cattle, every treatment and diagnosis made should be recorded and the information submitted to the National Animal Disease Recording System administered by the Swedish Board of Agriculture (Figure 1) (Swedish Board of Agriculture, 2009). This is mandatory regardless of the herd's participation in milk recording, i.e. the disease recording theoretically covers 100% of the dairy herds. Electronic reporting is available, but the veterinarian should use approved software. Manual recording should be done on a paper form provided by the Swedish Board of Agriculture. The veterinarian should send a paper copy of the record or submit the information to the Swedish Board of Agriculture electronically within a month of the visit. A copy of the record, which is often combined with the invoice, should be left at the farm. For herds that participate in the milk recording scheme, approximately 80% in 2008, the disease data are routinely and on several occasions per week transferred to the central cattle database at the SDA. There, the diagnostic codes are converted to internal diagnostic codes. Swedish farmers may also report the most common diagnoses themselves directly to the central cattle database at the SDA. This is, however, only rarely done.

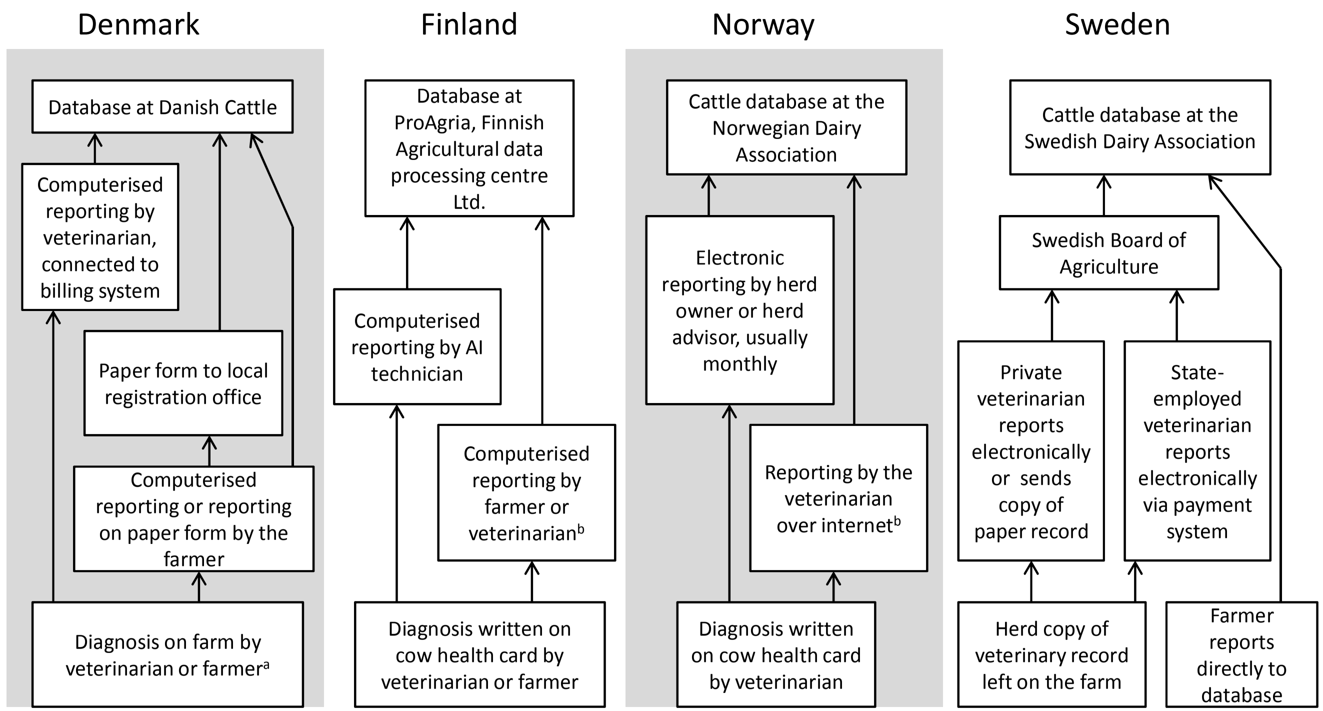

Figure 1. Data flow for disease records from the herd to the central cattle database in the four Nordic countries. [a] Farmers with a certain herd health contract (DNHH), [b] introduced in 2008.

In all four countries the disease record should include herd- and animal identification(s). Further, the veterinarian's identification number, date for the visit, diagnosis(-es) for each animal or group of animals (or more seldom, the entire herd), treatment(s) and withdrawal period(s) should be in the disease record. For a disease record to be successfully entered into the central cattle database there has to be a match with a herd- and cow identification registered in the database. When software is used by the veterinarian for record-writing, or by the person responsible for submitting the records, this includes an updated register of animals in the herd which reduces the risk of recording an incorrect herd id and/or a non-existing animal id.

There are cattle-specific diagnostic codes in DK and FI. In contrast, in NO and SE, a common diagnosis registry for several (NO) or all (SE) species is used. In 2008, a revision of the Swedish code list was initiated during which the initial ca 9000 codes were reduced to ca 4000. The diagnostic codes available in the Nordic countries for CM are presented in Table 1.

Table 1. *The country-specific diagnostic codes for CM in 2008.*

DK	FI	NO	SE
11 Mastitis	301 Acute clinical mastitis	303 Clinical mastitis, severe or moderate	2101 and 2102 Acute mastitis
12 Mastitis during dry period	303 Chronic mastitis	304 Clinical mastitis, mild	2103 Mastitis
14 Mastitis following teat lesion	610 Owners notes: Mastitis during lactation		2104 and 9765 Reoccurring mastitis
15 Acute mastitis			2116 Chronic mastitis
72 Summer mastitis			2117 and 9779 Exacerbating clinical mastitis
94 Toxic mastitis			2147 Teat lesion with mastitis
179 Mastitis with paresis			9764 Acute clinical mastitis
			9766 Mastitis with gangrene
			9767 Mastitis with sepsis
			9769 Chronic clinical mastitis
			9789 Teat lesion with clinical mastitis

1.5 Dairy cattle disease recording in other countries

Internationally, outside the Nordic countries, cattle disease recording systems where diagnoses and/or treatments are gathered in a central database are rare. However, most countries with developed dairy production have milk recording schemes (ICAR, 2011). Most milk recording schemes use SCC as an indicator of mastitis, but treatments are not recorded, and whether the case was subclinical or clinical is not assessed. In many countries dairy farmers may treat CM with antibiotics kept on-farm, without a veterinarian attending each case. Often, farmers' records on treated animals are not collected centrally. Even where veterinarians, by law, should keep records on treatments or prescribed drugs, this information may not be transferred to a central database, or the information may only be a summary, often without the possibility to link treatments to the dairy cattle population. Notifiable infectious diseases are, however, subject to compulsory reporting by veterinarians in the field or at the laboratory.

The National Animal Health Monitoring Scheme for livestock in the US is one example of data collection by surveys, including a sample of herds as an alternative to routine disease recording (Bush & Gardner, 1995; Kaneene & Hurd, 1990). In Canada, such epidemiological surveys have also been performed (Sargeant *et al.*, 1998). A recent example is the national cohort of dairy farms within the Canadian Bovine Mastitis Network (Reyher *et al.*, 2011). Some veterinary universities have developed recording systems for data collection in their region, e.g. Michigan state university (Bartlett *et al.*, 1986) and University of Prince Edward Island (Dohoo, 1992). There are other dairy disease recording systems than those presented here but most have limited coverage. A complete review of such systems is beyond the scope of this thesis.

1.6 Validation of secondary data

The quality of secondary data can be measured as accuracy, which may be defined by two terms; completeness and correctness. Completeness is defined as the proportion of observations (according to a gold standard) that are recorded in the database. Correctness is defined as the proportion of recorded observations that are correct, i.e. in agreement with the gold standard (Hogan & Wagner, 1997). In some literature, the terms validity or accuracy are used instead of correctness. Completeness is then not a part of accuracy but a complement.

Completeness of a database can be interpreted as the sensitivity of a diagnostic test, i.e. the probability that a diseased animal will be recorded in the database (be "test positive"). Correctness, on the other hand, corresponds to the probability that an animal in the database will have the condition it is recorded for, equivalent to the positive predictive value. Completeness and correctness are used for the evaluation relative to the gold standard. In validation of secondary data this is usually not the true state of the patient but medical records or similar. In a diagnostic test context, the terminology 'positive predictive value' and 'sensitivity' refers to the external validity. However, completeness and correctness refers to the internal validity, i.e. the data accuracy for the target population which is in medical records, not the entire population (Jordan *et al.*, 2004). For example, when evaluating the completeness of medical records in a national register there is no knowledge about the true number of diseased individuals in the population. Moreover, there is usually no knowledge about the number of healthy individuals, i.e. those not recorded in the gold standard, that were also (correctly) absent from the data under evaluation. In this case specificity and negative predictive values cannot be estimated (Jordan *et al.*, 2004).

The medical clinical records from veterinary or human medical care are primarily legal documents with information for the veterinarian or physician, the animal owner or patient, and other veterinarians or physicians in the same practice or after referral. It may, in addition to the diagnosis(es), include information from diagnostic tests, treatments and procedures. Further, demographic information about the animal and owner or patient is usually included. Often there is a field for free text notes. Depending on the computer system (or paper records) used, the number of parameters that are coded, or recorded as free text, varies. When medical records are transferred to a database, all or selected codes are included but free text is not always included. Transfer may be automatically or manually performed. Some databases are fed with a summary of a patient's medical record; the activity of summarising the record provides an opportunity for mistakes, in itself. Also, the coding in medical record data systems may differ from the coding in the database which adds an opportunity for unsuccessful transfer.

Consequently, the accuracy of a secondary database can be evaluated at different levels ranging from e.g. patients, diagnoses, visits, treatments, diagnostic tests, or co-morbidities. The ideal gold standard for accuracy of a database is the true state of the patient (Hogan & Wagner, 1997) but in practice this is (almost) impossible to assess and hence, other (imperfect) gold standards have to be used, such as medical records for patients (sometimes verified by additional surveying), original records in a general disease database or a combination of cases from medical records, prescriptions, other diagnoses or procedures related to a specific disease.

Medical records may be hard copy patient charts but are more often electronic records. Hospitals may gather information from records in their own database which may not have correct and complete coding of diagnoses

(Lofthus *et al.*, 2005). If the information is automatically transferred to a regional or country general disease register, an accurate record may depend on the coding of diagnoses and treatments which has called for evaluation of the quality of such general disease registers (Hjerpe *et al.*, 2010; Lofthus *et al.*, 2005). After drawing a sample of records according to the inclusion criteria specified for the study, the corresponding registrations in the database to be evaluated are identified and completeness and correctness can be assessed for the parameters of interest. This approach was used to validate a database of patients with end-stage chronic kidney disease but using a national general disease register that had already been validated as the gold standard (Hommel *et al.*, 2010).

Another approach is to first identify patients or cases in the database under evaluation e.g. for surveillance of AIDS (Klevens *et al.*, 2001) or tuberculosis (Sprinson *et al.*, 2006) or with a specific and rare diagnosis in a general database (Devine *et al.*, 2008). Thereafter the original files from a general database or medical record are identified and used as the gold standard. With this approach, completeness on a more detailed level, e.g. diagnoses or treatments can be estimated after reviewing the gold standard (see for example Klevens *et al.* (2001)). It is, however, more complicated to find the completeness of cases or patients, i.e. the same level as the sampling was made. One example of this approach is the study by Klevens *et al.* (2001) who scanned all records at selected hospitals, clinics and physicians for HIV infections, opportunistic illness associated with HIV infection, procedures related to treatment of HIV or AIDS and for prescriptions of specific drugs to identify persons likely to be infected with HIV. In a study by Devine *et al.* (2008), cases with a specific rare diagnosis identified in a general disease database were verified by questionnaires to the physician who recorded the diagnosis.

To assess the completeness of co-morbidities, i.e. other diagnoses than the primary diagnosis, in an administrative database, Preen *et al.* (2004) manually reviewed the hospital medical charts from sampled patients for co-morbidities. In addition, the most recent referring general practitioner for each patient was surveyed through a questionnaire about co-morbidities for that referral. In other words, the information in the database was compared against two preceding steps in the information flow.

1.7 Validation of veterinary secondary databases

The number of validation studies that have been performed within veterinary medicine is limited. However, the methods applied are similar to how secondary data from human medicine have been validated.

The medical records database at a veterinary teaching hospital were validated by comparing the information on elective surgery cases in the database to the original medical record and the information on the summary sheet kept with each patient's medical records (Pollari *et al.*, 1996). To investigate possible referral bias to the Veterinary Medical Database in the US, disease frequencies were compared for patients (canine and feline) from areas close by or further away from the participating hospitals (Bartlett *et al.*, 2010).

In Sweden, the Agria insurance database for dogs and cats has been validated, including both a comparison between insurance record and practice records to find the agreement for breed, sex, date of birth and diagnosis (Egenvall *et al.*, 1998), and the correctness of specific diagnoses, e.g. canine atopic dermatitis (Nodtvedt *et al.*, 2006). The Agria insurance database for horses has also been validated by comparison of insurance records to practice records (Penell *et al.*, 2007). Further, records in the database of a nationwide organisation of equine clinics have been validated against practice records (Penell *et al.*, 2009).

Medical records for cattle, with complete versus missing data, from routine visits at herds enrolled in a reproductive health programme were compared regarding parameters of reproductive performance (Mulder *et al.*, 1994). Similarly, comparison of herds with good versus poor reporting of the routine procedure dehorning, and comparison of herds where the herdsman judged the reporting as good versus poor, was used to validate disease recordings of calves to the Norwegian Dairy Health Recording Scheme (Gulliksen *et al.*, 2009). Bennedsgaard (2003) compared registrations in the Danish Cattle Database against withdrawal notes or cow files on-farm or in the veterinarians' diaries to estimate the completeness of the database.

Mork *et al.* (2009a) collected primary data on disease occurrence from dairy farmers instead of validating the Swedish cattle database against practice records. The incidence of disease according to farmers was then estimated both including all cases and for veterinary-treated cases only. The latter were then compared with incidence according to the cattle database.

1.8 Known issues with the Nordic dairy disease data

Within the Nordic countries, disease data are used in breeding programs, for research and in extension work. However, country differences in disease incidence in annual statistics, derived from the disease recording systems, have called for further investigation of the underlying causes. Plym-Forshell *et al.* (1995) compared incidence for several common disorders based on disease data and using the same case definition; for CM the incidence ranged from 21 cases per 100 cow-years in SE to 56 cases per 100 cow-years in DK. An in-depth comparison of the incidence risk for mastitis in different parities and -days in milk, where raw data were analysed with identical criteria and methods, also showed differences between the four countries. For instance, the risk of being treated for mastitis at calving among first parity cows was almost 3 times higher in NO than in SE (Valde *et al.*, 2004). Similar patterns of varying risk of recorded disease were found for a range of production disorders (Østerås *et al.*, 2002). These results raised concerns about data quality and completeness of recorded disease data, in particular regarding the completeness of the disease databases and presence of country-specific differences at certain critical steps in the recording process.

All areas where disease data are used would benefit from, firstly, knowing the country-wise completeness of data, i.e. what proportion of disease cases are captured by the recording systems. Secondly, it should be of interest to know what proportions of veterinary-treated cases are correctly recorded in the databases. If there are true differences in veterinary-treated disease incidence, it would be interesting to know if, and to what degree, that is because farmers of different nationality differ in their management of disease cases.

2 Aims of the Thesis

The overall aim of this thesis was to validate the Nordic disease recording systems for dairy cattle with special reference to the diagnosis clinical mastitis (CM).

The specific aims of the thesis were:

- to identify the proportion of farmer-detected CM cases that can be found as a correct registration in each of the four national cattle databases
- to estimate the country-specific incidence rates of farmer-detected CM and of cases recorded in the central databases
- to study Nordic dairy producers' behaviour regarding the action that initiates the disease recording process in a case of mild CM
- to quantify the information loss for known veterinary-visited disease events from the herd to a correct registration in the Swedish disease recording system, and
- to evaluate the spatial distribution of CM cases registered in the Swedish cattle database in relation to an objective measure of udder health.

3 Material and Methods

This section gives a brief description of the material and methods used in the different studies. Details are presented in each of the papers (I-IV).

3.1 The DAHREVA Project

In 2007 a common Nordic project started with the overall aim to validate the Nordic dairy cattle disease databases. Four PhD students have been responsible for one disease complex each, of which CM is one. The others are; locomotor disorders (Ann-Kristina Lind, DK), metabolic disorders (Mari Espetvedt, NO) and reproductive disturbances (Simo Rintakoski, FI). For all disease complexes only clinical disease is investigated.

Studies I-III included in this thesis are all part of DAHREVA. Study I was conducted for the other three disease complexes as well. In each country, studies with the same objectives as study III have been or are being undertaken. Also, a study focusing on the veterinarians' behaviour regarding the treatment decision for cases of mild CM has been initiated within DAHREVA.

3.2 Definitions of disease and diseased animals

In study I clinical disease was defined as clinical signs detected by the farmer during his or her normal routines. Results from measures such as milk samples taken prior to drying off or events based only on tests for subclinical disease, e.g. high SCC at the monthly test milking or high conductivity alerts from the milking system, were not to be recorded as CM. The definition of CM was according to the International Dairy Federation definition: visible abnormalities in the milk and or udder (International Dairy Federation, 1999).

Study II concerned cases of mild clinical mastitis (MCM) and the International Dairy Federation definition of MCM was used: observable abnormalities in the milk, generally clots or flakes with little or no signs of swelling of the mammary gland or systemic illness (International Dairy Federation, 1999)

In study III and IV all animals were veterinary-attended. In study III, an animal was considered diseased if it had a record with a diagnostic code, with a treatment procedure or with clinical signs indicating that it was diseased in the receipt left on the farm by the attending veterinarian. Study IV concerned veterinary-attended CM cases that were registered in the central cattle database.

3.3 Populations

The possibility to use disease registrations from the Nordic dairy cattle disease recording systems for research relies on the possibility to combine these with other information on the individual cow in the database, such as calving events and milk quality and quantity. This is only possible for cows in herds enrolled in the OMRS (DK, NO, SE) and participating in the health surveillance system (FI). Therefore, the target populations and eligible populations were dairy herds in milk recording (DK, NO, SE) and participating in the health surveillance system (FI). Further inclusion/exclusion criteria were:

- in study I and II herds should have an average herd size of at least 15 cow-years
- in study II herds participating in the DNHH were excluded
- in study III and IV Swedish herds with an average herd size of at least 25 cow-years were included, and
- in study III herds in eight counties with dense population of dairy cows were included.

3.4 Data collection and management

3.4.1 Study I

A random sample of eligible herds was invited in each country; 1000, 900, 800, 400 herds in DK, FI, NO and SE, respectively. The study was conducted during two 2-month periods during the Spring and in the Autumn of 2008. The participating farmers (n=105, 167, 179, 129 in DK, FI, NO and SE, respectively) recorded clinical disease in their dairy cows, detected within their normal routines. Recording was made on a purpose-made recording sheet (Appendix 1). In the following, this data will be referred to as the Farmer Recorded Data, FRD. At the end of the second study period all actively participating farmers received a short questionnaire. The questions concerned farm management, e.g. participation in DNHH, and also how the farmer rated their own participation in the study.

Information on the study herds, individual cows, reproductive events, disease registrations, hoof trimming data and test milking results were retrieved from the national cattle databases 6 months after the end of the second study period, i.e. in May 2009. The country-specific diagnostic codes for CM (Table 1) were re-coded to a common code of "CM". The data were transferred to a project database with a similar structure and coding for all countries. These data are referred to as the COmmon Disease Data, CODD.

Both in the FRD and in the CODD all CM events that occurred within eight days after a first disease event were treated as belonging to the same CM case. A CM event was defined as veterinary-visited if the farmer had recorded a date for a veterinary visit, if there was information saying that the cow was diagnosed by a veterinarian, that treatment had been initiated by a veterinarian or if the farmer had ticked the box for "veterinary-visited". In addition, all Finnish CM events treated with antibiotics were defined as veterinary-visited. In FI the common veterinary practice for treatment of milder cases of CM is phone prescription of antibiotics, after the results from a milk sample taken by the farmer are known. Likewise, CM events from Danish herds participating in DNHH were considered to be veterinary-visited if the cow was treated with antibiotics or NSAID. If any of the events associated with an FRD case was veterinary-visited, the entire case was considered as veterinary-visited. All CODD cases were veterinary-visited, by definition.

All CM cases in the FRD were matched against cases in the CODD. Matching was done by country, herd ID, cow ID and case date. Up to 7 days difference in case date was allowed. To verify that the cow was present in the herd on the date the farmer had recorded, FRD cases without a match in the CODD were compared with monthly test milking records one year before and after the case date and with the cow information (dates for entry into and removal from the herds, and calving dates) from the central databases. Any obvious mistakes regarding cow identification in the FRD were corrected. Furthermore, any CM cases present only in the CODD, i.e. not farmer-recorded, were added to the FRD. These were disease events that evidently had taken place but had failed to be recorded by the farmer. This dataset is hereafter referred to as the "adjusted FRD".

3.4.2 Study II

A questionnaire based on the Theory of Planned Behaviour (TPB) from social psychology was developed. In brief, according to this theory a person's behavioural intention is a proxy for the actual behaviour. The behavioural intention is in turn determined by the person's attitude, subjective norm and perceived control regarding the behaviour. Each of these constructs is the sum of beliefs that the person holds about outcomes from performing the behaviour, social referents or perceived control over the behaviour. Each belief is weighted by the respondent's, according to his/her corresponding outcome evaluation, motivation to comply or power of influence. The behaviour of interest for this study was defined as "*Contacting the veterinarian for a visit the same day as detecting a case of mild clinical mastitis in a lactating dairy cow*". In FI an alternative behaviour "*Taking a milk sample and sending it for analysis the same day as detecting a case of mild clinical mastitis in a lactating dairy cow*" was also defined.

To elicit beliefs held by Nordic dairy producers regarding the behaviour of interest, qualitative face-to-face interviews were done with eight to ten farmers per country. The farmers were chosen to represent a wide range of herd types, sizes and farmer characteristics. The primary investigator in each country performed the interviews using a common guideline. The most frequently mentioned statements were refined to beliefs and rephrased to questions in a questionnaire (Figure 1, study II). The questionnaire further included questions measuring attitude, subjective norm and perceived behavioural control on a more general level (Figure 1, study II; direct questions). The behavioural intention was assessed by eight scenarios describing cases of MCM. The English version of the questionnaire can be found in Appendix 2.

After translation of the questionnaire to the four Nordic languages and pilot-testing it, it was mailed to 400 randomly sampled farmers in each country in Spring 2010. After 2 weeks a reminder including a copy of the questionnaire was sent to non-responders.

The data were checked for errors, and questionnaires with a lot of missing data were removed. Composite variables for the direct attitude and subjective norm, respectively, were created as the mean value of the direct questions. Similarly, composite variables for indirect attitude and subjective norm, respectively, were created as the sum of the weighted beliefs. The answers to the eight intention scenarios were combined to an intention score, where the number of yes-answers was divided by the number of answered questions. To validate the questionnaire, two types of analyses were made. Firstly, the internal consistency, measured by Cronbach's alpha (Cronbach, 1951), was calculated for the direct attitude and for the direct subjective norm. Secondly, the Spearman rank correlations were calculated between the indirect and the direct attitude and subjective norm, respectively.

3.4.3 Study III

Copies (approx. 2700) of receipts left on-farm, from veterinary visits made between March 2003 and April 2004, were collected from 112 study herds

(28% of invited herds). A simple random sample of 900 copies from the study herds was made. After removal of unreadable copies 851 receipts remained. The information in the receipt, e.g. record number, herd identification, visit date, cow identification(s), diagnostic code(s), diagnoses or treatments for animals written only as free-text notes, was entered into a data file.

Two sets of disease data for the period of interest were retrieved from the SDA. Firstly, the raw data transferred from the Swedish Board of Agriculture (SBA) which had only been checked for animal identity. These are referred to as "raw data". Secondly, disease data from the dairy disease database at SDA, i.e. after conversion to the internal diagnostic codes of the cattle database at SDA. These data are referred to as the 'DDD'. Both datasets included disease events for individual animals only, because in practice, only individually recorded data are used, i.e. combined with other sources of data, in the cattle database. At the time period of interest, the SDA had a problem with data loss between raw data and DDD, caused by a lack of translation for some codes; therefore in study III, these two datasets from the cattle database were analysed separately. In study I the raw data, which is more detailed regarding the diagnostic code used by veterinarian, was used. In the discussion of this thesis, the DDD is referred to as data from the cattle database, similarly to study I.

The information in the copies was matched against the raw data and the DDD. For all diagnostic events not found in the DDD the copy and, where it existed, the observation in the raw data were scrutinised to find reasons for the event not being present in the DDD. The copies were also checked for records, cases and diagnostic events not found in the raw data.

3.4.4 Study IV

Herd-level data on veterinary-registered disease, e.g. incidence of CM, and production data, e.g. test milking results, for the period Sep 2008 to Aug 2009 were retrieved from the cattle database at the SDA for all herds in milk recording (n=4657). The geographical coordinates for all Swedish dairy herds were retrieved from the Swedish Board of Agriculture. The two data sets were merged, and herds with an average herd size of <25 cow-years or incomplete coordinate data were removed. The final dataset included 3847 herds.

3.5 Data analyses

3.5.1 Completeness of farmer-recorded CM cases in the CODD (I)

Completeness was calculated as the proportion of cases in the FRD or the adjusted FRD that were successfully matched to a case in the CODD, both for all farmer-recorded cases and including only cases that were defined as veterinary-visited. Two-sided confidence intervals (CIs) were calculated for each point estimate. The CIs were doubled to account for the unknown effect of clustering of cases within herds.

Farmers with herds where most or all CM cases in the CODD were also recorded in the FRD were classified as ‘good study reporters’, as this indicated that they had not failed to report any, or only few, veterinary-visited cases that had occurred during the study period. The cut-off was set to: number of cases in FRD/number of cases in CODD <0.9. The completeness calculations were repeated with only the good reporters included.

3.5.2 Incidence of CM (I)

The second objective of study I was to calculate incidence rates (IRs) for CM cases in the adjusted FRD, including all cases as well as veterinary-visited cases only, and for cases in the CODD. This was done by Poisson regression with the number of cases per herd as the outcome variable and the natural logarithm of cow-days at-risk per herd as the offset variable. The anti-logarithms of the parameter estimates were multiplied by 100*365 to obtain the number of CM-cases per 100 cow-years.

3.5.3 Farmer behavioural intention (II)

Descriptive statistics for behavioural intention, attitude, subjective norm, perceived behavioural control and demographic parameters were calculated. Because of the non-Gaussian and categorical nature of both the behavioural intention score, direct and indirect measures of attitude, subjective norm, perceived behavioural control and several of the demographic parameters, most analyses were done with non-parametric methods. The main objective of this study was to assess any between-country differences in farmer behaviour regarding the action that is a prerequisite for a CM event to enter the recording system; to contact the veterinarian for a visit, or in FI to take a milk sample and send for analysis. This was done by comparing the behavioural intention score for two countries at a time using the Wilcoxon rank-sum test.

The country-specific variation in behavioural intention that could be explained by attitude, subjective norm or perceived behavioural control was estimated by the adjusted coefficient of determination (adjusted R^2) from multivariable linear regression modelling. The dependent variable was the behavioural intention score and independent variables were the direct attitude, subjective norm or perceived behavioural control or a combination of two or three. The models’ fit were evaluated by examining the studentized residuals for normal distributions as well as checking for equal band-width when plotted against the predicted mean, a straight line in the Q-Q plot and the presence of outliers.

To study what beliefs were underlying the attitude and the subjective norm, country-specific Spearman rank correlations were calculated between each indirect attitude or subjective norm and the behavioural intention score.

3.5.4 Completeness of information from veterinary records (III)

Completeness of records, cases, and diagnostic events (Figure 2, study III) from the receipt copies and agreement for date of consultation (Table 1, study III) were calculated for the raw data (from the SBA). The completeness for diagnostic events (Table 1, paper III) found on the copies was calculated for the data from the DDD. Completeness was calculated as the proportion of matches both in total and separately for four different combinations of veterinary employment and record types. These types were; state-employed, computerised record (stat/comp), state-employed, manual record (stat/man), private practitioner, computerised record (priv/comp) and private practitioner, manual record (priv/man).

A multilevel regression analysis was made with completeness of diagnostic events in the DDD as the outcome variable and region (North, South, Middle and the Islands), employment type (state-employed or private practitioner), record type (computerised or manual), season (December-February, March-June, June-August and September-November), disease complex (udder, metabolic, reproduction, lameness and other disorders) and age category of the animal (<2 years, 2 years, 3 years, 4 years and > 4 years) as potential predictor variables. Veterinary identity was included as a random variable. First, a model with all main effects was created. It was reduced by manual backward elimination until all main effects had a p-value <0.05. Thereafter, two-way interactions between the main effects were evaluated and kept in the model if p<0.05. If a variable changed parameter estimates for other variables by >20% it was considered a confounder and kept in the model (Dohoo *et al.*, 2003).

3.5.5 Spatial odds for veterinary-registered CM (IV)

Two surfaces, representing the number of cattle per km^2, were constructed using a Gaussian-kernel smoothing function. The first (case) surface included all herds with at least one registered CM case during the study year, and the number of CM positive cows was used as a weighting variable. The second (control) surface included all herds without registered CM cases during the study year, and the number of CM negative cows, i.e. the average herd size, was used as a weighting variable. The (natural) logarithm of the ratio of the case surface to the control surface (Kelsall & Diggle, 1995) provided an estimate of the spatial distribution of the (log) odds for veterinary-registered CM. Adaptive smoothing was used. The grid cell resolution was 200, i.e. the length and width of Sweden were each divided into 200 segments. Four herds were removed because they shared coordinates with another herd. A sparsely populated area in the north of Sweden (containing 33 herds) was removed from the study area because of instability of the log odds estimates arising from sparseness of the data.

To test the hypothesis of a uniform spatial odds for CM across Sweden (i.e. a spatially uniform probability of having a case of CM recorded), a procedure based on the Z-test (Hazelton & Davies, 2009) was used and asymptotic p-values were assigned to each grid cell of the surface. Contour lines were added to the map of log spatial odds to delineate areas with significantly higher or lower spatial odds for CM.

The dairy cows in Sweden are not evenly distributed throughout the country. To aid the evaluation of elevated or decreased odds for CM, the Gaussian-kernel smoothed density of cows was estimated, using the average herd size as the weighting variable. A fixed bandwidth of 30 km was used, calculated by cross validation (Bowman & Azzalini, 1997).

For each study herd the number of cows with poor UD scores (6-9 on a scale from 0-9), at least once during the study year was available. Including all study herds, a Gaussian-kernel smoothed surface was constructed with the number of cows with poor UD score as the weighting variable. Next, a second surface was created; similar to the first one, but with the herd size as weighting variable. The two surfaces, cows with poor UD score per km^2 and cows per km^2, were combined to a surface illustrating the proportion of cows with poor UD score. Adaptive smoothing was used and the same grid resolution as for the log spatial odds. The contour lines for significantly high or low spatial odds for registered CM were superimposed on this map and areas where high/low frequency of CM did or did not coincide with high/low prevalence of poor UD score were identified by visual inspection of the map.

4 Main Results

4.1 Response rates and sample sizes

In the first study the number of participating herds in DK, FI, NO and SE were 105 (11% of invited), 167 (19%), 179 (22%) and 129 (32%), respectively. In total, 2280, 1403, 887 and 1178 recording sheets with clinical disease events seen during the study periods were returned.

In study II the response rates in DK, FI, NO and SE were 65% (n=256 distributed questionnaires), 45% (n=176), 54% (n=214), 52% (n=206), respectively, after 18 questionnaires where the farmer had discontinued milk production had been removed. After removal of another 18 unsatisfactorily filled-in questionnaires the final sample size was 834 observations.

In study III, the analysed data included 851 records of which 818 included a case in an individual animal (instead of a group of animals or a herd). In all, there were 1447 cases of which 1253 were in an individual animal, and in those individual animals there were 1185 diagnostic events (68 cases with a diagnostic code indicating a non-disease event were excluded).

In study IV, the number of herds included in the analyses were 3814 (82% of all herds in milk recording in 2008); of these 459 had no registered CM case during the study period.

4.2 Completeness of farmer-recorded CM cases in the CODD (I)

The number of CM cases and the country-wise completeness of the CODD are presented in Table 2. The number of CM cases in the CODD was 1218, 301, 359, 404 in DK, FI, NO, SE, respectively. That is, in DK there were actually less cases in the FRD than in the CODD. Further, in all countries except DK the number of herds with any CM case in the FRD exceeded the number of herds with any CM case in the CODD. All completeness estimates were highest in DK and lowest in FI. The completeness of the CODD was higher when comparing with the adjusted FRD than when comparing with the FRD. This was because the proportion of matching cases increased when excess cases in CODD were added to the original FRD.

To explore how the allowed date discrepancy between the FRD and the CODD affected the completeness estimates the number of days between observations that matched on country, herd ID and cow ID, but not on the exact date, were tabulated. For most matches there was only 1-2 days discrepancy. Consequently, changing the allowed data discrepancy from 7 to 10, 20 or 30 days had only minor effects on the completeness estimates.

When using data only from herds where the farmer was classified as a good study reporter, i.e. where there were proportionally few excess CM cases in the CODD, the completeness estimates decreased (Table 3, study I).

Table 2. *The number of farmer-recorded clinical mastitis cases (FRD) and the completeness (95% confidence interval) of these cases in four national central cattle databases (CODD). The adjusted FRD includes the cases in the CODD that the farmers failed to record.*

	Compared to the FRD (95% CI)				Compared to the adjusted FRD (95% CI)			
	n	All cases	n	Veterinary-visited	n	All cases	n	Veterinary-visited
DK	938	0.85 (0.80, 0.90)	794	0.90 (0.86, 0.94)	1422	0.90 (0.87, 0.93)	1302	0.94 (0.92, 0.97)
FI	536	0.45 (0.32, 0.58)	477	0.50 (0.41, 0.59)	598	0.51 (0.43, 0.59)	540	0.56 (0.48, 0.64)
NO	379	0.68 (0.57, 0.80)	331	0.77 (0.68, 0.86)	480	0.75 (0.67, 0.83)	432	0.82 (0.75, 0.90)
SE	498	0.61 (0.50, 0.72)	415	0.72 (0.63, 0.81)	600	0.67 (0.60, 0.75)	519	0.78 (0.70, 0.85)

4.3 Incidence of CM (I)

The IRs (cases per 100 cow-years) were highest in DK and lowest in SE (Table 4, study I). In FI there was a significant difference (non-overlapping CIs) between the IR from CODD and from the FRD, both when including all cases and only the veterinary-visited cases. Also in SE there was a significant difference between IRs from all FRD cases and from the CODD. The IR for all cases depends both on the proportion of cases that were veterinary-visited, and hence could be expected to be found in the CODD, and to what extent the recording process is successful; from record written by the veterinarian to a correct registration in the CODD.

4.4 Farmer Behavioural Intention (II)

The median behavioural intention score (first quartile, third quartile) for contacting a veterinarian the same day in DK, FI, NO and SE was 0.50 (0.25, 0.63), 0.00 (0, 0.25), 0.50 (0.25, 0.63), 0.38 (0.13, 0.63), respectively. This means that farmers in DK or NO would contact the veterinarian for every second case of MCM that they observe. In FI the behavioural intention to contact the veterinarian was low compared to the intention to take a milk sample and send for analysis the same day, where the median behavioural intention score was 0.63 (0.50, 0.88). In FI, the distribution of answers to the question on how often a milk sample is taken for MCM cases further supported that the common practice, and the behaviour relevant in this study, was the milk sample option. Therefore, the results below represent the Finnish milk sample option unless otherwise indicated.

The behavioural intention score differed ($p<0.01$) between countries in all pair-wise comparisons, except between DK and NO. This suggests that the null hypothesis of equal farmer behavioural intention in all four countries should be rejected.

The model, for all countries, that explained the largest proportion of variability in behavioural intention included attitude, subjective norm and perceived behavioural control (Table 2, study II). The adjusted R^2 for the model with all three constructs was 0.51, 0.32, 0.58, 0.62 in DK, FI, NO and SE, respectively. However, the attitude alone (DK and NO) or combined with the subjective norm (DK, NO and SE) or the perceived behavioural control (DK) explained approximately the same amount of variability. But also in FI and SE the attitude was the single construct with the highest adjusted R^2. The models' fit was, in general, acceptable.

The indirect attitudes, i.e. outcome belief weighted by its outcome evaluation, with the highest correlation to the behavioural intention was that the action would lead to a quicker recovery of the cow, prevent the cow from having a blind teat and contribute to a healthy herd. In DK, NO and SE the prevention of a reduced milk yield during the rest of the lactation was also important. All these indirect attitudes had a positive evaluation, i.e. they can be regarded as drivers for the behaviour.

4.5 Completeness of information from veterinary records (III)

In study III, it is understood that all animals were veterinary-visited because there had been a veterinary receipt left at the farm. The completeness of records was 100% (95% CI: 98, 100) for records from state employed veterinarians and 82% (78, 85) for records from private veterinarians. The completeness of cases in individual animals was 98% (95% CI: 97, 99) for state employed veterinarians and 80% (77, 82) for private veterinarians.

The completeness for diagnostic events in individual animals was, in total, 84% for the raw data and 75% in the DDD (Table 4, study III). The record type 'manual records from private veterinarians' had significantly lower completeness for diagnostic events in both data sources. About two thirds of the diagnostic events in the receipt copies, where a match in the DDD was missing (n=300), were also missing from the raw data, indicating that the record had never reached the Swedish Board of Agriculture. The most common reason why a diagnostic event could not be found in the DDD, although it was present in the raw data, was that the diagnostic code in the raw data was not included in the conversion key used in the DDD (n=69). For 34 diagnostic events, the reason for data loss remained unknown.

The final multilevel logistic regression model of factors that affected the completeness of diagnostic events in the DDD included the fixed effects of employment type, region, disease complex and the random effect of veterinarian (Table 6, study III). The effect of veterinarian accounted for 35% of the model variance. One interaction (employment type×disease complex) remained in the model. Moreover, the odds for a diagnostic event not being in the DDD was higher in the South and North of Sweden, compared to the Islands and the Middle (Table 6, study III).

4.6 Spatial odds for veterinary-registered CM (IV)

The herds included in the final analysis had, in total, 265,024 cow-years at risk. Also, there were in total 109,749 cows with poor UD score at least once during the study year and there were 37,148 cases of CM. The herds without any registered CM cases had, in general, fewer cows but the same average monthly proportion of cows with poor UD score (Table 1, study IV).

There were areas with significantly ($p<0.01$) higher as well as lower spatial odds for veterinary-registered CM (Figure 2, study IV). The geographical distribution of spatial odds for registered CM did not follow the distribution of proportion of cows with poor UD score completely (Figure 3, study IV). This suggests under-reporting or over-treatment of CM cases in areas with a high proportion of cows with poor UD score combined with low odds for CM, or a low proportion of cows with poor UD score combined with high odds for CM, respectively.

5 General Discussion

5.1 Completeness

It is not necessary to treat all cases of CM with antibiotics or other prescription drugs, i.e. not all cases need veterinary attention. This means that a disease recording system (mainly) based on veterinary recording, as in the Nordic countries, cannot be expected to capture all cases of CM. The studies in this thesis show that there is a difference in completeness with regard to CM cases in the Nordic cattle databases. We have shown that there was lack of completeness (in DK, FI, NO and SE), for both veterinary-visited (0.94, 0.56, 0.82, 0.78) and all cases (0.90, 0.51, 0.75, 0.67) of CM (study I). The completeness estimates were significantly higher in DK and lower in FI compared to NO and SE. For SE the results were consistent with the findings in study III, looking at veterinary-attended disease cases in general (0.75). The differences in completeness may in part explain the differences seen in earlier comparisons of disease incidences (Valde *et al.*, 2004; Østerås *et al.*, 2002).

Suggestions on how to evaluate degree of completeness (or agreement between the compared data sources) for diagnostic information have been given by other authors; with an overall agreement for diagnosis of 84% being rated as excellent (Penell *et al.*, 2007) and less than 10% major disagreement as fair (Egenvall *et al.*, 1998). In a review of quality of morbidity coding, completeness of 80-90% was regarded as high, 70% moderate and <60% poor (Jordan *et al.*, 2004).

A few studies aimed at validating Nordic dairy disease data have already been published. In a Norwegian study, veterinary-treated morbidity among dairy calves was underestimated by approximately 40% (Gulliksen *et al.*, 2009). In a Swedish study by Mörk and co-workers (2009a), 71% of all veterinary-treated disease events, as registered by study farmers, could be found in the central cattle database, and there were significant differences between farmer-registered incidence and the central cattle database for several diagnoses. The IR estimates for CM in the Mörk study are in line with the IRs for CM in the FRD (study I).

A Nordic study reported an incidence risk for recorded CM of 0.18, 0.14, 0.22 and 0.13 in the first lactation and 0.23, 0.22, 0.36 and 0.20 in lactation 3 or higher, in DK, FI, NO and SE, respectively (Valde *et al.*, 2004). This between-country pattern does not agree with the IRs from study I, neither in the FRD nor in the CODD. However, the data were from 1997 and, for example, in NO the officially published incidence has decreased since then (TINE, 2008). A Danish study using data from 1993-94 and excluding herds with unsatisfactory disease recording data showed an incidence rate of between 36 and 48 cases per 100 cow-years (Bartlett *et al.*, 2001) which agrees with the IRs in the adjusted FRD (study I).

Within the DAHREVA project, study I has been performed for other disease as well complexes (reproductive, metabolic and locomotor disorders). For example, the completeness for all cases of retained placenta in DK, FI, NO and SE were 0.89, 0.34, 0.76 and 0.65, respectively. Similarly, for all cases of milk fever it was 0.77, 0.67, 0.79 and 0.79, (personal communication Mari Espetvedt and Simo Rintakoski). The results from these studies and study I agrees with the hypothesis from the pilot project (Østerås *et al.*, 2002) that it is not only the actual disease levels that differs between the Nordic countries, but that the proportion of clinical disease captured by the disease recording systems, i.e. veterinary-attended and successfully recorded, also varies.

The overall completeness of diagnostic events in the cattle database in the Swedish study III was 75% (Table 4, study III), but it was considerably higher for state employed veterinarians (86%) and lower for private practitioners (69%) (Jansson Mörk, 2009). Studies with the same objectives as study III have been carried out in FI and NO within the DAHREVA project. In FI, the overall completeness was 83% (95% CI: 82, 84) when allowing minor disagreements for e.g. date (personal communication Simo Rintakoski). In NO, the overall completeness was approximately 90% (personal communication Mari Espetvedt). A Danish study with the same objective as study III reported that the completeness of the Danish cattle database, with regards to veterinary-treated disease cases in dairy cows, was 78-85% in year 1998 to 2001 (Bennedsgaard, 2003).

5.1.1 Consequences of imperfect completeness

Incomplete disease data may lead to biased results when the data are used, as it will result in an erroneous classification of animals without registered disease events as being healthy. This type of “measurement error” of a categorical variable like disease status is called misclassification bias. If the variable of interest, e.g. diseased or not, is equally affected in groups that are being compared, the misclassification is non-differential, meaning that the misclassification of the outcome and exposure are independent. Non-differential (or random or non-systematic) misclassification tends to bias relative measures of association, e.g. odds ratio or relative risk, towards the null. If, on the contrary, completeness of the disease data differs between groups that are compared this may lead to differential misclassification. The effect of differential misclassification is often difficult to predict (Dohoo *et al.*, 2009; Rothman, 2002). For example, apparent spatial clusters with increased number of children with congenital malformations in New York State were concluded to be caused by underreporting to the register for congenital malformations by some hospitals in these areas (Forand *et al.*, 2002). In veterinary medicine, subgroups that may have different completeness of disease data are animals/herds in different countries (because their context differ, e.g. farmer and veterinary attitudes, recording system), or animals/herds that are served by different veterinarians within the same country (if the implementation of the recording system differs).

The results from study I suggest that a comparison of CM incidences in dairy cows between DK or FI or NO and SE will be subject to differential misclassification because of different completeness of CM in the central databases. Similarly, the results from study III and IV suggest that in SE, a comparison of disease incidence between subgroups based on geographical regions may be subject to differential misclassification. However, Sorensen *et al.* (1996) suggested that the degree of completeness is less important than whether misclassification is random or differential. The effect of imperfect completeness and potential differential misclassification has to be considered in relation to how the data are to be used.

The main use of the disease data in the central cattle databases is in herd management, advisory work, and breeding programmes. Correct assessment of an individual animal's disease status is important for all these purposes. If disease data from the four countries are to be combined and valued equally, without considering how the data are generated, any differential misclassification between countries (and between disease complexes) will continue to be a source of incomparability. It is therefore important to identify the steps in the information flow of each recording system that causes loss of information. If the cause concerns the recording of veterinary-attended (or veterinary-treated) cows and/or the transfer of information to the database, actions could be taken to improve completeness. But if the cause is that proportionally fewer cows are e.g. treated with antibiotics, focus should instead be on reasons for different treatment incidence, e.g. any differences in treatment criteria or diagnostic criteria.

Secondary data have been used for epidemiological studies in the Nordic countries for many years, and could become an even more attractive alternative to primary data collection in the future as the number of herds decreases and the number of farmers willing to participate in field studies is reduced. Combining data from several Nordic central databases would allow a larger sample, but the results from study I suggest that for studies on CM, attention should be given to the differences of completeness. With knowledge about the degree of completeness, and the nature of any lack of data, the researcher is in a position to judge whether the secondary data source is acceptable for his/her intended research. In addition, knowledge about the completeness of the disease data can improve the use further and also target activities aimed at improving the data collection, either by enhancing the system as a whole, or for diseases of specific interest.

Disease recording, as performed in the Nordic countries, is a potentially powerful way of capturing clinical surveillance data. The systems have good coverage in the dairy populations and recording is performed continuously. If the recorded data are complete, both long- and short-term changes in disease occurrence should be detectable. In fact, if the completeness is constant, although not 100%, a baseline of recorded disease could be established, and deviations from the baseline occurrence could, possibly, still be detected. In a system where submission and analysis of disease data is made frequently (continuously), such deviations could give an early signal of disease outbreak. Compared to diagnoses made at animal (or human) hospitals, the cow-side diagnoses in dairy cattle are relatively unspecific, but on the other hand dairy producers and veterinarians may have a more frequent contact than animal hospitals have with their clients. Therefore, although diagnostic information from the field is unspecific and sometimes unconfirmed, its potential use for early warning should be investigated.

5.2 Farmer threshold to contact a veterinarian

The farmer's action upon detecting a diseased animal determines whether the disease case enters the recording process or not (Figure 2). Reasons for not contacting the veterinarian could be that the farmer first treats the cow with non-prescription drugs, e.g. udder liniment, or performs actions such as frequent milking or hoof trimming. Depending on how the disease case develops the veterinarian might be contacted at a later stage (or even the day after).

The completeness for all CM cases (study I) is influenced by the proportion of cases that are put under veterinary attention. In study II, it was shown that the behavioural intention to contact a veterinarian for a case of MCM was significantly lower in SE, compared to in DK and NO. The absolute effect on completeness for all CM cases in these countries is difficult to estimate without knowing what proportion of mastitis cases that are MCM, or were MCM when detected by the farmer, in each country.

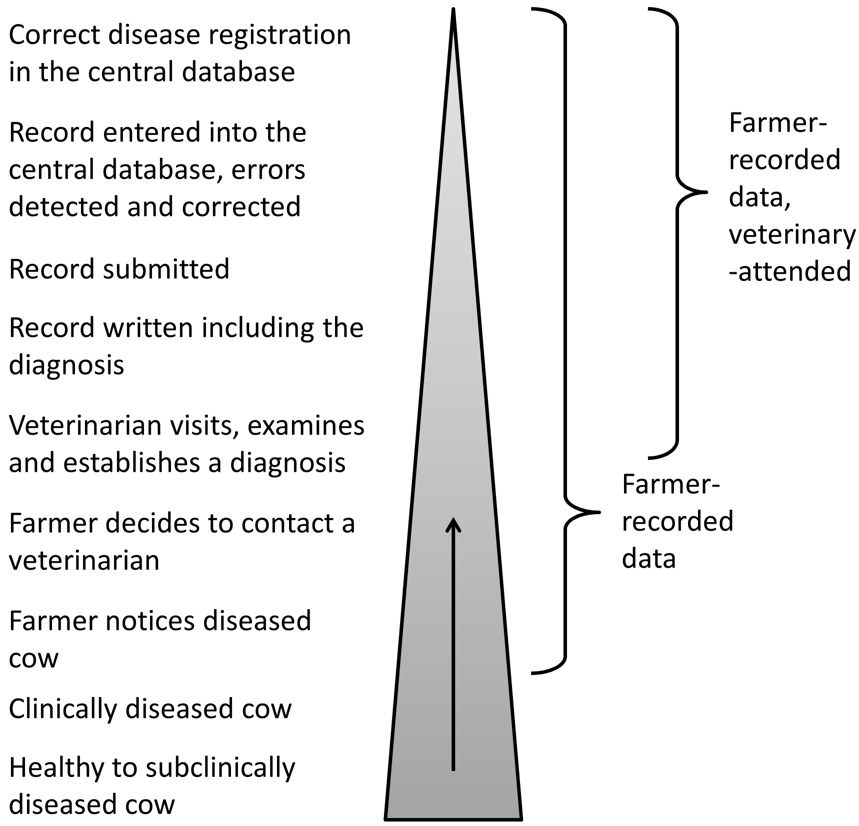

Figure 2. Illustration of the data flow from the diseased cow to the central cattle database. 'Farmer-recorded data' refers to study I.

In FI the results from study II cannot be directly compared to the other countries. The threshold for taking a milk sample and sending it for analysis can be expected to be lower than that for contacting a veterinarian for a visit, since it is easier and less costly. Not all milk samples will be positive and not all positive samples will result in a treatment; the cow might have self-cured, possibly with the aid of frequent milking, massage of the udder etc. In our study, we did not have any information about the proportion of sampled cows that were not treated, as not all FRD records in study I were detailed enough to correctly identify all cows that were first sampled by the farmer, and whether there was bacterial growth or not.

Study IV identified some areas in Sweden with relatively lower spatial odds for veterinary-registered CM. Within a region, not only the veterinarian(s) influence disease management but there may also be non-veterinary advisors acting. In other words, a low incidence of veterinary-treated CM may also be a result of the mastitis management promoted in that area; for example, farmers may have been advised to primarily use alternatives to antibiotic treatment before they contact a veterinarian.

The most important indirect attitudes for contacting a veterinarian the same day for a case of MCM, and drivers to perform the behaviour, were that the action would lead to a quicker recovery of the cow, prevent the cow from having a blind teat and contribute to a healthy herd. In DK, NO and SE, it was also important that the action would prevent a reduced milk yield during the rest of the lactation (table 3, paper II). If one wishes to influence farmers' attitudes and behaviour regarding MCM treatment these drivers could be targeted in communication with farmers.

Farmers' treatment decisions regarding CM are complex. A Danish study showed that after qualitative interviews with 16 dairy farmers, four main factors were suggested to influence the decisions; the severity of clinical signs, the characteristics and history of the cow, the herd situation (for example milk quota), and treatment alternatives. Each interviewed farmer had different priorities and put different weight to each factor (Vaarst *et al.*, 2002). One could hypothesise that in NO and FI, where the average herd is small, the milk from one cow is relatively more important, both with regards to the amount produced, and for the tank cell count. Farmers could hence be more eager to have a cow with CM treated. This was, however, not supported by the results in study II. On the other hand, farmers with large herds could be more eager to use drug treatments, instead of alternative actions like frequent milking which is labour demanding. In addition, other factors, e.g. extra payment, or penalties, by dairies based on cell content of the milk, may affect the farmers' treatment threshold.

Moreover, each farmer will have his or her own definition of what clinical manifestations are signs of disease or normal variation, respectively; this will also influence their threshold to contact a veterinarian. In a Swedish study evaluating large dairy herds with a high milk production, low BMSCC and high or low incidence of veterinary-treated CM, different treatment strategies were seen. One significant difference was how cows with visible changes in the milk were handled; in herds with a high incidence of registered CM the farmer more often called for a veterinary-visit and -treatment compared to the farmers in herds with low incidence of registered CM who waited until the general appearance of the cow was affected (Nyman *et al.*, 2007). It would be interesting to study the influence of factors such as BMSCC, herd-size and breed on the behavioural intention and attitudes assessed in study II.

It should be noted that the results from study II only covered MCM and the same day as the case was detected. Farmers may have other thresholds for contacting the veterinarian with regards to diagnoses other than MCM, depending on e.g. what treatment the farmer can provide without veterinary prescription, but also depending on the direct impact on milk production. A Swedish study found that e.g. the main breed in the herd, the lactation stage of the cow and disease complex affected the odds for a cow to be veterinary-treated (Mork *et al.*, 2009b). In the same study the random variable 'herd' accounted for approximately 40% of the model variation. The effect of herd includes characteristics of the herd that were not evaluated as fixed effects, e.g. farmer attitudes to disease treatment.

Several authors have put attention to farmer behaviour and attitudes in relation to management and farm performance, e.g. disease occurrence. A Canadian study found that not only management practices but also socio-demographic and psychological characteristics of the farmer, e.g. satisfaction with farming, were associated with the frequency of several common reproduction disorders in dairy cows (Bigras-Poulin *et al.*, 1985) which is in line with the results from study II. Incidence of CM and high BMSCC in Dutch dairy herds has been reported to be partly explained by the farmer's attitudes. For example, the farmer's perceived frame of reference of BMSCC was important to explain variation in the BMSCC. Also, a perceived lack of control of mastitis was important to explain the variation in both BMSCC and CM incidence (Jansen *et al.*, 2009). However, the outcomes in these studies were disease occurrence, and not the behavioural intention of the farmer as in study II.

Farmers in DNHH were not included in study II because they do not perform the behaviour of interest, i.e. they do not call a veterinarian for a case of MCM, and hence could be regarded as being outside the target population. A separate study on DNHH farmers, where the behaviour of interest is to treat a case of MCM, is ongoing. Of interest is to see if the behavioural intention to treat MCM in these herds is stronger than the intention to contact a veterinarian in study II. It could be hypothesised that DNHH farmers will be shown to have a lower action threshold because initiating treatment would be easier and less costly than arranging a veterinary visit.

5.3 Information loss from the veterinary-attended cow to the database; effects of veterinarian and region

The total completeness partly depends on the completeness for veterinary-attended disease cases, i.e. the part where the completeness should, in theory, be 100%. In study I, a lack of completeness was seen in all four countries for CM cases that, according to the farmers, were veterinary-visited. This demonstrates a failure in the information flow from record-writing by the veterinarian via the submission and transfer to the central database, to a correct registration in the database (Figure 2). Lack of completeness for veterinary-visited cases was also present in the other disease complexes investigated in DAHREVA; e.g. 0.93, 0.63, 0.81 and 0.88 for retained placenta, 0.88, 0.71, 0.80, and 0.82 for milk fever and 0.88, 0.56, 0.60 and 0.33 for locomotor disorders in DK, FI, NO and SE, respectively (personal communication Mari Espetvedt, Ann-Kristina Lind and Simo Rintakoski).

The results from study III showed that factors such as the veterinarian and his/her employment type, as well as disease complex and geographical region, influence the completeness of known veterinary-visited disease cases in Sweden. This completeness only covers the submission of records by veterinarians and the transfers to the central cattle database since the standard for comparison in this study was the written records, i.e. theoretically one step further in the recording process (from "visited case" to "recorded case") compared to the veterinary-visited-case completeness in study I (Figure 2). However, the modelled completeness of the cattle database for CM was 0.80 (95% CI: 0.78, 0.83 (Jansson Mörk, 2009) which corresponds well to the completeness for veterinary-visited CM (adjusted FRD) in study I which was 0.78 (95% CI: 0.70, 0.85) in SE.

In SE, there was no difference in completeness of the CODD when comparing to CM that was veterinary-visited (study I) according to farmer and when comparing to CM from a herd receipt (study III). This is in contrast to FI, where the discrepancy between completeness of CM compared to veterinary-visited CM in the FRD and completeness compared to information from the cows' health cards was larger (personal communication Simo Rintakoski). This suggests that for veterinary-visited CM cases in SE, it is the submission and transfer of records, rather than the writing of the record that reduces the completeness in the central database (Figure 2). In study IV, there were geographical differences in the odds for veterinary-registered CM, and the areas of high or low odds did not fully follow the distribution of cows with poor udder health. This suggests under-reporting by veterinarians in some areas. It would be interesting to see to what extent the completeness for all cases of CM (study I) is affected by geographic region. The number of veterinarians providing health care for dairy cattle is limited in all four Nordic countries. If some or all veterinarians in a local area or region under-report this will impact on completeness and veterinary-registered incidence rates. Under-ascertainment of CM (or any disease) that varies between areas will lead to differential misclassification; cows in some areas appear healthier than they are.

The code used by the veterinarian to record an event will affect the incidence of specific diseases in the central cattle databases. Danish veterinarians serving herds in DNHH were found to adopt their scoring of metritis to cow- and herd-characteristics, their own experiences and external factors such as the common strategy within the practice. The scoring was not consistent within or between herds (Lastein *et al.*, 2009). In a Swedish study on sensitivity of diagnostic coding in human primary care, diagnoses with clearly defined diagnostic criteria had higher sensitivity (i.e. completeness using our terminology) compared to more complex diagnoses (Hjerpe *et al.*, 2010). It has also been shown that conditions with clear diagnostic criteria tend to be better recorded than conditions with subjective criteria (Jordan *et al.*, 2004). The diagnosis CM is made based on clinical signs (International Dairy Federation, 1999), and should be straightforward for a veterinarian, although the type of CM, e.g. in SE (Table 1) might be incorrect. A vast majority of Norwegian veterinarians correctly identified cases of CM in a questionnaire-based survey, but some subclinical mastitis cases were classified as CM (Sviland & Waage, 2000). One objective of the ongoing behavioural study for veterinarians within DAHREVA is to compare treatment decisions for MCM among Nordic dairy practitioners.

5.4 Do farmers and veterinarians value disease data?

Farmers in the Nordic countries receive regular reports on disease occurrence in their own herd based on data from the cattle databases. If the disease recording process is unsuccessful, farmers should note a discrepancy between the cases actually attended by a veterinarian and the herd report. One may argue that a way to improve the recording would be if farmers express their interest in having complete disease data to their veterinarians. If a farmer values disease data, he/she also has the opportunity to do the recording him-/herself. This route is, however, sparsely used in SE.

DK had the most complete disease data for CM (study I). The completeness for veterinary-visited cases (0.90 and 0.94 for cases from the FRD and the adjusted FRD) was higher than the results 0.79-0.85 (years 1998-2001) by Bennedsgaard (2003) who compared veterinary diaries and herds' treatment records against the information in the database, i.e. at a later step in the information flow, similar to study III. The average herd-size in DK has increased, from 66 cows in year 2000 to 126 in 2008 (Danish Cattle Federation, 2009) and is by far the largest in the Nordic countries. An increasing herd-size may have lead to an increased need for routines, computerised management systems etc. where the use of disease data is a part. Possibly, the monthly herd health visits, or even more frequently for herds in DNHH, has brought disease recording under attention because the data are actually used by farmers and practitioners.

In FI on the other hand, the under-recording of CM cases treated with drugs prescribed by phone (study I) suggest that disease data, at least for CM, are not regarded as important. Already in the early 80's it was noted that about two thirds of CM cases were treated with phone prescriptions and that the recording of such cases was insufficient (Gröhn *et al.*, 1986; Saloniemi, 1980).

The veterinarian's record-writing, and in SE, the submission of the records, is a crucial step for successful disease recording. Nevertheless, the results presented in this thesis indicate that veterinarians, as a group, could perform better. In study I, the veterinary-visited completeness was less than 100%. A part of this could be attributed to other, later steps, in the recording process, e.g. unsuccessful entry in the cattle database. Nevertheless, in SE the random effect of veterinarian accounted for 35% of the variation in completeness of diagnostic events (study III). Under-reporting of CM was suggested in some areas in Sweden (study IV). These results raise the question if and why some (Swedish) veterinarians do not value valid disease data.

Swedish veterinarians are already by law required to report all treated animals to the Swedish Board of Agriculture. Disease records could potentially be used for quality assurance purposes, for a veterinarian or practice, with respect to incidence of cattle diagnoses and treatments. If the incidence of diagnoses and/or treatment is high overall or for certain diagnoses, this could be a reason to investigate diagnostic- and treatment criteria used in the practice. There is, however, no regular feed-back to cattle practitioners of e.g. frequency of recorded diagnoses compared to other veterinarians in the same or other districts.

In NO, the recording system was updated in mid-2008 and now allows electronic submission of disease data directly by the attending veterinarian. Similarly, FI has launched a new internet-based recording system in 2008 (NASEVA) where the veterinarians and farmer can record and submit electronically to the database. It would be interesting to study whether these changes in the recording process in NO and FI have increased the completeness of veterinary-visited CM cases and other diagnoses.

5.5 Evaluation of farmer performance

In study I the disease occurrence, as observed and recorded by the study farmers, was used as the gold standard against which the disease data in CODD were to be compared. It was beyond the scope of this thesis to study to what extent there was a variation between or within countries in the farmers' ability to detect disease. However, CM is a common clinical diagnosis with impact on milk production which is a motivation for farmers to detect new cases.

However, the threshold for detection will inevitably vary between dairy producers. If study herds are representative of the target population and farmer's detection behaviour did not change because of the participation in the study, it should still reflect what the disease recording systems normally captures. But if the participating farmers were not representative of the target population or did not record all detected cases this introduces bias.

To what extent the farmers actually recorded all observed cases of clinical disease in their dairy cows is important; if farmers in the different countries, i.e. the groups we want to compare, recorded to the FRD with different intensity, observation bias will be present, which leads to poor internal validity. The farmers' recording to the FRD in relation to their detection ability was not validated. Assuring that the FRD was a true reflection of the observable disease burden would have improved the validity of the study.

One indication of observation bias was the number of excess CM cases in the CODD after matching to the FRD, suggesting poor compliance with the study instructions by, in particular, the Danish farmers. A large difference between FRD and adjusted FRD also raises concern about the amount of CM cases neither in CODD nor recorded by farmers in the FRD. The completeness for all CM cases was lower when including only good study reporters (Table 3, study I), although the difference was significant only in DK. If there were many CM cases missing in the FRD or the CODD, the completeness for all CM cases will have been overestimated and the IRs will have been underestimated. In a Swedish validation study, farmers recorded only 88% of the disease events that were found in the central cattle database (Mork *et al.*, 2009a). The reason for under-recording by study farmers could be the length of the study period; in total four months when every clinical disease in the dairy cows should be recorded. Another possible reason for under-recording is if the work was delegated to employees without proper instructions; a possibility that may increase with increasing herd size.

The questionnaire sent to all farmers at the end of the second study period included two questions on the farmers' self-rated performance, one for the Spring period and one for the Autumn period. The scale ranged from 1=extremely poor to 5=excellent. The median value (first and third quartile) was 3 (3,4), 4 (4,5), 4 (4,4) and 4 (4,5) for the Spring period and 3 (3,4), 4 (3,4), 4 (4,4) and 4 (4,5) for the Autumn period in DK, FI, NO and SE, respectively. This indicates that the Danish farmers were indeed less content with their recording to the FRD, which is consistent with the main conclusions from study I.

Further, participation in the study could have affected the herdsmen to change their behaviour (and detect more disease cases) and/or veterinarians to improve recording; the farmers were neither encouraged nor prohibited to discuss their participation in the study with their veterinarian. One way such a change could have been assessed would have been by comparison of disease frequency before, during and after the study periods.

5.6 Representativeness of study populations

The percentage of invited herds that actively participated in study I was low, particularly in DK. The representativeness of the study populations was investigated, e.g. by comparison of production parameters (Table 1, study I). The results do not contradict that the study herds were representative. This is, however, not a guarantee that selection bias was not present. The participating farmer might, for example, have had a special interest in disease recording and the data generated. Or, the farmers that did not accept the invitation could have been those where disease recording, to a higher extent, was unsatisfactory. In a Danish study the authors chose three counties, known for superior disease reporting. Nevertheless, approx. 350 of 2146 dairy herds were found to have an inadequate reporting of mastitis (Bartlett *et al.*, 2001). The completeness estimate for veterinary-treated CM in DK in this study (0.94, CI 0.92-0.97) does not agree with Bartlett's findings, which supports that it may be overestimated. The presence of selection bias in study I would reduce the external validity of the study, i.e. to what extent the results can be generalized to the target population.

In study II the response rate was approx 50% in all four countries which, considering the length of the questionnaire, should be regarded as good. Nevertheless, the question regarding selection bias is equally valid here; if the responders as a group differed from non-responders the results are not applicable to the whole population.

In study III, 28% of the invited farmers accepted the invitation to participate and fulfilled the inclusion criteria. The receipt copies that were collected from the study herds were already in the farmer possession when he/she accepted to participate, hence the recording itself could not have been influenced by study participation. Moreover, the median number of veterinarians per herd was 4, and the total number of veterinarians was 155 out of approximately 450 in all, with any cattle practice at that time. Consequently, study III was done with a good representation of the Swedish veterinary population (i.e. the reporting behavior of approximately 30% of all veterinarians were covered). In other words, as the veterinarian's reporting behaviour has been identified as an important step in the recording process in SE, the study is likely to have a fair external validity even if the response rate of farmers was not very high.

Study IV was basically a census of all herds in the target population minus herds that were not geo-referenced, or situated in the far North of Sweden, and herds that had either discontinued milk production or left the milk recording scheme and i.e. were not longer in the target population.

One inclusion criteria for study I and II was an average herd size of at least 15 cow-years. Such a limit was judged as necessary because farmers with smaller herds were hypothesised to differ from colleagues with larger herds concerning their threshold for treatment of disease. It has previously been shown that herds in NO with 15 cows or less have a higher incidence of CM than larger herds (Sviland & Waage, 2002). The choice of 15 cows or more was a compromise between excluding smaller herds and including enough herds for the results to be interesting and applicable in each country. In DK and SE there were few herds with less than 15 cows.

The Swedish studies (III and IV) had an inclusion criterion of 25 cows or more. Herds with fewer cows were expected to contribute with few disease cases (III) or the herd incidence of CM would be more variable because of random variation (IV). In the milk recording year 2008 17% of the herds had <25 cows, and they held 5% of the cows, and these numbers are decreasing, year after year (Swedish Dairy Association, 2011).

5.7 Study design

The DAHREVA project is mainly concerned with clinical disease events in individual cows. Any treatments of CM cases are, in the Nordic countries, to be recorded at the individual animal level. The diagnosis CM can be made based on clinical signs, bacteriological results or using a SCC cut-off. However, the disease recording systems are based on the clinical diagnosis which is why only the diagnosis based on clinical signs was used in this evaluation of the recording systems.

In study I the farmer-recorded disease case was the standard used for evaluation of completeness in the central databases. This standard is, however, not perfect as there is an inherent risk of incomplete recording and/or misunderstandings. In contrast, study IV used an alternative measure of udder health based on SCC, which is to be regarded as more objective.

If the FRD had been ground-proofed by a researcher, i.e. if an on-herd control had been implemented to confirm that recorded disease events were true and verifying that cows without recorded disease event were clinically healthy, there would have been no excess disease cases in the CODD and no need for the adjusted FRD. This would have allowed calculation of correctness and hence a full estimate of the accuracy of the CODD as recommended by Hogan and Wagner (1997). However, this was beyond the resources of the project.

Still, the approach with farmers recording disease is suitable for studies on dairy cattle since animals are clustered in herds, and when focus is on more common disorders. A sufficiently large number of disease cases can then be achieved with a sample of herds (farmers) that is still possible to manage practically. The farmer is as close to the diseased cow, i.e. the 'true gold standard', as is possible without more intensive monitoring of the cows.

An alternative application of the Theory of Planned Behaviour in study II could have been by interviews or focus group discussions. However, because one objective was to compare behaviour between countries, a quantitative approached was desirable, i.e. resulting in a number that could be subject to comparison. The TPB does not perfectly predict behaviour; for example moral, habits or self-identity are not taken into account (Burton, 2004). It does however provide a structured approach to behavioural studies for researchers from other areas than social science.

In study III, a standard method for validation studies was used; comparison of medical records against observations in a database. Since sampling was made at record-level, the completeness of records, cases and diagnostic events in the database could be assessed.

5.8 Cross-country studies

To our knowledge, this is the first cross-country validation of animal disease recording systems. One of the challenges in the project has been the lack of a common native language. For instance, for practical reasons, study III was made within each country instead of across countries, like study I, as it was not considered possible to read copies of veterinary records (receipts left at farm or cow cards) in a non-native language. To manage the language barrier all critical project documents, e.g. instructions and information to farmers, were first written in English and thereafter translated to the four languages. For study II it was particularly important to ensure a high degree of comparability of statements. Therefore, the questionnaires were both translated and back-translated into English so that any value differences in the choice of words would be detected.

To perform data collection identically in four countries was also a challenge, and practical compromises had to be made, e.g. the frequency of reminders. The beliefs finally included in the study II questionnaire were also a compromise; it was not possible to accommodate all beliefs from all countries in the final questionnaire.

The fact that four persons were responsible for data entering and for the first editing in study I and II meant that every decision made had to be discussed and documented. This procedure was highly time-consuming but had the advantage that all considerations were thoroughly discussed and possibly led to fewer mistakes.

6 Main conclusions

The disease recording systems in the Nordic countries do not manage to capture all cases of farmer-detected CM. This is partly by design, as the systems are based primarily on registration of veterinary-attended disease cases. However, although all veterinary-visited CM cases should, in theory, be captured, this was not the case. The proportion of farmer-detected and veterinary-visited CM cases that could be found in the central cattle database differed between the countries with the highest proportion in DK, the lowest in FI and with NO and SE in between. This difference in completeness may lead to differential misclassification when data on CM occurrence are used for between-country comparisons.

The incidence rate for veterinary-visited CM (as reported by farmers) was highest in DK and lowest in SE. In FI, this was significantly higher than based on cases recorded in the central cattle database (in the sampled herds).

In DK and NO, the behavioural intention to contact a veterinarian the same day for a case of MCM was higher compared to in SE. In FI, behavioural intention to contact a veterinarian was very low; instead the intention to take a milk sample and send for analysis was high. These differences in behavioural intention are likely to affect the incidence of recorded CM. The most important drivers to perform the behaviour were that the action would lead to a quicker recovery of the cow, prevent the cow from having a blind teat and contribute to a healthy herd. In DK, NO and SE preventing a reduced milk yield during the rest of the lactation was also important.

In SE, the proportion of veterinary-visited diagnostic events (all diagnoses) in herd receipts that were also found in the central database was 0.75, i.e. under-reporting was present. The under-reporting of veterinary-visited diagnostic events varied between veterinary employment type, geographical region and disease complex.

In SE, there were geographical areas with significantly higher or lower spatial odds for veterinary-registered CM. These areas did not fully match the geographical distribution of cows with poor udder health, as measured by a SCC-based index. This suggests that under-reporting by veterinarians was present in some areas.

7 Future research and development

Differences in completeness were shown to be partly attributed to what farmers regard as sick, i.e. in need of veterinary attention. This in turn is likely to be influenced by what farmers regard as ‘disease’. Farmers’ disease definitions may vary, e.g. due to tradition. This calls for further research.

How farmers’ treatment behaviour and attitudes are influenced by herd factors, e.g. BMSCC and herd-size, and farmer characteristics, e.g. age and educational level, should be further studied.

Treatment strategies promoted by veterinarians are likely to influence farmer treatment decision. The education at the four Nordic veterinary schools could be compared and harmonisation of diagnostic and treatment criteria made, where relevant. The treatment and management strategies promoted should be evidence-based.

In DK, the behaviour regarding treatment of MCM for farmers in DNHH is currently being studied. However, the effect of farmer access to antibiotics on disease incidence should be studied in general, not only for MCM. If farmers with permission to initiate antibiotic treatment themselves are more prone to do so, in comparison with farmers who have to arrange a veterinary visit to have the cow treated, the access to antibiotics may both increase the registered disease occurrence and lead to increased treatment, possibly over-treatment, of clinical and subclinical disease. Moreover, the quality of disease data from this group of farmers should be validated.

In FI and NO, the effect of recent changes to the recording systems, i.e. the fact that veterinarians and farmers can now report directly to the database, on completeness should be studied.

The disease recording systems include a large part of the Nordic dairy populations and are already used to monitor disease occurrence at the herd-level, mainly for management purposes. If recording is timely, and without too large geographical 'blind spots', for all or certain diagnoses, they could possibly serve as an early warning system for emerging disorders or changes in occurrence of endemic disease. The usefulness of the data in this respect should be further studied.

In FI, action should be taken to improve the recording of diagnoses when cows are treated after phone prescriptions of antibiotics.

Disease records could potentially be used for quality assurance purposes by veterinary practitioners. For example, if the incidence of disease is high overall or for certain diagnoses, this could be a reason to investigate diagnostic criteria and treatment regimen, e.g. use of antibiotics, in the practice. Such use of the data could be promoted as a reason for veterinarians to improve their disease recording, but studies on the usefulness or validity of such quality assurance is first needed.

In SE, one major reason for lack of completeness was unsatisfactory reporting by veterinarians. Improving the reporting by, in particular, private veterinarians would improve the completeness. Studies on factors that may motivate veterinarians are therefore advocated.

8 Populärvetenskaplig sammanfattning

8.1 Bakgrund

Inom modern och hållbar mjölkproduktion är ett gott hälsoläge ett självklart mål. För att uppnå det behöver man tillgång till information om sjukdomsförekomst så att hälsan hos enskilda djur och resultat av förebyggande hälsoarbete kan följas upp. I de nordiska länderna Danmark (DK), Finland (FI), Norge (NO) och Sverige (SE) finns sedan flera decennier system för sjukdomsregistrering hos mjölkkor. Det unika med dessa system är att de dels inkluderar en stor del av mjölkkopopulationen och att registreringar görs på individnivå så att det går att koppla sjukdomsuppgifter till provmjölkningsresultat, slaktdata, reproduktionsdata, uppgifter från kalvningar m.fl. data som finns i de olika ländernas kodatabaser. Uppgifter om vilka individer som är diagnosticerade med sjukdom och när, och olika mått på sjukdomsförekomst på besättningsnivå används av mjölkproducenter, i rådgivningsarbete, i avelsarbete, för statistik och för forskning.

För epidemiologisk forskning är tillgång på sekundära data, dvs. data som ursprungligen är insamlade för ett annat syfte, en viktig resurs, eftersom primär datainsamling är tidskrävande och kostsam. För att kunna utnyttja sådana sekundära data bör dessa inkludera en stor del av den population man vill kunna uttala sig om och vara av god kvalité. De nordiska ländernas sjukdata för mjölkkor uppfyller det första kravet men kvalitén behöver kontrolleras. För det svenska systemet har ett sådant valideringsarbete redan påbörjats, och i NO och DK har enstaka mindre studier genomförts.

Registreringsprocessen för sjukdata börjar med att lantbrukaren upptäcker sjukdom hos kon och beslutar sig för att kontakta veterinär. I de nordiska länderna får lantbrukare inte själva starta behandling med receptbelagda läkemedel (ex antibiotika) av nötkreatur utan djuret måste först undersökas kliniskt av en veterinär. Veterinären journalför diagnos, behandling mm. Informationen överförs till respektive lands centrala databas av veterinär, lantbrukare, rådgivare eller semintekniker beroende på land och besättning. I DK kan lantbrukare upprätta ett särskilt avtal med sin besättningsveterinär och få rätt att starta behandling med läkemedel för vissa sjukdomar. Veterinären gör då planerade besök varje till varannan vecka beroende på besättningens storlek och hälsoläge. I FI är det för milda fall av klinisk mastit (MKM) praxis att lantbrukaren först själv tar ett mjölkprov och skickar för bakteriologisk analys. När resultaten är klara kontaktar lantbrukaren veterinär för bedömning av resultaten. Veterinären kan då förskriva antibiotika för lokalt bruk utan att först undersöka kon. I dessa fall är det djurägaren som ska registrera diagnos och behandling på kokortet.

Vid tidigare jämförelser av registrerad sjukdomsförekomst, baserat på uppgifter från respektive lands Kokontroll, så har skillnader mellan de nordiska länderna konstaterats. Dessa skillnader har inte gått att helt förklara med exempelvis olikheter i åldersstruktur eller ras hos korna. Istället har hypotesen varit att det finns olikheter i själva registreringsprocessen, dvs. att de olika systemen skiljer sig åt i sin förmåga att fånga veterinärbehandlade sjukdomsfall.

Om sjukdata har dålig täckningsgrad, dvs. om många sjukdomsfall missas, underskattas sjukdomsförekomsten i populationen. Om sjukdomsförekomst jämförs mellan olika grupper, där sjukdata har olika täckningsgrad, finns risk för en felaktig jämförelse mellan grupperna och att betydelsen av andra faktorer för sjukdomsförekomst underskattas eller feltolkas.

År 2007 påbörjades ett samnordiskt projekt (DAHREVA) med det övergripande målet att utvärdera kvalitén på sjukdata för mjölkkor i de nordiska länderna. I projektet deltar DK, FI, NO och SE. Projektet inkluderar sjukdomskomplexen hälta, metabola respektive reproduktionsstörningar samt klinisk mastit (juverinflammation, här förkortat KM). Studierna i denna avhandling har särskilt fokus på KM, som är vanligt förekommande hos mjölkkor och orsakar stora direkta och indirekta kostnader för lantbrukaren.

8.2 Genomförda studier

Syftet med den första studien var att uppskatta täckningsgraden för sjukdata, alltså vilken proportion av de mastitfall som upptäcks av lantbrukarna som också återfinns i respektive lands databas. I varje land registrerade mjölkproducenter alla kliniskt sjuka kor under totalt fyra månader. Dessa data jämfördes sedan med besättningarnas sjukdata från respektive lands kodatabas. Täckningsgraden beräknades både för alla fall av KM och för veterinärbehandlade fall av KM, dvs. de som per definition ska vara registrerade i databasen (tabell

3, studie I). I DK, FI, NO och SE var täckningsgraden för veterinärbehandlade fall av KM 0,94, 0,56, 0,82 respektive 0,78. Den var statistiskt signifikant högre i DK och lägre i FI.

Vidare beräknades incidensrater (IR) för både veterinärbehandlade fall och för alla fall av lantbrukarregistrerad KM, samt för de KM som fanns registrerade i databaserna (tabell 4, studie I). I DK, FI, NO och SE var IR för veterinärbehandlad (enligt lantbrukaren) KM 39,4, 34,4, 27,9, och 22,2 fall per 100 koår. I SE och NO var denna IR signifikant lägre än i DK, i SE även signifikant lägre än i FI. Dessutom var denna IR i FI signifikant högre än vad som var registrerat i databasen.

I den andra studien undersöktes om det fanns skillnader i lantbrukarnas benägenhet att kontakta veterinär, vilket (i praktiken) utgör det första och nödvändiga steget för att ett sjukdomsfall ska registreras i databasen. En enkät baserad på en social-psykologisk modell (TPB) utvecklades. Enligt TPB så finns ett starkt samband mellan en persons beteende och intentionen att utföra ett visst beteende. Intentionen i sin tur bestäms av de tre psykologiska begreppen attityd, subjektiv norm och upplevd kontroll över beteendet. Beteendet som definierades i denna studie var att kontakta veterinär (i FI att ta ett mjölkprov och skicka för bakteriologisk analys) samma dag lantbrukaren upptäcker ett fall av mild KM. Lantbrukarna i SE hade signifikant lägre intention att tillkalla veterinär vid en mild KM jämfört med lantbrukarna i DK och NO. I landsvisa analyser förklarade attityd den största delen av intentionen, medan subjektiv norm och upplevd kontroll över beteendet förklarade mindre delar.

I Sverige studerades informationsflödet från ett veterinärbehandlat djur till kodatabasen i detalj (studie III). Journalkopior samlades in från lantbrukare. Data från dessa jämfördes mot sjukdata i kodatabasen, dels råsjukdata från Jordbruksverket, dit veterinärer rapporterar sina sjukdata, och dels mot sjukdata i kodatabasen, efter att data kodats om till Svensk Mjölks interna diagnoskoder. Täckningsgraden beräknades som andelen journalkopior vars uppgifter återfanns i databasen. För diagnoser var täckningsgraden 0,84 i råsjukdata och 0,75 i sjukdata. För sjukdata fanns skillnader i täckningsgrad mellan sjukdomskomplex, geografisk region och mellan privata och statligt anställda veterinärer men den enskilda veterinären stod för en stor del av variationen.

Den fjärde studien inkluderade alla svenska besättningar i Kokontrollen med minst 25 årskor och med tillgängliga geografiska koordinater. Data på besättningsnivå (nyckeltal) för 2008/9 användes. Med hjälp av metoder från spatial epidemiologi beräknades chansen (oddset) för veterinärregistrerade KM i olika områden i Sverige. Områden med signifikant högre eller lägre odds identifierades och jämfördes mot den geografiska distributionen av en indikator för juverhälsa (antal kor med juverhälsoklass 6-9). Jämförelsen visade att det i vissa områden i Sverige finns färre eller fler veterinärregistrerade KM än vad man kan förvänta sig i förhållande till det allmänna juverhälsoläget i området. Det beror antingen på att sjukdomsrapporteringen inte fungerat eller på olika behandlingsstrategier för KM.

Skillnader i täckningsgrad förklarar en del av landsskillnaderna i förekomst av registrerad KM. I Sverige fanns även skillnader mellan sjukdomskomplex, geografiska regioner och mellan privata och statligt anställda veterinärer. En del av landsskillnaderna förklaras också av skillnader i intention och attityd till behandling av KM.

Ett system för sjukdomsregistrering som till stor del baseras på (veterinär-) behandlingar kan inte förväntas fånga upp alla fall av klinisk sjukdom – alla djur behöver inte behandlas på ett sätt som involverar veterinär. Ett ämne för framtida studier är vad mjölkproducenter egentligen definierar som sjukdom respektive sjukdom nödvändig att behandla.

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Acknowledgements

This work was carried out at the Division of Ruminant Medicine and Veterinary Epidemiology, Department of Clinical Sciences, Swedish University of Agricultural Sciences. Funding for the project was provided by the Swedish research council FORMAS.

This thesis would not have been possible without the help and support from many people. I would like to thank all of you and in particular:

First of all my three fantastic supervisors:

Professor Agneta Egenvall, main supervisor, for always encouraging me and for giving me plenty of freedom in my work, for your honest answers and your good sense of humour.

Professor Ulf Emanuelson, the Swedish project leader of DAHREVA, for your professionalism in everything including supervision of PhD students, for being so kind and for always taking the time to answer questions on any topic no matter how full your schedule already is.

Associate professor Ann Lindberg, for always being full of ideas, for your optimism, and for your ability to explain even the most complicated issues in just a few simple statements.

My fellow DAHREVA PhD students and co-authors Ann-Kristina, Mari and Simo for all the good times and interesting discussions on both project related issues and not project related.... Ann-Kristina, for all the laughs and the last months lots of cheering. Mari, for your good eye for details and for your never-ending energy at numerous skype meetings. Simo, for joining the project and for asking ”does it really matter?” when most needed.

Associate professor Anna-Maija Virtala, project leader of DAHREVA, for excellent organisation of the project and for being so kind and helpful.

The Danish, Finnish and Norwegian supervisors in DAHREVA: Hans Houe, Olav Østerås, Peter Thomsen, Anna-Maija Virtala, Juhani Taponen, Olli Peltoniemi, and Annette Ersbøll, for good ideas, constructive feed-back and fruitful meetings.

Associate professor Mark Stevenson, for teaching me everything I know about spatial epidemiology and for accepting me as an intern at the EpiCentre, Massey University.

All the participating farmers in Denmark, Finland, Norway and Sweden.

The Swedish Dairy Association, the Danish Cattle Federation, the Finnish Agricultural Data Processing Centre Ltd, the Norwegian Cattle Health Services, the Norwegian Dairy Herd Recording System and the Swedish Board of Agriculture for providing access to data and for answers to the numerous questions from the DAHREVA PhD students.

Frøydis Hardeng, for help with setting up the DAHREVA project database which saved us PhD students months of work.

Mette Vaarst, for valuable advice on qualitative interviews and analysis techniques.

Jonna Oravainen, for giving the Finnish project a good start.

Marie Jansson Mörk, för att du lät avdelningens färskaste doktorand bli medförfattare, för ditt alltid goda humör, och för all hjälp.

Alla kollegor på IME, med avdelningschef Camilla Björkman, för att ni gör det kul att gå till jobbet!

Ivar Vågsholm för omtanke och goda råd.

Kerstin Mover-Berglund för alla timmar du lagt på att knappa in (sanslöst många) journalkopior och enkäter så att vi fick data att arbeta med.

The PhD students and the personnel at the EpiCentre for great hospitality and a nice atmosphere. A special thanks to my flat-mates Lesley and Anou!

Administrationen på institutionen för kliniska vetenskaper för smidigt hanterande av allt det där med fakturor, intyg, reseräkningar, kurspoäng…

Kjell-Åke Ahlin för datorhjälp, skrivarsupport och trevliga pratstunder i korridoren.

Personalen vid KC-biblioteket för god service.

Alla deltagare vid Epiforums träffar för intressanta diskussioner om mer eller mindre komplicerad epidemiologi.

Nuvarande och tidigare doktorander på IME: Ann N, Johanna P, Marie JM, Nils, Charlotte, Maria N, Lena, Anna, Emma, Malin, Karin, Cecilia L, Helena O, Jenna, Krister, Stefan W – det har varit roligt att doktorera ihop med er! Och alla andra doktorander på KV, särskilt Kia, Sara, Johanna L, Laki, Odd, Ingrid, Aldo, Oskar, Jonas, Frida och Jenny för trevligt sällskap på diverse kurser och äventyr.

Makarna Fall för renoveringssupport och för att jag får låna Ikka.

Oasen-grannarna Anna och Lena för alla skratt orsakade av ditt och datt. Lena för din stora klokhet och humor. Anna för att du alltid är full av smarta idéer och roliga historier och får mig att tänka utanför lådan.

Vännerna utanför jobbet som gör livet så mycket bättre. Särskilt Malin för din humor (och för att du förstår betydelsen av ett gott kaffe) och Helena för stödutfodring och för att du påminner mig om att njuta av delsegrarna.

Mor och bror för att ni alltid finns där.

Tack!