Validation of Disease Recordings in Swedish Dairy Cattle

Marie Jansson Mörk
Faculty of Veterinary Medicine and Animal Science
Department of Clinical Sciences
Uppsala

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Abstract

This thesis examines the completeness of the Swedish dairy disease recording system: it attempts to quantify how much disease the system's database captures relative to what farmers find and veterinarians treat. Two field studies were conducted. In the first, 177 farmers recorded information about disease events, regardless of whether the disease event had resulted in a veterinary visit. In the second, farm copies of veterinary records (851 records from 112 herds) were collected.

The proportion of disease events receiving veterinary treatment was estimated, and measures of disease incidence based on the farmers' data were compared with incidences estimated from the Dairy Disease Database (DDD). Further, the completeness of the DDD was estimated based on agreement between information in the DDD and farmer-reporting and herd-copies, respectively. Differential completeness was also evaluated. Finally, the probability of a successfully registered disease event for the whole disease recording process was estimated for five different disease complexes, based on the results of both field studies.

The overall completeness of veterinary treated disease events in the DDD was estimated to be 71% and 75%, based on the farmers' recordings and on the farm copies, respectively. Differential completeness linked to regions, veterinary employment type and between different groups of animals was found. The probability of a successfully registered disease event (regardless of veterinary treatment) in the DDD varied between 30% for diarrhoea and 72% for puerperal paresis. Whether or not the farmer contacted a veterinarian was found to be the most influential step in the recording process, followed by whether or not the disease record was registered in the raw data file at the Swedish Dairy Association.

Lack of completeness in the DDD will result in conservative disease incidence measures. Underreporting of veterinary treated disease events, as well as under-coverage of farmer-observed events, was found to vary depending on several factors which could introduce bias in estimates based on the DDD, which primarily is a problem if the data are used for epidemiologic research and less so for other areas.

Keywords: dairy cow, epidemiology, disease monitoring system, validity, completeness, sensitivity, differential misclassification, detectable

Author's address: Marie Jansson Mörk, Division of Ruminant Medicine and Epidemiology, Department of Clinical Sciences, Swedish University of Agricultural Sciences, P.O. Box 7054, SE-750 07 Uppsala, Sweden
E-mail: Marie.Mork@kv.slu.se

To my family

Contents

List of Publications

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

I Mörk, M., Lindberg, A., Alenius, S., Vågsholm, I. and Egenvall, A. (2009). Comparison between dairy cow disease incidence in data registered by farmers and in data from a disease-recording system based on veterinary reporting. *Preventive Veterinary Medicine* 88, 298-307.

II Jansson Mörk, M., Wolff, C., Lindberg, A., Vågsholm, I. and Egenvall, A. (2009). Validation of a national disease recording system for dairy cattle against veterinary practice records (Accepted).

III Jansson Mörk, M., Emanuelson, U., Lindberg, A., Vågsholm, I. and Egenvall, A. (2009). Herd and cow characteristics affecting the odds of veterinary treatment for disease – a multilevel analysis. *Acta Veterinaria Scandinavica* 51:34.

IV Jansson Mörk, M., Egenvall, A., Vågsholm, I. and Lindberg, A. Estimation of the diagnostic sensitivity of a disease recording database for dairy cattle – a scenario tree approach (Manuscript).

Papers I and III are reproduced with the permission of the publishers.

Abbreviations

CI	Confidence Interval
DDD	Dairy Disease Database
SBA	Swedish Board of Agriculture
SDA	Swedish Dairy Association
SOMRS	Swedish Official Milk Recording Scheme
VPC	Variance Partition Coefficient

General background

1.1 Data sources in observational studies

It is essential to reduce and prevent disease in production animals in order to have both an ethically defendable and economically profitable dairy production. The causal background of production-related diseases is often multi-factorial, i.e. many factors combine to trigger disease. To study the incidence or prevalence of production diseases as well as their causes, observational studies using population-based data need to be performed. Disease data used in observational studies are either collected for the purpose of research as primary data or retrieved from secondary data sources.

1.1.1 Primary data

Primary data – collected for a specific time period and on a sample of the population of interest – are often used to estimate the incidence or prevalence of diseases and to identify their risk factors. The advantage of primary data is that the researcher can control the data collection process; this gives the researcher knowledge of the data's quality. Numerous epidemiological studies based on random or convenience sampling of dairy herds and farmer and/or veterinary recordings of disease have been performed to estimate the incidence or prevalence of disease and risk factors at both herd and individual animal level (e.g. Barnouin *et al.*, 2005, Espejo *et al.*, 2006, Svensson *et al.*, 2006, Menendez *et al.*, 2008, Riekerink *et al.*, 2008). Further, in the National Animal Health Monitoring System in the USA, information on, for example, animal health, animal welfare and the impact of production animals on the environment have been recorded by livestock producers (Dargatz, 2009).

Although primary data retrieval is considered the most optimal method it has potential drawbacks. Examples of problems in primary data collection are poor response rate, loss to follow-up, non-representative study population (as some study populations are based on convenience samples and some farmers may be more likely to participate than others), over- or underreporting, and differences in farmers' definitions of disease (Roos *et al.*, 1987, Bartlett *et al.*, 1992, Elbers *et al.*, 1998, Barnouin *et al.*, 2005, Riekerink *et al.*, 2008). In human medicine, differences between responders and non-responders as well as the effect of non-response have been investigated. For example, De Melker *et al.* (2000) found that characteristics such as gender, age, marital status and type of reminder differed between responders and non-responders; of these, gender and age were likely to be associated with the outcome of interest (immunity to vaccine-preventable diseases). Further, Van Loon *et al.* (2003) found underestimation of the prevalence of smoking, of low physical activity and of bad subjective health due to differences between responders and non-responders.

1.1.2 Secondary data

Secondary databases holding data mainly collected for purposes other than research have also been used in observational studies. Such databases are interesting because they often contain individual person/animal data on a large proportion of a population. Other important factors are the savings in cost and time achieved when data are already available rather than being collected as primary data. Secondary databases may cover long periods of time, and the data may be easily accessible for research; and because primary data collection is not needed, studies based on secondary data can be relatively inexpensive. The major drawback is that the researchers lack control over the data collection process and, hence, also over data quality. (Problems with secondary data are described more thoroughly in Section 1.2.2).

National dairy disease recording systems operate in all of the Nordic countries with the exception of Iceland. They all rely mainly on the reporting of veterinary-treated disease events. The recording systems are described in Gröhn *et al.* (1984), Olsson *et al.* (2001), Sviland and Waage (2002), Bennedsgaard (2003), Gulliksen *et al.* (2009) and Wolff *et al.* (2009), among others. In brief, disease recording is compulsory in Sweden and compulsory for herds affiliated to heard health schemes in Denmark and Norway, while in Finland dairy farmers can choose whether to participate in recording (about 90% participated in 2008). Common to all countries is the rule that treatments with prescribed drugs should be preceded by a clinical examination by a veterinarian. There is an exception for Danish herds affiliated to the so called "New Herd Health Contract", under which the herds are regularly visited by a herd veterinarian and where, for certain diseases, the farmer is allowed to initiate treatments himself. In all recording systems, the animal's unique identity is the link between the disease data and other information such as production and fertility data. The ability to link disease data to other information at the individual animal level, in combination with a defined target population, makes data from these disease recording systems interesting for research purposes.

Another source of disease data, more commonly used in studies of small animals and horses, is that from animal insurance companies. These databases include information on both the diseased and healthy population (all insured animals before they had a claim). Information from a Swedish animal insurance database has been used to estimate mortality rates in dogs (Bonnett *et al.*, 2005) and the occurrence and mortality rates of colic in horses (Egenvall *et al.*, 2008), among other things. Another example is a study of the occurrence of neoplasia based on a population of insured dogs in the UK (Dobson *et al.*, 2002). Disease data are also recorded at veterinary practices and veterinary hospitals. These data sources have also been used in research, although one major drawback here is the undefined target population to which the disease data relate. One example is the National Animal Disease Information Service in the UK described by Laven and Lawrence (2006), a network of private veterinary practitioners and veterinary schools in the UK. Both individual disease events and outbreaks of disease are included in that database.

1.2 Data quality

1.2.1 Study validity

A study population comprises those individuals that are selected to participate in a study. The individuals in question are selected from the target population to which the results obtained should apply. External validity relates to whether the study results can be extrapolated to populations other than the target population. Internal validity is about the study's ability to measure what it sets out to measure, i.e. that the results represent an unbiased estimate of the true value in the target population. Delgado-Rodriguez and Llorca (2004) describes bias as "the lack of internal validity or incorrect assessment of the association between an exposure and an effect in the target population in which the statistic estimated has an expectation that does not equal the true value". Bias is often categorized into the following three groups (Thrusfield, 1995, Grimes and Schulz, 2002, Dohoo *et al.*, 2003, Delgado-Rodriguez and Llorca, 2004):

- *Selection bias* — May occur when the study population does not represent the target population in some important aspect.

- *Information bias* — Occurs during data collection. Also called observation-, misclassification- or measurement bias, it is a result of either the exposure or outcome, or both, being incorrectly measured. Information bias is differential when it is of different magnitude in the groups being compared and non-differential otherwise.

- *Confounding bias* — Occurs when the apparent effect of a factor is in fact an effect of another, often unmeasured, factor, known as the confounding factor. Confounding factors are associated with both the exposure and the outcome and precede both of these in the causal web.

1.2.2 Quality of databases

The practical use of secondary health data is dependent on the data quality, the ability to link individuals across datasets and the traceability of individuals through time (Roos *et al.*, 1987). Advantages of secondary data for research include the fact that contact with participating individuals is not needed (which saves time and costs), there is often good population coverage, large sample sizes are easily obtained, pre- and post history of the disease is available, long term follow-up is easy, and there is no reliance on individual recall. Some disadvantages that have been described are that the individual patient (or animal owner) decides whether to contact health care (and thus the early stages of disease are likely to be missed), that not all of the information sought is always reported, and that there may be inconsistency in recording patterns and difficulty distinguishing herds with missing records from herds with true low incidence (Roos *et al.*, 1987, Kadarmideen, 2002).

Validity measures are used to assess whether the data of interest measure what the researcher sets out to measure – i.e. whether the information is true. The accuracy of the information in a database can be described in terms of completeness and correctness (Hogan and Wagner, 1997). Other terms used to assess the quality of databases are sensitivity (equivalent to completeness), positive predictive value (equivalent to correctness) and agreement. Agreement is used to evaluate how similar information is when it derives from two sources of information, without necessarily estimating completeness or correctness. The relation between information in the database and true health state is shown in Table 1, where:

- *Completeness* The proportion of truly diseased animals that are correctly identified in the database (a/a+b).

- *Correctness* The proportion of animals with a reported disease event in the database that truly have the disease in question (a/a+c).

Specificity and the negative predictive value are seldom used to measure the accuracy of databases. In a disease database for which the base population is defined, animals that are not reported in the disease database are regarded as healthy.

Table 1. Relation between database information and true health state.

		Database		
		disease record present	disease record absent	Total
True health state	diseased	a (truly diseased)	b (falsely healthy)	a+b
	healthy	c (falsely diseased)	d (truly healthy)	c+d
		a+c	b+d	a+b+c+d

1.3 Validation studies

1.3.1 Human medicine

In human medicine, several validation studies have been performed on databases from general practices (e.g. Wurst *et al.*, 2007, Devine *et al.*, 2008), national health registers (e.g. Garne *et al.*, 1995, The National Board of Health and Welfare, 2004, Contiero *et al.*, 2008), and insurance companies (e.g. Barzilai *et al.*, 2004, Song *et al.*, 2008). The representativeness of general practices participating in the Research General Practice Network in the UK has also been evaluated (Hammersley *et al.*, 2002). The databases were evaluated against other relevant databases, medical records, questionnaires sent to the practitioners with questions about the diagnoses, tests and referral information that was used to diagnose, or whether the patient was referred to a specialist. Most databases were considered useful for research, but there were also some problems. Thus it was found that there was over-registration of some diagnoses that varied over time, differences in completeness for various diseases, changes in recording-policy, and a need for continuous validation of specific diagnoses.

1.3.2 Veterinary medicine

There are two recent validation studies of the Nordic dairy disease databases. Bennedsgaard (2003) evaluated the quality of the data registered in the Danish Cattle Database, stratified by year (1998-2001) against written information (from veterinarians or farmers) from 87 herds. The completeness of observations was 79-85% for cows and 34-48% for calves and young stock. Herd-specific completeness varied between 15-100% for cows and 0-100% for young animals. Disease data for calves in the Norwegian Cattle Health Recording System was validated against blood samples from diseased calves, records of dehorning (serving as indicators of a well-operating recording system) and feedback from the farmers on their degree of commitment to the study. The completeness of disease in calves in the Norwegian recording system was estimated to be approximately 60% (Gulliksen *et al.*, 2009). In the USA the National Animal Health Monitoring System used producers' reporting to obtain disease information from a representative sample of animal populations. The sensitivity and specificity of disease diagnoses, reported from one beef feedlot by the feedlots health crew, were estimated in 1985/86 (Salman *et al.*, 1988). The reports from the feedlot's health crew were compared with i) observations of the general appearance of one group of animals, ii) clinical evaluation of diseased animals (as reported by the feedlot crew), and iii) blood samples for serologic screening from both healthy and diseased animals. The sensitivities and specificities ranged between 18-100% and 76-99%, respectively. The authors concluded that the data collection approach used in the National Animal Health Monitoring System was adequate for estimating baseline animal health, but that diseases that were not economically important would be underestimated. Mulder *et al.* (1994) evaluated the quality of data from 70 herds recorded by a single veterinary practice in Canada in a routine reproductive health monitoring system. Based on the levels of errors, missing values and outlier values, the data quality was deemed acceptable for research. However, a potential bias resulting from missing observations was identified, because cows with complete records seemed to have poorer reproductive performance than cows with incomplete records.

Validations of pet insurance data have also been performed. Life claims and health claims reported in a Swedish insurance database have been validated against veterinary practice records. The sampled claims were assessed using information from the animals' practice records, which was either available in the claim's paper file or requested from the attending veterinarian. For cats and dogs the agreement with diagnostic information was 84% for health claims and 85% for life claims (Egenvall *et al.*, 1998). For horses, the agreement with diagnostic information was 85% for health claims and 83% for life claims (Penell *et al.*, 2007). In the validation of horse data, health claims resulting from veterinary clinic visits had a significantly higher level of agreement than claims from veterinary field visits (88% (95% confidence interval (CI) 84, 91) compared with 74% (95% CI 65, 81)). From the same insurance database the correctness of recorded events of canine atopic dermatitis was evaluated against practice records (Nødtvedt *et al.*, 2006). All dogs diagnosed as having canine atopic dermatitis were considered to have some allergic skin disease, but the number of dogs that were truly atopic could not be estimated. Depending on whether a conservative or liberal approach was used, the re-classification suggested a correctness of 41% or 84%, respectively, of the cases found atopic in the computerized insurance database. Further, from a Canadian veterinary hospital, computerized medical records have been evaluated against the information in the practice record (Pollari *et al.*, 1996). The intention was to study post-operative complications. However, the frequency of post-operative complications was found to be 4-7 times higher when estimated from paper records than it was when estimated from the computerized data, and the data were therefore considered unfit for the research purpose.

1.3.3 Usefulness of secondary databases

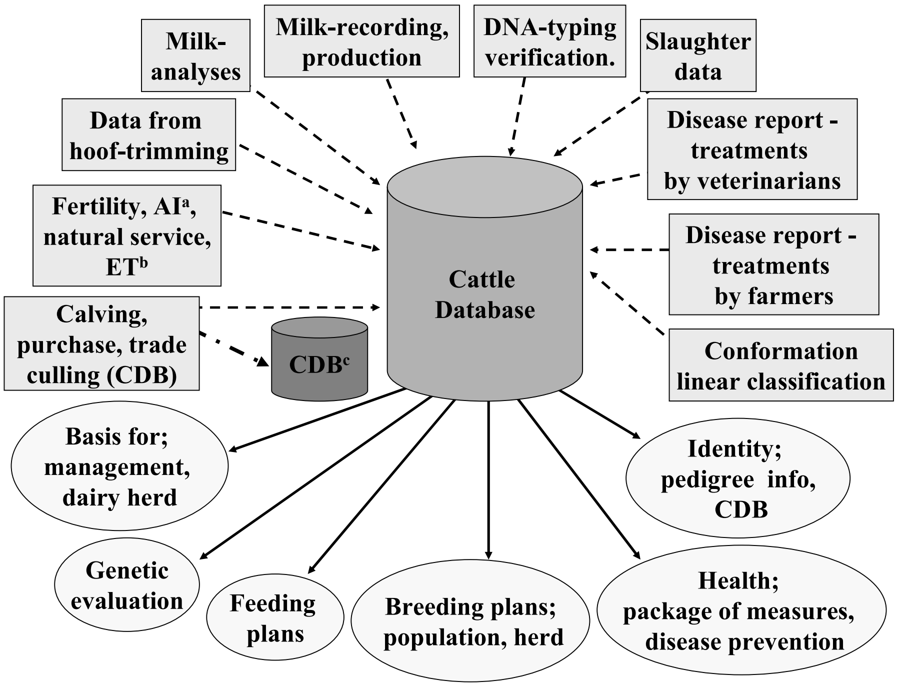
The usefulness of a secondary database, as mentioned above, depends on the accuracy of the data. Authors of previous validation studies in veterinary and human medicine have regarded an overall completeness, or agreement, in a disease database above 90% as high and 80-89 as fair whereas judgements for estimates below that are more varying (Salman *et al.*, 1988, Pollari *et al.*, 1996, Egenvall *et al.*, 1998, Barzilai *et al.*, 2004, Jordan *et al.*, 2004, Penell *et al.*, 2007). An estimated agreement of 59% was judged too low for the research intended by Pollari *et al.* (1996) although the data quality would have been sufficient for a study of mortality. On the other hand, an overall completeness of 60-70% was deemed acceptable in health information collected from beef feed lots in the National Animal Health Monitoring System operating in the USA (Salman *et al.*, 1988). Completeness of 75-80% was regarded as sufficient to monitor congenital malformations in the Swedish Registry of Congenital Malformations (The National Board of Health and Welfare, 2004). Hence, the criteria for deciding upon the usefulness of a database appear to depend on the kind of research being undertaken; they should be determined on a case by case basis given the specific objectives of the planned study.

1.4 Swedish dairy data recordings

1.4.1 The Swedish Official Milk Recording Scheme

The Swedish Official Milk Recording Scheme (SOMRS) is a voluntary service for dairy farmers (an equivalent of dairy herd improvement programs). For herds enrolled in the SOMRS, the Cattle Database at the Swedish Dairy Association (SDA) includes data on, for example, pedigree, cattle movements, disease events, production, fertility treatments and pregnancy examinations. Information in the Cattle Database is used for extension services, sire evaluation, annual statistics and research. The information flow in the database is visualized in Figure 1. Note that herds enrolled in the SOMRS can use the system for the compulsory reporting of births, deaths and cattle movements to the Central Animal Database at the Swedish Board of Agriculture (SBA), and thereby avoid double reporting.

In 2004, when the studies in this thesis were initiated, 7072 (80% of the Swedish dairy herds) dairy herds and 345,000 (86%) cows were enrolled in the SOMRS. In the same year, herds within the SOMRS had an average size of 47 cows and an average annual milk yield of 9177 kg energy corrected milk.



[a] Artificial Insemination, [b] Embryo Transfer, [c] Central Animal Database

Figure 1. Data flow in the Cattle Database at the Swedish Dairy Association (Nils-Erik Larsson, Swedish Dairy Association)

1.4.2 The Swedish dairy disease recording system

A national disease recording system in Sweden was set up in the 1980s with the aim of monitoring national- and herd disease status, including disease data in breeding goals and providing data for research (Emanuelson, 1988). The SBA is the authority responsible for the system. For veterinarians, the reporting of disease events in cattle to the SBA is compulsory (Swedish Board of Agriculture, 2000). During the years 2003/2004, the veterinary care for food animals in Sweden was delivered by approximately 350 state-employed veterinarians and approximately 100 private veterinarians with large animals (including food animals and horses) as their main practice (personal communication, Johan Beck-Friis, Swedish Veterinary Association). Sweden was (and still is) divided into 99 veterinary districts, half of which were served by state-employed veterinarians at the time of the studies in this thesis.

Disease events necessitating drug treatment are likely to be reported to a high degree, because drugs used in food animals require prescription (Swedish Medical Product Agency, 1997) and this should be preceded by medical examination of the animal (Swedish Board of Agriculture, 2006). Farmers are obliged to keep a record of the medical treatments at their farm for five years, including a copy of the veterinary medical record.

For dairy cattle, the information reported to the SBA includes: the herd identity number, the veterinarian's identity number, animal information (animal category receiving treatment (i.e. individual, group or herd) and sex and identity number when applicable) and case information (codes for diagnosis, type of treatment and prescribed medicine). The records can be either manual (handwritten) or computerized (examples are given in Figures 2-5). According to a questionnaire sent to cattle practicing veterinarians in 2005, computerized recording on the farm was used by ~84% of state-employed veterinarians and ~26% of private veterinarians (Mörk *et al.*, 2005). When the studies included in this thesis were conducted (in 2003 and 2004) most state-employed veterinarians reported through an in-house-developed computer software; those who wrote manual records on the farm later entered the information into the computerized reporting system (Mörk *et al.*, 2005). Private veterinarians could, and still can, either send manual records by regular mail or send electronic files to the SBA. The information on manual records is then scanned and entered into the database.

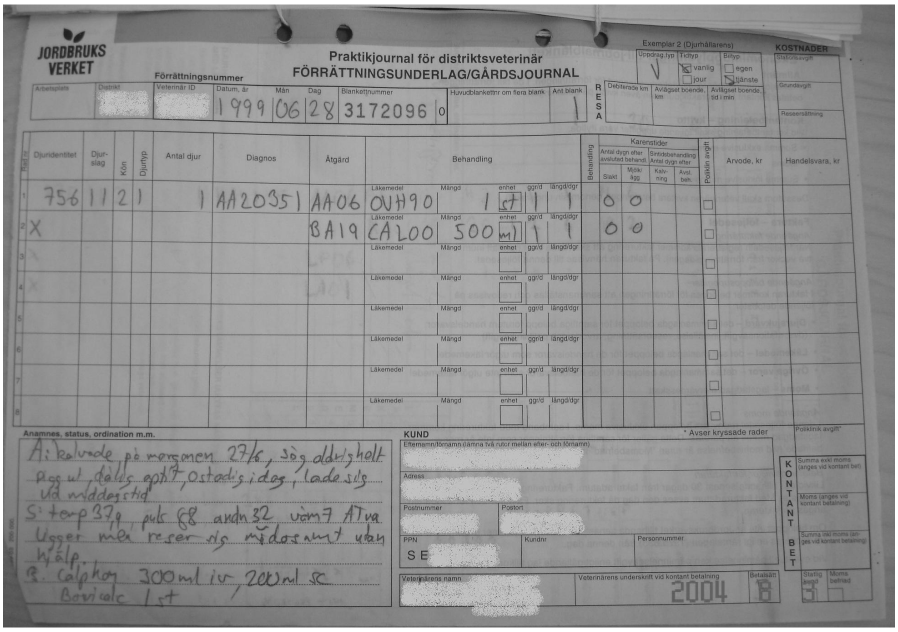
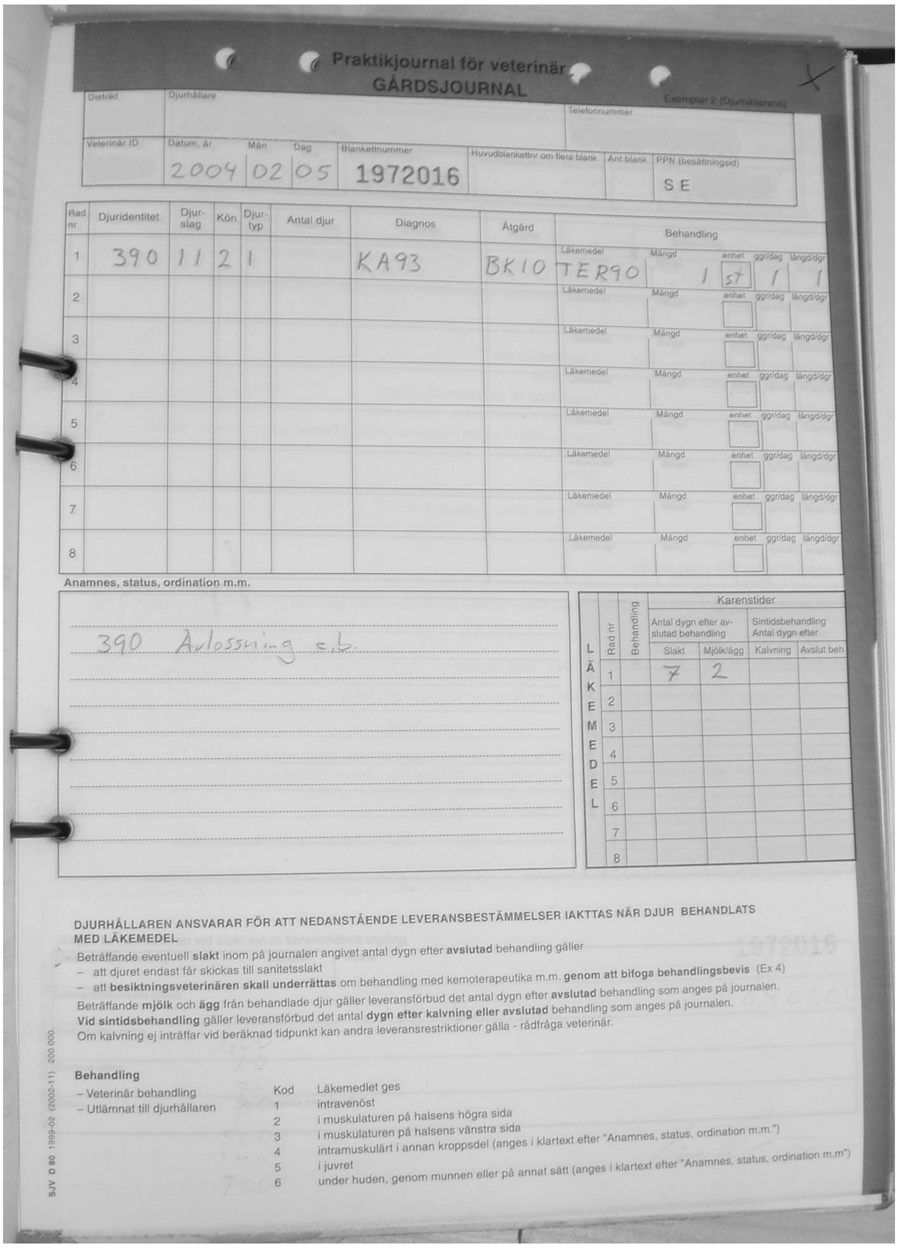


Figure 2. Example of a manual clinical record from a state-employed veterinarian.



Praktikjournal för veterinär
GÅRDSJOURNAL

Distrikt | Djurhållare | Exemplar 2 (Djurhållarens) | Telefonnummer

Veterinär ID | Datum, år 2004 | Mån 02 | Dag 05 | Blankettnummer 1972016 | Huvudblankettnr om flera blank | Ant blank | PPN (besättningsid) SE

Rad nr	Djuridentitet	Djur-slag	Kön	Djur-typ	Antal djur	Diagnos	Åtgärd	Behandling
1	390	11	2	1		KA93	BK10	Läkemedel TER90, Mängd 1, enhet st, ggr/dag 1, längd/dgr 1
2								Läkemedel, Mängd, enhet, ggr/dag, längd/dgr
3								Läkemedel, Mängd, enhet, ggr/dag, längd/dgr
4								Läkemedel, Mängd, enhet, ggr/dag, längd/dgr
5								Läkemedel, Mängd, enhet, ggr/dag, längd/dgr
6								Läkemedel, Mängd, enhet, ggr/dag, längd/dgr
7								Läkemedel, Mängd, enhet, ggr/dag, längd/dgr
8								Läkemedel, Mängd, enhet, ggr/dag, längd/dgr

Anamnes, status, ordination m.m.

390 Avlossning e.b.

LÄKEMEDEL — Karenstider

Rad nr	Behandling	Antal dygn efter avslutad behandling: Slakt	Mjölk/ägg	Sintidsbehandling Antal dygn efter: Kalvning	Avslut beh
1		7	2		
2					
3					
4					
5					
6					
7					
8					

DJURHÅLLAREN ANSVARAR FÖR ATT NEDANSTÅENDE LEVERANSBESTÄMMELSER IAKTTAS NÄR DJUR BEHANDLATS MED LÄKEMEDEL

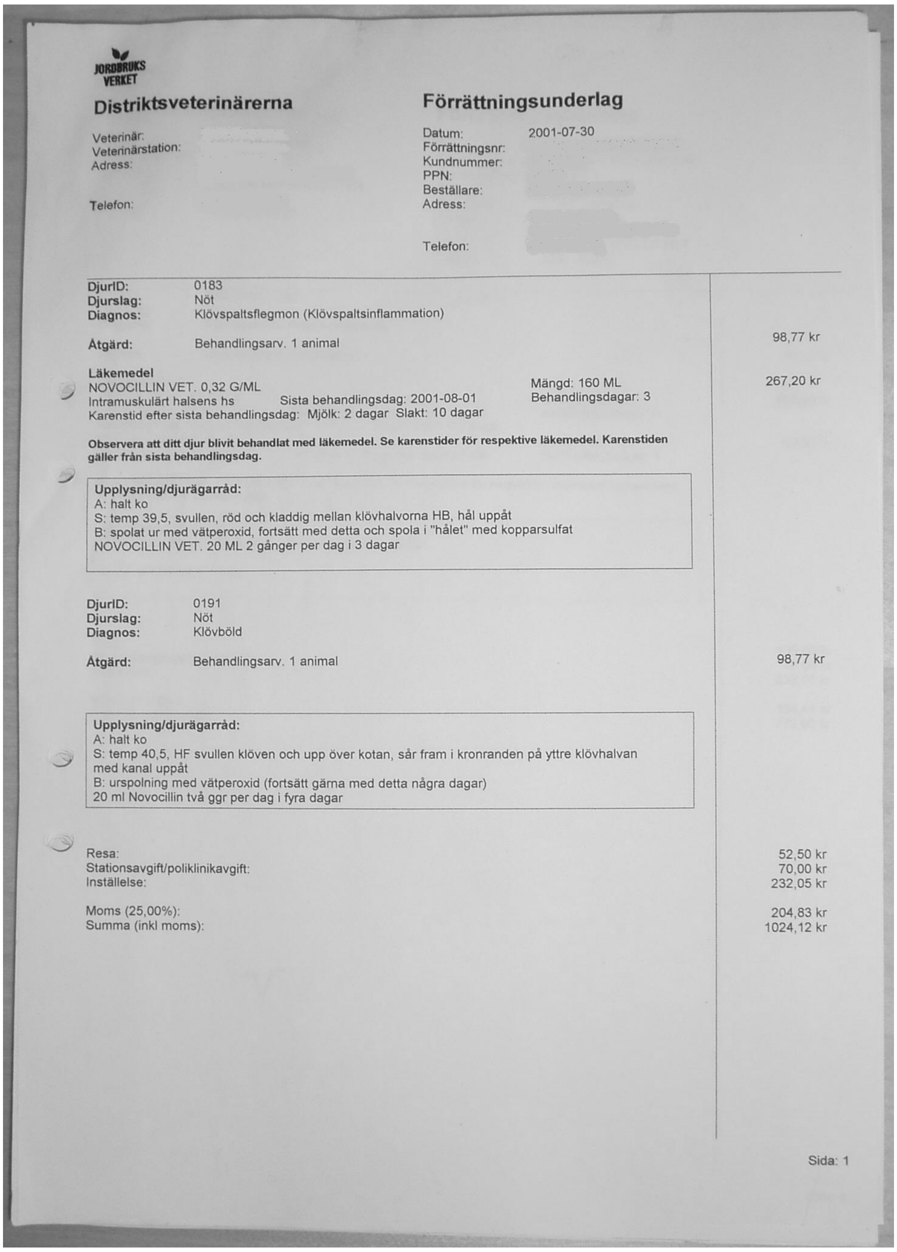
Beträffande eventuell **slakt** inom på journalen angivet antal dygn efter **avslutad** behandling gäller
– att djuret endast får skickas till sanitetsslakt
– att **besiktningsveterinären skall underrättas** om behandling med kemoterapeutika m.m. **genom att bifoga behandlingsbevis** (Ex 4)
Beträffande **mjölk** och **ägg** från behandlade djur gäller leveransförbud det antal dygn efter **avslutad** behandling som anges på journalen.
Vid sintidsbehandling gäller leveransförbud det antal **dygn efter kalvning eller avslutad** behandling som anges på journalen.
Om kalvning ej inträffar vid beräknad tidpunkt kan andra leveransrestriktioner gälla - rådfråga veterinär.

Behandling
– Veterinär behandling
– Utlämnat till djurhållaren

Kod	Läkemedlet ges
1	intravenöst
2	i muskulaturen på halsens högra sida
3	i muskulaturen på halsens vänstra sida
4	intramuskulärt i annan kroppsdel (anges i klartext efter "Anamnes, status, ordination m.m.")
5	i juvret
6	under huden, genom munnen eller på annat sätt (anges i klartext efter "Anamnes, status, ordination m.m")

SJV D 80 1999-02 (2002-11) 200 000

Figure 3. Example of a manual clinical record from a private veterinarian.



JORDBRUKSVERKET

Distriktsveterinärerna

Förrättningsunderlag

Veterinär:
Veterinärstation:
Adress:

Telefon:

Datum: 2001-07-30
Förrättningsnr:
Kundnummer:
PPN:
Beställare:
Adress:

Telefon:

DjurID: 0183
Djurslag: Nöt
Diagnos: Klövspaltsflegmon (Klövspaltsinflammation)

Åtgärd: Behandlingsarv. 1 animal — 98,77 kr

Läkemedel
NOVOCILLIN VET. 0,32 G/ML — Mängd: 160 ML — 267,20 kr
Intramuskulärt halsens hs — Sista behandlingsdag: 2001-08-01 — Behandlingsdagar: 3
Karenstid efter sista behandlingsdag: Mjölk: 2 dagar Slakt: 10 dagar

Observera att ditt djur blivit behandlat med läkemedel. Se karenstider för respektive läkemedel. Karenstiden gäller från sista behandlingsdag.

Upplysning/djurägarråd:
A: halt ko
S: temp 39,5, svullen, röd och kladdig mellan klövhalvorna HB, hål uppåt
B: spolat ur med vätperoxid, fortsätt med detta och spola i "hålet" med kopparsulfat
NOVOCILLIN VET. 20 ML 2 gånger per dag i 3 dagar

DjurID: 0191
Djurslag: Nöt
Diagnos: Klövböld

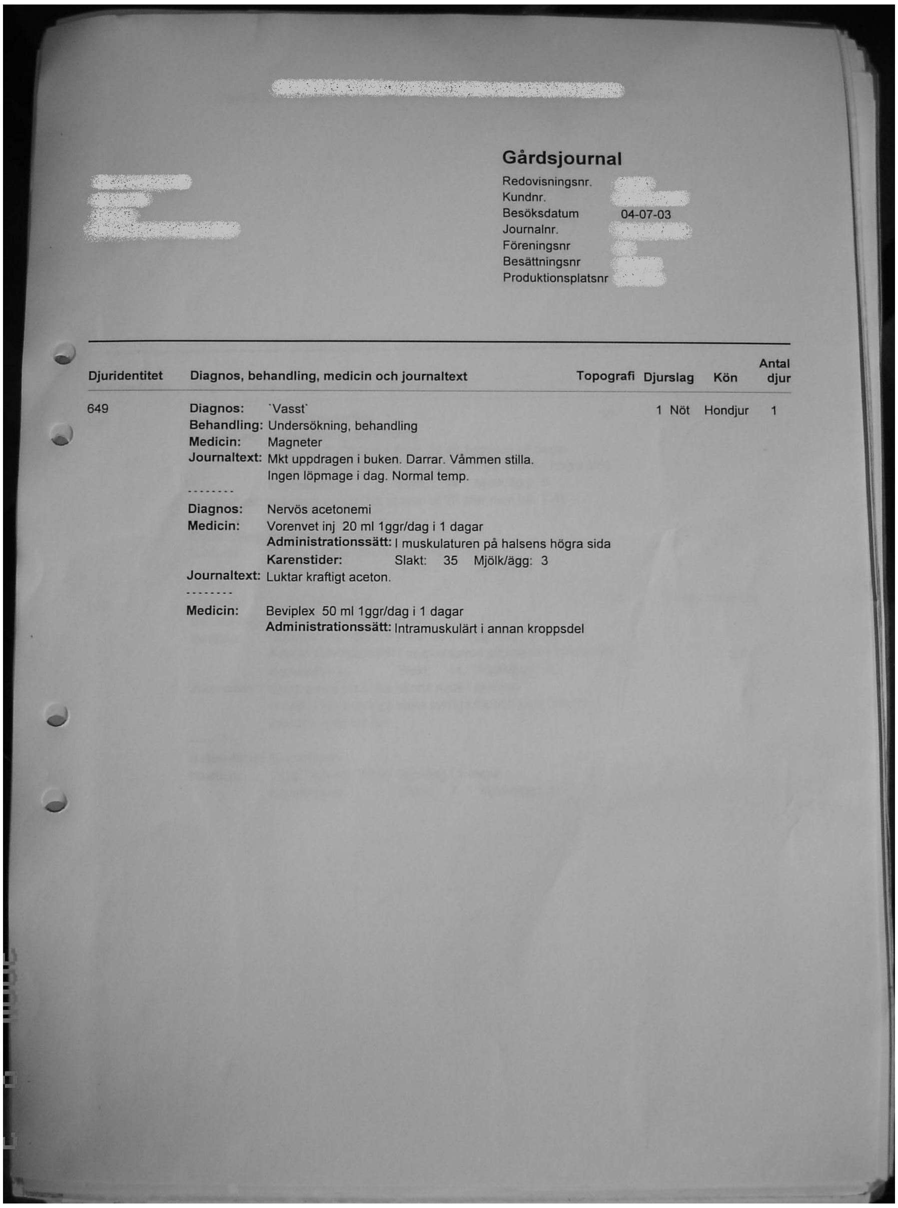
Åtgärd: Behandlingsarv. 1 animal — 98,77 kr

Upplysning/djurägarråd:
A: halt ko
S: temp 40,5, HF svullen klöven och upp över kotan, sår fram i kronranden på yttre klövhalvan med kanal uppåt
B: urspolning med vätperoxid (fortsätt gärna med detta några dagar)
20 ml Novocillin två ggr per dag i fyra dagar

Resa:	52,50 kr
Stationsavgift/poliklinikavgift:	70,00 kr
Inställelse:	232,05 kr
Moms (25,00%):	204,83 kr
Summa (inkl moms):	1024,12 kr

Sida: 1

Figure 4. Example of a computerized clinical record from a state-employed veterinarian.



Gårdsjournal

Redovisningsnr.
Kundnr.
Besöksdatum 04-07-03
Journalnr.
Föreningsnr
Besättningsnr
Produktionsplatsnr

Djuridentitet	Diagnos, behandling, medicin och journaltext	Topografi	Djurslag	Kön	Antal djur
649	**Diagnos:** \`Vasst\` **Behandling:** Undersökning, behandling **Medicin:** Magneter **Journaltext:** Mkt uppdragen i buken. Darrar. Våmmen stilla. Ingen löpmage i dag. Normal temp. -------- **Diagnos:** Nervös acetonemi **Medicin:** Vorenvet inj 20 ml 1ggr/dag i 1 dagar **Administrationssätt:** I muskulaturen på halsens högra sida **Karenstider:** Slakt: 35 Mjölk/ägg: 3 **Journaltext:** Luktar kraftigt aceton. -------- **Medicin:** Beviplex 50 ml 1ggr/dag i 1 dagar **Administrationssätt:** Intramuskulärt i annan kroppsdel		1 Nöt	Hondjur	1

Figure 5. Example of a computerized clinical record from a private veterinarian.

All disease records involving cattle are regularly transferred from the SBA to the SDA, where they are entered into the Cattle Database. During this transfer, the diagnostic codes are translated into other, less detailed, diagnoses through a conversion key so as to fit the structure of the data in the Cattle Database.

Farmers can also report disease events through the SOMRS, but this route is not extensively used. Of the 800 herds comprising the sampled population in the studies in this thesis, 165 (21%) had events that could not be related to a veterinary-reported event entered through the SOMRS. Of the reported events, 67% involved dry-cow therapy and 16% involved clinical mastitis. Of all herds enrolled in the SOMRS in 2007/2008, 11%, 7%, 5% and 4% had reported events, respectively, of clinical mastitis, dry-cow therapy, inappetence and other diseases through the SOMRS. Between 1-2% of herds had events of retained placenta, hoof disorders, leg disorders, teat tramp and prophylactic treatment for puerperal paresis (personal communication, Nils-Erik Larsson, SDA).

In this thesis, the disease information in the Cattle Database at the SDA (including disease events reported by veterinarians and/or farmers) is referred to as the Dairy Disease Database (DDD). The key to all data in the Cattle Database is the animal's unique identity, and therefore only disease records with full and correct individual animal identity can enter the DDD. This means that disease events in animals treated as a group (and reported as a group or herd treatment) never enter the database. Additional checks of the data are performed before entry into the DDD; for example, it is confirmed that the animal was in the herd at the time of the disease event. The information flow in the disease recording system is visualized in Figure 6.

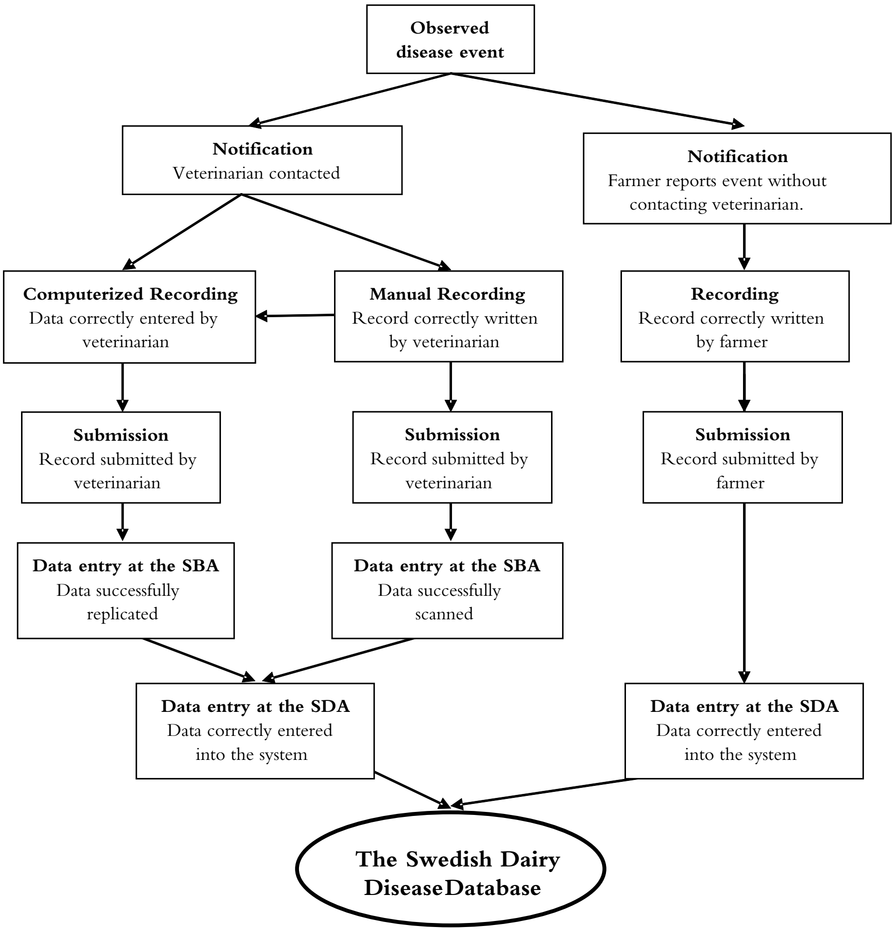


Figure 6. The information flow, in the disease recording system for dairy cattle, from morbidity in the population to the dairy disease database at the Swedish Dairy Association.

1.4.3 Use of the dairy data recordings in research

Disease data from the disease recording system have been used in dairy research since the middle of the 1980s, an early example is Anderson and Emanuelson (1985). In this section, some recent studies from various areas of dairy research that have used data from the DDD are described. In genetics, heritabilities of clinical mastitis and lactation average somatic cell count have been estimated (Carlen *et al.*, 2004). The disease data have also been used to compare the precision of two different methods to predict breeding values (Carlen *et al.*, 2005) and to map quantitative trait loci affecting health in Swedish dairy cows (Holmberg and Andersson-Eklund, 2004). In epidemiological research risk factors for disease have been studied (Emanuelson *et al.*, 1993, Gustafsson and Emanuelson, 2002, Hultgren, 2002, Nyman *et al.*, 2009) as well as the effect of disease on reproductive performance and on the risk of culling and the association between diseases (Niskanen *et al.*, 1995, Emanuelson and Oltenacu, 1998). The data have further been used to compare health in cows managed conventionally and organically (Hamilton *et al.*, 2002, Fall *et al.*, 2008a, Fall *et al.*, 2008b). A recent study investigated whether welfare indicators in the SOMRS could be used to identify herds with poor welfare (Hallén Sandgren *et al.*, 2009). Also, the information has been used to identify herds with high or low disease incidence with the aim of clarifying differences between those herd types (Holtenius *et al.*, 2004, Nyman *et al.*, 2007).

2 Aims of thesis

The general aim of this thesis was to evaluate the completeness of a national disease recording system for dairy cattle, with special reference to the Swedish dairy disease database, in order to assess its usefulness in research and identify areas of improvements.

More specifically, the aims were:

- ♦ To assess under-coverage due to diseased animals not receiving veterinary treatment (paper I).
- ♦ To assess underreporting of veterinary-treated disease events (paper I and II).
- ♦ To investigate whether differential underreporting of diseased animals was due to factors in the veterinary recording process (paper II).
- ♦ To investigate whether differential under-coverage occurred depending on factors influencing farmers' decisions to employ veterinary treatment (paper III).
- ♦ To assess the overall probability of capturing five different types of disease events in the dairy disease database (diagnostic sensitivity) and identify the steps in the disease recording process that influence this probability most (paper IV).

3 Materials and methods

This section gives a general description of the material and methods used. A detailed description is given in each of the papers (I–IV).

3.1 Study populations

The papers in this thesis are based on two studies, combining data from the field with that from the DDD. In both studies, herds eligible for participation were required to have a herd size above 24 dairy cows at the time of sampling, and to be enrolled in the SOMRS. Herds sampled for the first study (papers I, III and IV) were not eligible for the second study (papers II and IV). Judging by previous experiences with this type of research (which requires a high level of commitment from participating farmers), we expected participation from approximately 50% of farmers. Therefore, for the first study, 400 herds were randomly sampled from all dairy herds meeting the inclusion criteria although aiming for 200. A total of 177 herds participated, giving us a total of 7807 cattle-years of observation. As a gesture of appreciation the farmers that agreed to participate were offered a subscription to a Swedish dairy magazine or a gift voucher of similar value.

In the second study, eligible herds had to be located in one of eight counties that were selected on the basis that they had high densities of dairy cows, were served by both private and state-employed veterinarians and were geographically well spread across Sweden. Four-hundred herds were randomly selected, and of the 132 farmers giving a positive response after the initial contact (i.e. those claiming to be interested in more information and to have medical records from the time period of interest), 112 agreed to participate.

3.2 Data collection

In the first study (papers I, III, IV), the farmers were instructed to report "observed deviations in health from the normal," regardless of whether they chose to wait, treat the animal themselves, contact a veterinarian or cull the animal. The farmers reported disease events during January, April, July and October in 2004. For each disease event, the farmer reported the animal's identity and gender, the date when the health deviation was observed, a diagnosis (of those listed below) and whether or not the veterinarian was contacted. (Veterinary consultation is further referred to as veterinary-treated. Hence, veterinary-treated, as used in this thesis, does not necessarily mean that the animal received medical treatment.) Farmers were also asked to describe, in a written statement, the characteristics of the health deviation and the treatment given. In cases of veterinary consultation, the veterinarian's codes for diagnosis and treatment were also reported. In cases where a group of animals were affected, the farmer did not have to report all animal identities but only the number of animals affected. The diagnoses available for use by the farmers were as follows: acetonemia/inappetence, abomasal displacement, calving problems, clinical mastitis, clinical puerperal paresis, coughing, diarrhoea, lameness (located to the hoof or limb, respectively), retained placenta, teat tramp and a generic code denoting all other diseases.

In the second study (papers II and IV), farm copies of the veterinary records were sent to us by mail, or the farms were visited and the records were digitally photographed. From all farm copies (~2700) covering the time period March 1, 2003 to April 30, 2004, 900 copies were randomly sampled. The information given on the sampled copies was entered into a database (MS Access, Microsoft Corporation, Redmond, USA) by an animal technician. Variables of interest were: record type (manual or computerized, from state-employed or private veterinarian), date of consultation, veterinary identity number, herd identity number, animal identity number, animal category (individual, group or herd), sex and diagnosis. Data on additional animals with clinical signs and/or treated by the veterinarian that were only written as free text on the record (and therefore not registered in the recording system) were also entered.

3.3 Data from the Swedish Dairy Association

Information from the SDA was obtained in November 2005 for all animals and herds sampled in the two studies (n=800). The information used in paper I and paper III included disease information from the DDD, herd characteristics (e.g. annual disease incidence, housing system and herd size) and individual cow parameters (e.g. parity, calving dates and milk yield). The information used in paper II included two data files from the DDD: i) raw disease data transferred from the SBA and checked only for correct identity; and ii) disease data entered into the DDD (similar to the disease information used in papers I and III). Individual animal data on identity, gender, date of birth, calving date and dates for entering and leaving the herd were also used in paper II.

3.4 Definition of disease events

In paper I, a disease event was defined as a new case with a specific diagnosis. Thus, an animal could have several disease events at the same time, e.g. one event of clinical mastitis and one of teat tramp. The generic disease code "other diseases", as reported by the farmers, was broken down into gastro-intestinal disorders (including diarrhoea), laminitis, paresis (not puerperal), peripartum disorders, ringworm/lice, traumatic reticuloperitonitis, udder disorders (mastitis and teat tramp not included) and "other disorders".

The time-intervals used to define a new disease event (labelled "recovery cattle-days") were set to be equal to those used by the SDA: 7 days for acetonemia/inappetence and paresis (not puerperal) and 21 days for all other diseases. Exceptions were peripartum disorders, puerperal paresis and retained placenta, which were counted just once and only if they appeared during a defined period around calving. In paper III, the cow diseases reported by the farmers were categorized into lameness, metabolic disorders, peripartum disorders, udder disorders and other disorders; young animal (calves and heifers) diseases were categorized into cough, diarrhoea, lameness and other disorders. In paper II, each reported diagnostic code (or diagnosis in free text) was counted as a diagnostic event. Thus, as in paper I, an animal could have several diagnostic events on the same occasion.

3.5 Representativeness and completeness of the farmers' data

To evaluate possible selection bias in paper I, the participating herds were compared with the negative responders/drop-out herds. Differences in herd size, annual milk yield and disease incidence were tested for with the non-parametric Wilcoxon test, and geographic differences were tested for with

Pearson's chi-square test. Also, in paper I, the completeness of the farmers' data was estimated as the proportion of disease events in the DDD that were also found in the farmers' data.
For the herds studied in paper III, we compared farmers that reported directly after each study month and the farmers that had to be reminded once and several times with respect to their proportion of animals not receiving veterinary treatment (in the thesis only). Differences were tested for using the Pearson chi-square test.

3.6 Comparisons of incidence

In paper I, incidence proportions (equivalent to cumulative incidence) were estimated for the following disorders: calving problems, peripartum disorders, puerperal paresis and retained placenta. Incidences were calculated by dividing the number of events by the total number of animals at risk. Animals were at risk during a study month if the defined time at risk for those diseases overlapped this month. Incidence rates were estimated for the remaining diseases as the number of new events divided by the total cattle-time at risk. Time at risk was calculated as per Eq. (1).

Time at risk = (total number of cattle-days in the herd during the study period) – (number of recovery cattle-days)
Eq. (1).

Incidence rates (equivalent to incidence density) were calculated separately for cows and young animals. For cough and gastro-intestinal disorders, they were calculated in two different ways: first, including all reported disease events, and second, including only disease events that were not related to herd outbreaks. We calculated 95% CIs and adjusted for clustering within herd. Comparisons of incidences were made, per disease, between the DDD and 1) all disease events reported by the farmers (to investigate under-coverage) and 2) all disease events reported by the farmers as veterinary-treated (to investigate underreporting). Non-overlapping 95% CIs were treated as statistically significant differences.

In herds where the farmer reported during all four study months, herd-specific incidences were estimated for events in the farmers' data and in the DDD, respectively. The Wilcoxon rank-sum test was used to test for differences in the median herd incidence between the farmers' data and the DDD. A p-value <0.05 was considered significant.

3.7 Evaluation of the completeness in the dairy disease database

In this thesis, a number of different definitions are used to evaluate and describe the completeness of the DDD. The proportion of all disease events receiving veterinary treatment was estimated in paper I. Also in paper I, the completeness of farmer-reported veterinary-treated disease events was estimated as per Eq. (2).

Completeness$_{\text{(disease events)}}$ = (number of disease events in the farmers' data also found in the DDD) / (number of disease events in the farmers' data reported as veterinary-treated)

Eq. (2).

In paper II, the completeness was estimated at different steps in the disease recording process by comparing the information in the raw data at the SDA and the DDD, respectively, with the information reported in the farm copies of the veterinary record. The completeness of records, cases and diagnostic events was estimated as per Eqs. (3)- (6).

Completeness$_{\text{(records)}}$ = (number of records found in agreement with the raw data at the SDA) / (number of records with cases reported in individual animals in the farm copies)

Eq. (3).

Completeness$_{\text{(cases)}}$ = (number of cases found in agreement with the raw data at the SDA) / (number of cases reported in individual animals in the farm copies)

Eq. (4).

Completeness$_{\text{(diagnostic events, raw data)}}$ = (number of diagnostic events found in agreement with the raw data at the SDA) / (number of diagnostic events in individual animals in the farm copies)

Eq. (5).

Completeness$_{\text{(diagnostic events, DDD)}}$ = (number of diagnostic events found in agreement with the DDD) / (number of diagnostic events in individual animals in the farm copies)

Eq. (6).

Completeness of disease events (Eq. (2)) and completeness of diagnostic events in the DDD (Eq (6)) are similar, although estimated with different "gold standards" in farmers' data and farm copies of veterinary records, respectively.
In paper IV, the completeness of the DDD was estimated with reference to the whole disease recording process: and the method used is described further in Section 3.9.

3.8 Assessment of under-coverage and underreporting

In paper II, the completeness was estimated, divided by the four different veterinary record types (computerized and manually written records from state-employed and private veterinarians, respectively). Furthermore, factors affecting the probability that diagnostic events were missing (i.e. lack of completeness) were investigated using multilevel logistic regression.

The disease events reported by farmers in the first study were used in paper III to investigate whether herd or individual animal characteristics influenced the animals' odds of receiving veterinary treatment when diseased. Disease events that the farmer had failed to report to us but that was registered in the DDD, (i.e. reported by the veterinarians) were also included. Dairy cows and young animals were analyzed separately. The study only considered events in animals where the animal's identity number was reported by the farmer and where there was a matching identity number in the Cattle Database. Further, only one disease event per animal was used in the analysis. In cases of several disease events per animal the event used was randomly chosen by giving each disease event a random number and using the event with the lowest number. Disease events from herds with less than four disease events among cows or young animals were excluded from the analysis. This was done in order to reduce the risk of bias, since small group sizes (few observations per herd in this case) have been shown to bias estimates in both fixed and random effects in multilevel regression models (Clarke, 2008). Some farmers had failed to report disease events that did indeed exist in the DDD i.e. that had been reported by a veterinarian (paper I). Based on the number and proportion of failures, each farmer's "record-keeping ability" was defined. "Good record-keeping ability" (yes/no) was then included in the model, with the hypothesis that farmers who failed to report veterinary-treated disease events also, to a larger extent, failed to report non veterinary-treated disease events.

In both papers II and III, potential explanatory variables obtained from the Cattle Database and the field data were tested for inclusion in a multilevel logistic regression model. In paper II, the outcome modelled was "event missing in the DDD" (1=missing) and in paper III, the outcome modelled was veterinary treatment (1=veterinary-treated). Veterinarian and herd were included as random effects in the analysis in paper II and paper III, respectively. The model for event *i* was expressed (using logit*(p)=(log(p/(1-p)))* as

$$\text{logit}(p_i) = \beta_{0j} + \beta_1 x_{1ij} + \ldots + \beta_n x_{nij}$$

where $\beta_{0j} = \beta_0 + u_{0j}$

Initially, all potential explanatory variables were tested in a univariable analysis (including herd, or veterinarian, as a random factor) and variables with a p-value <0.2 were included in the multivariable analysis. Extra-binomial variation was reasonably close to 1 and was therefore not considered further in the analysis. Correlations between potential explanatory variables were tested using Spearman correlation coefficients. The model was then reduced manually by backward elimination until all the remaining variables had a p-value ≤0.05 and could therefore be considered significantly associated with the outcome. All of the two-way interactions between variables that remained after the backward elimination were tested, one by one, for inclusion in the final model. Confounding was assessed by inspecting changes in the parameter estimates during the backward elimination process. A change >20% was considered indicative of confounding (Dohoo *et al.*, 2003). The variance partition coefficient (VPC) was estimated by ($\sigma^2_{\text{veterinarian}} / \sigma^2_{\text{veterinarian}} + \sigma^2_{\text{event}}$) in the model in paper II and as ($\sigma^2_{\text{herd-level}} / \sigma^2_{\text{herd-level}} + \sigma^2_{\text{event}}$) in the models in paper III, assuming that the level-one (event) variance was $\pi^2/3$ (where π =3.1416) on the logit scale (Snijders and Bosker, 1999). The fit of the model was evaluated by inspection of the second level (veterinary or herd) standardized residuals plotted against the normal scores and against the fixed part prediction.

3.9 Probability of correctly reported disease events in the DDD

In paper IV, the completeness of the DDD was estimated relative to the whole disease recording process, i.e. how much of the farmer-observed morbidity that is covered by the DDD. The various steps in the disease recording system were described as a scenario tree, with each step constituting a node with a probability of a successful outcome associated with it (the various step are described in Table 2). The outcome modelled was the diagnostic sensitivity (equivalent to completeness) of the disease recording process, i.e. the probability of a farmer-observed disease events resulting in a correct record in the DDD. Input variables (steps in the recording process) were defined by probability distributions for each node. The diagnostic sensitivity of the DDD was estimated for clinical mastitis, cough, diarrhoea, lameness and puerperal paresis in 2003/2004, overall and by veterinary employment type. A sensitivity analysis was also performed in order to rank the influence of the different recording steps for the diagnostic sensitivity of the DDD.

Table 2. Steps in the disease recording process, from a farmer-observed disease event to a successfully reported event in the DDD, for dairy cattle in Sweden, as used in the estimation of the diagnostic sensitivity of the DDD.

Step	Description
Notification	The farmer contacts the veterinarian for a detected disease event, or reports him-/herself through the SOMRS
Recording	The veterinarian writes a correct record. This step is subdivided into individually treated, correct diagnosis, correct herd identity and correct animal identity.
Raw data entry	This step covers all of the following; submission (i.e. that the veterinarian sends the record to the SBA), data entry at the SBA, transfer of data to the SDA, and data entry into the raw data at the SDA. It was subdivided into medical record registered (yes/no) to separate the risk of data loss for diagnostic events where the whole record was missing, from diagnostic events where other events from the same record were reported.
Data entry into the DDD	The diagnostic event was correctly entered into the DDD. This step was subdivided into correct conversion key (yes/no) and other reasons for loss.

The probabilities of success for each step in the recording process were assumed to follow BetaPert distributions defined by their minimum, most likely and maximum values. Probability distributions were defined based on the basis of results from papers I and II, and from studies of Swedish dairy calves and heifers (Svensson *et al.*, 2003, Svensson *et al.*, 2006). Information from the SDA about losses connected with incorrect animal identity and events reported that did not enter the DDD for other reasons (e.g. group treatments, lacking conversion key) was also used (personal communication, Katarina Roth, SDA). Simulation was performed in @RISK (Palisades Corp., Newfield, USA), using latin hypercube sampling with 5000 iterations. The sensitivity analysis was based on regression coefficients (standardized beta estimates) and showed the amount of change in the probability of successfully reported events (i.e. the output) when the input changed with +1 standard deviation at each step in the recording process.

3.10 Differences between state-employed and private veterinarians

In paper I, differences between state-employed and private veterinarians were tested for using logistic regression (adjusting for clustering within herd) and the Wilcoxon rank-sum test, for overall and herd-specific incidences, respectively. In paper II, non-overlapping 95% CIs were treated as significant differences between record types. Veterinary employment type was also tested for inclusion in the logistic regression model in paper II in order to examine whether it was significantly associated with the probability of missing diagnostic events. In paper IV, the diagnostic sensitivity of the DDD was estimated separately for state-employed and private veterinarians.

The notification step is almost a prerequisite for successful recording in Sweden. Therefore, to further understand the disease recording process (illustrated in Figure 6), the sensitivity of the DDD was also estimated disregarding the notification step, and divided by state-employed and private veterinarians (in the thesis only).

4 Results

4.1 Representativeness and completeness of the farmers' data

In the evaluation of representativeness in paper I there were no significant differences between study herds and herds that did not participate.

In the same paper, to validate the farmers' data, the completeness of the farmers' data was evaluated. Only 88% of the veterinary-treated disease events that existed in the DDD were actually identified in the farmers' data. The degree to which the recordings were incomplete varied from farmer to farmer. At herd level, the median proportion of disease events that were reported in the DDD and identified in the farmer's data was 1.0, but 0.8 at the 25^{th} percentile, i.e. 25% of the farmers reported 80% or less of the veterinary visits made during the study period.

In the data used in paper III, the proportion of diseased animals that were reported by the farmers as not receiving veterinary treatment was significantly higher in herds where the farmers reported directly after each study month (39%) than it was in herds where the farmer had to be reminded once (31%) or several times (29%) ($p=0.001$).

4.2 Comparison of incidence

In paper I, incidences calculated with data reported by farmers were in general higher than incidences based on the DDD. When all farmer-observed disease events were included, the following disorders had significantly higher incidence in the data reported by farmers: for cows; calving problems, clinical mastitis, cough (only when including herd outbreaks), gastro-intestinal disorders, lameness, retained placenta, teat tramp and udder disorders; and for young animals (calves and heifers); cough, gastro-intestinal disorders and other disorders. In other words, these disease complexes were found under-covered because the recording system is designed to capture only veterinary-treated disease events. The higher incidence for cough and gastro-intestinal disorders in the farmers' data when herd outbreaks were included was expected, since herd outbreaks would most likely be reported as group treatments and therefore not enter the DDD.

When the farmers' data were limited so that only events reported as veterinary-treated were considered, the incidence rates for cough and gastro-intestinal disorders in young animals were still significantly higher in the farmers' data, i.e. those diseases were found to be underreported in this age group. In contrast, the incidence rate was significantly higher in the DDD for "other disorders" in cows. One reason for this was that several events categorized as "other diagnoses" in the DDD were found in the farmers' data with another, in general more specific, diagnosis.

Herd-level incidences (based on all events in the farmers' data) were significantly higher in the farmers' data than in the DDD for most diseases (in cows; acetonemia/inappetence, calving problems, clinical mastitis, gastro-intestinal disorders, lameness, paresis (not puerperal), peripartum disorders, retained placenta, ringworm/lice, teat tramp and udder disorders, and in young animals; cough, gastro-intestinal disorders, ringworm/lice and other disorders). The consistency between under-coverage at individual-event level and herd level indicates that this is randomly distributed across the whole population, and that the differences found are not merely an effect of a few herds having no or few veterinary consultations.

4.3 Evaluation of completeness in the dairy disease database

In paper I, the percentage of veterinary-treated events varied depending on the disease complexes. For the most common disease complexes, the percentage veterinary-treated events was; 90% for puerperal paresis, 78% for clinical mastitis, 59% for lameness (hoof), 53% for cough, 43% for lameness (limb) and 39% for gastro-intestinal disorders (including herd outbreaks). The overall completeness was 71%, i.e. 71% of all disease events reported to be veterinary-treated (by the farmers) was identified in the DDD.

In the validation of the raw data at the SDA against veterinary practice records (paper II) the overall completeness was 88% for records (Eq. (3)) and 87% for cases (Eq. (4)). The overall completeness for diagnostic events in the raw data at the SDA (Eq. (5)) was 84% and in the DDD (Eq. (6)) it was 75% (compared to 71% in paper I). Of the 302 diagnostic events that were missing, 63% were not registered in the raw data file at the SDA, and for the majority of those diagnostic events the whole record was missing (45% of all missing events). However, 37% of the missing diagnostic events were indeed registered in the raw data file but were missing in the DDD. The most common reason for losses that occurred after registration in the raw data file was that the conversion key was undefined for the diagnosis reported (23% of all missing events). Completeness was found to be differential between regions, disease complexes and veterinary employment type.

In paper IV, the completeness of the DDD (i.e. the probability of disease events being correctly recorded in the DDD) was estimated for the whole disease recording system, i.e. including the farmers' decision to contact a veterinarian. The completeness was 72% for puerperal paresis, 63% for clinical mastitis, 41% for lameness, 40% for cough and 30% for diarrhoea. The ranking of the steps in the disease recording process showed, not surprisingly, that "notification" (i.e. the farmer contacting a veterinarian or reports through the SOMRS) was the most influential step in the recording process and in determining whether or not a disease event will appear in the DDD. The second most important step was "raw data entry at the SDA" (this step covers submission in which the veterinarian sends the record to the SBA, data entry at the SBA, transfer of data to the SDA and data entry into the raw data at the SDA) and, for cough, diarrhoea and lameness also whether the disease events were reported to be "individually treated".

4.4 Odds of receiving veterinary treatment

In paper III, it was found that, in dairy cows, the probability of veterinary treatment, given a disease event, was higher in herds mainly consisting of Swedish Holstein cows than it was in herds mainly consisting of Swedish Red cows. Cows with a disease event early in lactation had a higher probability for veterinary treatment than cows in which the disease event occurred later in lactation. There was also a higher probability of veterinary treatment when the event occurred in January or April than there was when it occurred in July or October. The probability of veterinary treatment was different for different disease complexes, both for cows and young animals; and for most disease complexes this probability increased if there was another animal with a disease event on the same day. In young animals, the probability of veterinary treatment was lower if the farmer was classified as being good at record keeping. This was in line with our hypothesis that farmers in study I with good record-keeping ability reported events that were not veterinary-treated to a greater extent than farmers with poor record-keeping ability. The random effect of herd was significant in both the cow model and the young animal model; it accounted for 41-44% (based on different models) and 30-46% of the variation, respectively.

4.5 Differences between state-employed and private veterinarians

In paper I, the probability (at the individual-event level) that disease events reported as being veterinary-treated in the farmers' data would be identified in the DDD was significantly lower in herds located in a district served by private veterinarians (OR 0.6; 95% CI 0.38, 0.94) than it was in herds located in districts served by state-employed veterinarians. The difference in the proportion of disease events identified within herd was also significant ($p=0.03$), and in the same direction (with the 25th, 50th and 75th percentile being 0.5, 0.67 and 0.89 for private veterinarians and 0.62, 0.83 and 1.00 for state-employed veterinarians).

Similarly, in paper II, there were significant differences between state-employed and private veterinarians in the completeness of records, cases and diagnostic events in individual animals in the raw data at the SDA, and diagnostic events in the DDD (Tables 3 and 4).

Table 3. Completeness (% found) of records and cases in individual animals in the raw data at the SDA evaluated against farm copies of veterinary records.

Employment type	Farm copies	Records found in the raw data at the SDA			Ind. animal cases on farm copies	Ind. animal cases found in the raw data at the SDA		
	No.	No.	%	95% CI	No.	No.	%	95% CI
State-employed	277	276	100	98, 100	390	384	98	97, 99
Private	541	442	82	78, 85	863	687	80	77, 82
Total	818	718	88	85, 90	1253	1071	85	83, 87

Table 4. Evaluation of completeness of diagnostic events in individual animals, by veterinary employment type; number of diagnostic events on farm copies and number and percentage of diagnostic events with the diagnostic code found in the raw data at the SDA and in the DDD.

Employment type	Diagnostic events in farm copies	Raw data at the SDA			DDD		
	No.	No.	%	95% CI	No.	%	95% CI
State-employed	383	367	96	93, 98	330	86	82, 89
Private	802	627	78	75, 81	555	69	66, 72
Total	1185	994	84	82, 86	885	75	72, 77

Also, in paper IV, the modelled diagnostic sensitivities of the DDD were lower for private veterinarians than they were for state-employed veterinarians, although the difference was only statistically significant for puerperal paresis. The notification step was the most influential step in all analyses.

When the notification step was disregarded, i.e. given a veterinarian was contacted (only in this thesis), the diagnostic sensitivities were significantly higher for state-employed veterinarians than for private veterinarians, for all disease complexes (Table 5). The step "raw data entry at the SDA" was ranked highest or second highest in the analysis for private veterinarians, but it was not ranked at all in the analysis for state-employed veterinarians (because that step was found to be complete for state-employed veterinarians in paper II). Where the other steps were concerned, the ranking was similar for state-employed and private veterinarians.

Table 5. Sensitivities of the DDD for 2003/2004 divided by veterinary employment type estimated for the recording steps subsequent to veterinary consultation (i.e. given that the case has been subject to a veterinary visit).

	Total		State-employed		Private	
Disease complex	Mean	95% CI	Mean	95% CI	Mean	95% CI
Clinical Mastitis	0.80	0.78, 0.83	0.91	0.88, 0.93	0.75	0.72, 0.79
Cough	0.75	0.70, 0.79	0.85	0.80, 0.90	0.70	0.65, 0.75
Diarrhoea	0.77	0.74, 0.80	0.87	0.83, 0.90	0.72	0.68, 0.76
Lameness	0.78	0.74, 0.82	0.89	0.84, 0.93	0.73	0.69, 0.78
Puerperal paresis	0.82	0.79, 0.84	0.93	0.90, 0.95	0.77	0.73, 0.80

5 General discussion

5.1 Completeness of the dairy disease database

Throughout this thesis, the term "veterinary-treated" is used as an equivalent to veterinary consultation, and therefore not all of the animals receiving veterinary treatment were treated with prescribed drugs. Several different definitions of "completeness" have been used in the papers included in this thesis, but completeness with regard to a) veterinary-treated diagnostic events and with regard to b) all observed disease events are the most important among these.

The completeness with regard to veterinary-treated diagnostic events focuses on the actual performance of the system given its design. It should, in theory, be 100%, otherwise underreporting is present. In most validation studies, this dimension is investigated by validating the information in the database against paper records or some other source of information regarded as the gold standard. The basis of the validation then becomes all cases (or individuals) in which the person who is ill or the animal owner seeks medical care - for example, patients at a hospital or general practice, or animals examined by veterinarians. In all such cases the individual will probably have a medical record, even though they may have the wrong diagnostic code. In this situation, the only kind of cases that can be expected to be included in a disease recording system, and become the basis for the validation, are those that actively seek medical care. The completeness of veterinary-treated events was estimated to be 71-75% in papers I and II. Those figures could be compared with the estimated completeness of disease events registered in the Danish Cattle Database, which was about 80% for cows and around 45% for calves and young stock (Bennedsgaard, 2003).

The completeness with regard to all observed disease events studies the fact that the Nordic national dairy disease databases do, in general, not capture information on those disease events where the animals do not receive medical care. Similarly, medical databases in human medicine based on information from hospitals or general practices fail to include information for non-severe problems that do not require medical attention. Strictly speaking, this type of information loss is not underreporting, because the relevant events are not, by design, supposed to be recorded in the database. In this thesis this is referred to as under-coverage. However, the magnitude of disease events not receiving veterinary treatment is clearly important when assessing the health of a population. When disease data based on veterinary recordings are combined with information on the population under study, animals with disease events that are not veterinary-treated will be regarded as healthy. This type of data loss (non-veterinary-treated disease events) was investigated in paper I. In that paper, the proportion of disease events actually receiving veterinary care was estimated. It was also investigated in paper IV where the completeness with regard to the whole chain of events in the reporting process was estimated, i.e. from notification to a correct registration in the DDD. The estimated completeness of the DDD with regard to all farmer-observed disease events was between 30% and 72%, depending on disease complex.

5.2 Causes of information loss

The papers included in this thesis identify several causes of information loss in the DDD. The first step in the disease recording process, i.e. "notification" was found to be the most important factor for such loss, followed by "raw data entry at the SDA" (paper IV). Overall, 54% of the disease events observed by the farmers were veterinary-treated. A current Nordic project has collected farmer-reported disease data from Denmark, Finland, Norway and Sweden in a manner that is comparable to the methods employed in this work. Preliminary results show that, of the cows with clinical mastitis, 78% (95% CI 74%, 83%), 74% (68%, 79%), 88% (82%, 92%), and 84% (79%, 89%) were examined by a veterinarian in Denmark, Finland, Norway and Sweden, respectively (personal communication, Cecilia Wolff, Swedish University of Agricultural Sciences). This compares with figures of 78% (95% CI 75%, 81%) in paper I.

With infectious diseases commonly affecting more than one animal, another important reason for information loss – and one that operated at the "raw data entry at the SDA" step – was that the animals receiving veterinary treatment were reported as a group (paper IV). Group treatments are reported without each animal's unique identity number, and the disease events therefore cannot enter the DDD.

An important reason for loss of diagnostic events, as identified in paper II, was that the veterinary record as such was not registered in the raw data at the SDA (45% of all lost diagnostic events). There could be several reasons for this: events might simply not have been reported, or there might be problems in the scanning process, or some of the information reported, such as the animal identity, might be incorrect. However, in paper II it was not possible to distinguish between these different reasons. This step in the recording process therefore needs to be investigated further. Of the total loss, 37% was accounted for by diagnostic events that were indeed registered in the raw data from the SBA but lost because they could not be entered into the DDD. Most of these were lost because a conversion key, translating the codes used by the veterinarians to the codes used in the DDD, had not been defined. The majority of the diagnostic events lost as a result of the incomplete conversion key were events of sub-clinical mastitis. The conversion key was updated so as to handle sub-clinical mastitis in 2005; where the remaining missing codes were concerned, the conversion key was updated at the end of 2008 (personal communication, Katarina Roth, SDA). Consequently, disease data from 2009 and onwards should not suffer from data loss for this reason. For example, as long as the data loss prior to registration in the raw data is constant, a correct conversion key will increase the completeness estimated in paper II from 75% to 81%.

5.3 Differences between veterinary employment types

Papers II and IV report a difference in the completeness (i.e. underreporting) of events that depend on whether the consulting veterinarian is state-employed or in private practice. This difference favours the state-employed veterinarians. The results in paper I also indicated differences between veterinary employment types, with higher completeness in data from regions that were served by state-employed veterinarians. Most of the information lost concerned disease events treated by private veterinarians using manual records, the reason being that the records were never registered in the raw data file at the SDA (83% of the losses in manual records from private veterinarians). By contrast, most of the losses for private veterinarians keeping computerized records and state-employed veterinarians occurred after registration in the raw data (60–74% of the losses from those veterinarians) (paper II). This shows that the recording process works less well for private veterinarians with manual record keeping. However, the reasons are not clear, because it was impossible to identify sources of loss in records that were not registered in the raw data. For example, it is not possible to say to what extent the records were submitted, but did not arrive, or were impossible to scan, and to what extent records were not reported at all. The majority of state-employed veterinarians leaving manually written documentation at the farm later enter the information through the computerized system (Government Offices of Sweden, 2005). Therefore scanning is used almost entirely for manual records from private veterinarians. However, the extent to which records are stopped in the scanning process has not been evaluated. Having said this, the fact remains that there has been a dispute between large animal private practitioners and the SBA regarding the disease recording system for food animal practice, and some private practitioners have refused to report their consultations. The number of veterinarians involved is not known; it is estimated that it involves only a few practitioners (Government Offices of Sweden, 2005).

Completeness was analyzed by employment type in paper IV. Here, estimated completeness was higher for state-employed veterinarians than it was for private practitioners, although it was only statistically significant for puerperal paresis. However, when the completeness of the DDD was estimated for events that received veterinary treatment only (i.e. by excluding the notification step in the scenario tree), state-employed veterinarians had significantly higher completeness than private veterinarians for all disease complexes (Table 5). Whether or not the data was entered into the raw data file seems to be the step in the recording process mainly responsible for the difference in underreporting between state-employed and private veterinarians. As was mentioned earlier, the step "raw data entry at the SDA" includes several reasons for loss: at the one end, there is the question whether the veterinarian sends the record to the SBA; at the other, there are questions about raw data entry at the SDA. To reach clarification, the reasons for underreporting in this step need to be studied further.

5.4 Consequences of lack of completeness

The fact that data regarding disease and production can be linked to other information about the target population is an important quality of the Cattle Database at the SDA. This enables, for example, estimation of the incidence of disease in the population and also investigation of potential risk factors for disease. However, individuals that do not have reported disease events will, in this context, be regarded as healthy. Underreporting of veterinary treated disease events and under-coverage of non-veterinary treated disease events both contribute to this misclassification.

5.4.1 Non-differential misclassification

If data from the DDD are used to study risk factors for disease, and if the misclassification is independent (i.e. equal in the groups being compared), then it is non-differential (Thrusfield, 1995, Dohoo *et al.*, 2003). Non-differential misclassification should bias the measures of association towards null; and thus the apparent effect of risk factors will be smaller than the true value (Copeland *et al.*, 1977, Weinberg *et al.*, 1994, Dohoo *et al.*, 2003). However, even very small differences between groups have been shown to produce bias away from null. In a study, random error alone can also produce bias away from null (Maldonado *et al.*, 2000, Jurek *et al.*, 2005, Jurek *et al.*, 2008).

5.4.2 Differential misclassification

If the magnitude of the misclassification differs in the groups being compared, the misclassification is differential. The effect of differential misclassification is difficult to predict as the bias could be in any direction; thus the apparent risk factor could be either larger or smaller than the true value (Thrusfield, 1995, Dohoo *et al.*, 2003). Age-related differential under-coverage of cough (with greater under-coverage in young animals than in cows) was found in paper I. Differential under-coverage was also found in paper III, as the odds of an individual cow receiving veterinary treatment was found to be associated with the herds' main breed, stage of lactation and study month. In both cows and young animals, the odds for veterinary treatment was associated with whether there was another animal with an event on the same day, and also with the type of disease complex.
Also, in paper I, differential underreporting was found to be associated with veterinary district (with greater underreporting in private districts than in state-employed). Differential underreporting associated with region and veterinary employment type was found in paper II.

5.4.3 Possible effects of misclassification in the dairy disease database

Both under-coverage and underreporting will lead to misclassification of diseased animals as healthy. When data from the DDD are used to estimate incidences of disease this will lead to conservative estimates. The results presented in paper IV, (completeness of 30% for diarrhoea, 40% for cough, 41% for lameness, 63% for clinical mastitis and 72% for puerperal paresis) suggest that the incidence (regardless of veterinary treatment) would be about 3.3 times higher for diarrhoea, 2.5 times higher for cough and lameness, 1.6 times higher for clinical mastitis and 1.4 times higher for puerperal paresis, than the incidence estimated in the DDD. Similarly, the incidence of veterinary-treated disease would be about 1.2-1.3 times higher than in the DDD, (based on the estimated underreporting in Table 4). (Note that these figures are an average for the dairy cow population in the SOMRS, since differential underreporting was not accounted for.) For example, in 2007/2008 the estimated incidence of veterinary-treated clinical mastitis in Swedish milk-recorded herds was 14.3 (per 100 completed/interrupted lactations). Taking the underreporting into account a more accurate figure would be 17.9 (i.e. 14.3/0.8). Further, considering under-coverage, the incidence of clinical mastitis would be 22.7 (i.e. 14.3/0.63) events per 100 completed/interrupted lactations. These figures do, however, assume that the completeness of the DDD was constant between 2004 and 2007/2008.

Disease data are also used for advisory work. For example, for herds affiliated to the SOMRS, herd-specific, as well as national, key measures of health and production are produced. For most herds, the health measures included should be representative estimates following the herd status over time, but conservative. However, where there is differential misclassification present, the health measures may be biased for comparisons between groups of herds, or between groups of animals within herds. Moreover, the disease data in the DDD are used in the genetic evaluation of dairy bulls in Sweden. The underreporting and under-coverage found is most probably randomly distributed over test bulls and will only add to the uncertainty of the evaluation and not create biased evaluations. However, an increase in the number of daughters may be needed to provide accurate sire evaluations, but it will have little negative effect considering the size of the cow population.

For diseases with obvious signs of illness and/or a severe course - i.e. the types of disease event that are most likely to be detected by the farmer and demand veterinary treatment - the completeness of veterinary-treated events should be similar to the completeness of all disease events. Therefore, for these diseases, the risk of bias due to differential misclassification (because of under-coverage) should also be minor. For other diseases, which are not as easily detected or where the decision to contact a veterinarian is less readily made, the completeness of veterinary-treated events will differ from that of all disease events. For these diseases, the probability of a successfully reported disease event is much more dependent on the farmer (i.e. the notification step).

The results in this thesis (paper III) indicate that a comparison of disease incidence in herds of different sizes could be biased. This is because the probability of disease events appearing close in time is higher in large herds owing to the larger number of animals and therefore, milder disease events are more likely to be subject to veterinary consultation; the veterinarian is already at the farm. On the other hand, Østerås *et al.* (2007) have pointed out that cows in smaller herds have a larger relative value and therefore are more likely to receive veterinary treatment than cows in larger herds. A confounding effect of herd size has also been discussed, the thought being that herd size is likely to affect management practices and chances of exposures (Willeberg, 1985). Thus, the farmers' treatment strategies and their effect on the DDD need to be investigated further.

Other studies have shown results that support the findings of differential under-coverage presented in this thesis. For example, Nyman *et al.* (2007) concluded that the threshold for contacting the veterinarian in cases of clinical mastitis was higher in herds mainly consisting of Swedish Red than it was in herds mainly consisting of Swedish Holstein. Differences in treatment strategies for cows with mastitis at different lactational stages have also been found, and in the same orientation as our results (Vaarst *et al.*, 2002). Moreover, in a Swedish study, farmers with herds with low somatic cell counts were more willing to call the veterinarian for mild cases of clinical mastitis than farmers with herds with high somatic cell count (Ekman, 1998). Treatment strategies have also been suggested to explain differences between herds with respect to the accuracy of reproductive performance indicators in Swedish dairy herds (Löf *et al.*, 2007). Østerås *et al.* (2007) speculate that changes in diagnostic codes, treatment strategies and milk quality payment systems are likely to have an impact on disease recording based on veterinary-treated events and, consequently, complicate annual comparisons. Severe cases are more likely to become veterinary-treated, so another possible explanation of differences between breeds and between animals at different lactational stages would refer to whether there are any underlying factors that cause differences in severity of disease. As metabolic and physical stress have a negative impact on health during pregnancy, parturition and early lactation (Mallard *et al.*, 1998), it could possibly also cause a more severe disease course. Nyman *et al.* (2008) found differences in the immune response around calving between Swedish Red and Swedish Holstein. If this is correct, it could explain the apparent difference in threshold for veterinary treatment between farmers managing herds with different characteristics.

The reasons for underreporting, as well as under-coverage, presented in this thesis need to be considered when using disease data from the DDD. The potential negative effect of underreporting/under-coverage seems to be a problem mostly in epidemiological research. When the data is used for advisory work the usefulness of the data will vary between herds depending on the data quality for the individual herd. The areas for which the data from the DDD are used today that will be least affected by the underreporting seems to be genetic research, breeding values and annual health statistics (although the latter will be conservative).

5.5 Improvements in the completeness

Both the SBA and the SDA have worked on improving the recording process. As mentioned above, the conversion key translating codes used by the veterinarians to the less detailed codes used in the DDD has been updated. Also, data loss due to incorrect animal identities has decreased from 9-18% between 2000 and 2004 to 1.3% by the end of 2008. However, in a recent study of the sensitivity of the Nordic dairy health recording systems, the sensitivity of the DDD in Sweden for clinical mastitis was estimated at 59% (95% CI 52%, 66%). This sensitivity is equivalent to the estimated overall completeness of 71% presented in paper I (Eq. (2)). This estimate was significantly lower than that pertaining to the Danish DDD (78%; 73%, 82%) and the Norwegian DDD (76%; CI 70%, 83%), though it was similar to the sensitivity of the DDD in Finland (51%; 44%, 57%) (Wolff *et al.*, 2009). Although these are only preliminary results from a subsample of the data, they could indicate that the completeness of the DDD has decreased. Differences between the studies, such as regional coverage or the proportion of herds served by private and state-employed veterinarians, could explain the differences found; this has, however, not been evaluated yet.

The main reason for data loss in Sweden is that the registration system is based largely on veterinary-treated disease events. The inclusion of farmer-reported disease events would theoretically increase completeness most. However, adding an extra step to the recording system (and burdening the farmers without offering suitable incentives), could also introduce new problems. A recording system based on veterinary recording have several advantages; veterinary diagnosed diseases should have higher precision and accuracy than farmer diagnosed diseases, veterinary medical records could be used as the basis for reporting, among others. Instead, reducing underreporting must be considered the most important matter. The most effective measure through which to improve the completeness of the DDD seems to be that of further investigating why records are not registered in the raw data at the SDA, and then improving that step. Furthermore, Bartlett *et al*, (1986) discuss the importance of giving feedback to those who report data to promote reliable data recording. For example, providing all veterinarians with food animal practice with useful comparative information on disease frequency in their practice area as well as nation-wide, and data on medical use might well encourage correct reporting, and therefore the completeness.

However, considering the system's design, differences between veterinary-treated and non-veterinary-treated disease events, factoring in animal-, herd- and farmer characteristics, need to be studied further.

Since the animal's unique identity is the key to the DDD, herd outbreaks of disease, reported as group treatments, are excluded. This may lead to substantial underreporting of signs associated with viral pathogens, such as bovine corona virus and bovine respiratory syncytial virus. As reporting of all animal identities during a herd outbreak is not feasible, group treatments could be treated separately and incidences calculated directly at herd level. This would improve the reporting without increasing the workload for veterinarians in the field.

5.6 Methodological considerations

5.6.1 Accuracy

One limitation of this validation of the DDD is that only completeness, and not correctness has been evaluated: only one of the two measures that constituting accuracy is adressed. When evaluating correctness from medical records, detailed information about the cases is needed to fully assess whether the diagnosis was correct. Here, however, correctness could not be evaluated, because there was insufficient information in the veterinary clinical records. As discussed by Hogan and Wagner (1997), estimates of both completeness and correctness are necessary to assess the accuracy of a database – for example, high levels of correctness might be achieved in the presence of many unrecorded observations, with the latter resulting in a low level of completeness. Conversely, an impressive level of completeness can be achieved despite many errors in the diagnostic information, i.e. poor correctness. Given the limitation – i.e. granted that it was not possible to evaluate correctness - the studies in this thesis still present results that highlight data quality issues in the DDD.

In the papers included in this thesis the DDD has been evaluated against farmers' records of disease events and against farm copies of veterinary records. In total, 12% of the veterinary-reported events in the DDD were not reported to us by the farmers (paper I). Those events were treated as true disease events that the farmers had failed to report to us (papers III). The failure of farmers to report disease events has been reported elsewhere. In a study of health in Swiss dairy herds, the farmers' data were compared to veterinary records on a sub-sample of the data (only 15 farmers and 7 veterinarians) and 22% of these disease events were reported only by the veterinarian (Menendez *et al.*, 2008). The missing disease events in the farmers' report in paper I and in the paper by Menendez and colleagues, show that the same problem with misclassification bias (i.e. the classification of animals without a reported disease event as healthy) can arise also in connection with primary data collection. Moreover, all veterinary-treated events in the farmers' data that were not identified in the DDD (and vice versa) were thoroughly scrutinized, and apparent errors in animal identity were corrected. Therefore, there is little risk that we misclassified events as missing as the result of incorrect identities.

It is possible, of course, that some of the events in question here were reported by the veterinarians but with the wrong herd identity number, and that an animal with that specific identity was present also in the other herd. According to the SBA, however, this scenario is unlikely - although there have been a few such episodes (personal communication, Ulrika Heintze-Pettersson, SBA). In the second study, the herd identities were incorrect on 7 farm copies. In 5 of those records, the information was indeed registered with the correct herd identity in the DDD (i.e. it was corrected after the veterinary visit at the farm), but the information from 2 records was missing in both the raw data and the DDD, indicating that it never entered the recording system in the first place. The fact that events registered in the DDD only were regarded as true disease events in paper III could have introduced some false disease events (if some of those events were from records with incorrect herd identities). However, judging by information from the SBA and the results from paper II, the risk of this seems small.

Farm copies of veterinary records should give sufficient information for the evaluation of completeness. Most farmers kept their records for at least 5 years, either in a binder or box, or together with the invoices required for book-keeping, and the farm copies of the veterinary records are probably representative of the records delivered by the veterinarians.

In human medicine, medical paper records have previously been found to be incomplete. When paper records were compared with word-for-word transcripts of outpatient visits, they were found to be more complete for the chief complaint than they were for specific symptoms relating to the chief complaint, impression, tests, therapy and medical history (Romm and Putnam, 1981). Also, the physicians were imprecise in their statements to the patients about tests and therapies, information that was then reported in the record. In a questionnaire sent to cattle-practicing veterinarians in 2005, the majority of respondents (82%) stated that they reported essential diagnoses while the remainder (18%) reported diagnoses for which the animal received prescribed drugs (data not shown). This indicates that the information on the records could be insufficient for minor disorders.

In the course of the present research, the data on herd copies of the veterinary record were entered into a database by an animal technician. To handle possible transcribing errors we double-checked all records where the information in our database did not agree with the information in the DDD. Information in agreement with the DDD was assumed to be correctly entered in our database.

5.6.2 Study population and design

In the first study (papers I, III and IV), data were collected from farmers during January, April, July and October 2004. That approach was chosen to provide representative data through seasons; it was not regarded as feasible for the farmers to report data for a whole year. Farmers that did not report were contacted by telephone every second week until the report was received. However, it is possible that the results from the first study may have been biased by farmers forgetting to report disease events (i.e. recall bias). Firstly, in the data used in paper III, the proportion of diseased animals that were reported by the farmers as not receiving veterinary treatment was significantly higher in herds where the farmers reported directly, than it was in herds where the farmer had to be reminded. Also, the majority of those farmers that had failed to report veterinary-treated events belonged to the group that had to be reminded repeatedly (data not shown). Secondly, in the model for young animals in paper III, animals in herds where the farmer had good record-keeping ability appeared to have a lower probability of veterinary treatment than their peers in herds where the farmer was a poor record keeper. Consequently, as s a result of this recall bias, the incidences estimated in paper I may be underestimated. Likewise, the associations found in paper III may have been biased, as failure to report disease events to us was more likely for events not receiving veterinary treatment. Although seasonal variation in disease severity has been reported previously (Dohoo *et al.*, 1984, Hogan *et al.*, 1989, Riekerink *et al.*, 2007), the differences between study months found in paper III could have been affected by recall bias. The farmer's ability to detect mild clinical disease events may vary between housing and pasture seasons. Moreover, as the veterinarian leaves documentation on the farm, veterinary-treated events are likely to be easier to recall. This in combination with a hectic schedule during the harvest in July and a, possibly, reduced interest in the study in October, could have affected the reporting in favour of veterinary-treated events. In other studies where farmers have reported disease data, herds with reporters who were expected to perform poorly have been excluded (Olsson *et al.*, 1993, Ortman and Svensson, 2004). However, such measures may instead introduce further risk of selection bias, because the herds chosen may not be representative of the target population.

In the second study (paper II), eligible herds were located in one of eight counties that were selected on the basis that they had high dairy cow density, both private and state-employed veterinarians, and were geographically well spread over Sweden. Since most of the selected herds were visited, it was not practical to have a random sample of all herds in Sweden. In paper II, there were records from 155 veterinarians of which 55% were private. Also, in 2003 and 2004, the numbers of veterinarians with private practice that reported at least one record regarding cattle to the SBA were 357 and 443, respectively. The numbers of records reported from private and state-employed veterinarians in 2003/2004 were about the same (Government Offices of Sweden, 2005). Judging by those figures, our sample seems to be fairly representative.

As mentioned previously, a small number of events per group can result in biased estimates in multilevel logistic regression models (Clarke, 2008). To account for that, only herds with at least four events were included in the analyses in paper III. However, by doing this we reduced the representativeness of the sample, having significantly greater herd size and herd average milk yield in the 140 herds that were included than in the 31 herds that were excluded (Wilcoxon rank-sum test, $p<0.01$).

Main conclusions

- When all disease events were considered, incidences measures in the DDD were conservative, i.e. under-coverage was found, for: in cows; calving problems, clinical mastitis, cough (only when including herd outbreaks), gastro-intestinal disorders and lameness (both hoof and limb); and in young animals; cough, gastro-intestinal disorders and "other disorders".

- When only disease events that were veterinary-treated (according to the farmers) were considered, incidence measures in the DDD were conservative for cough and diarrhoea in young animals while the incidence for "other disorders" was significantly higher in the DDD than in the farmers data.

- The completeness, i.e. underreporting, of veterinary-treated disease events was estimated to 71% and 75% when the DDD was evaluated against farmers' data on veterinary-treated disease and the herd copy of the veterinary record, respectively.

- For diseases commonly associated with herd outbreaks, the possibility to provide herd-level incidence measures, also including group-reported disease events, needs to be considered further.

- Differential under-coverage in the DDD was found both for herd-specific factors (herd's main breed and possibly also herd size) and animal-specific factors (lactational stage and age).
  Differential underreporting of veterinary-treated events due to demographic factors (region and veterinary employment type) were

found. Differential underreporting and under-coverage needs to be considered when data from the DDD are used.

- The overall probability of capturing a disease event ranged from 30%-72%, depending on disease complex. Two important factors reducing completeness was if there was a low likelihood of disease events being veterinary-treated and if the disease complex was associated with herd outbreaks of disease, resulting in group-reporting. Those are, however, situations that the DDD is not designed to cover.

- To improve the registration from veterinarians, and specifically to further investigate why the completeness is lower for records from private veterinarians, seems to be the single most important step in the recording process in order to increase the completeness of the DDD.

6 Future research and development

- To fully estimate the accuracy of the DDD, correctness (i.e. the proportion of animals with a registered diagnostic event, that had the reported disease) will have to be evaluated. Because the information reported on the veterinary record was found to be insufficient for this task, other sources of information are needed. The correctness and consistency in the use of different diagnoses can be evaluated against qualitative interviews with veterinarians, an approach recently used by Lastein *et al.* (2009).

- The differential underreporting as well as the under-coverage found could have biased the association between disease and its risk factors when the data in the DDD was used in combination with other information (retrieved, for example, from the Cattle Database or farmer recordings). If the knowledge gained and the decisions made based on data from the dairy disease recordings and the Cattle Database are based on incorrect inferences, the tools for extension service, preventive health care and welfare measures may be misleading. Thus, there is a risk that we focus preventive health care on other factors than those that best promote animal health and welfare. The effect of underreporting or under-coverage can be studied by creating a model that predicts a likely disease scenario closer to the truth, by using prior knowledge regarding data loss.

- The differences between animals within herd and between herds with regard to whether diseased animals receive veterinary treatment needs to be studied further. This can be approached either qualitatively by interviewing farmers or quantitatively by using farmer-reported disease data including both diagnosis, thorough description of signs and the reasoning for the decision whether to contact the veterinarian or not.

- Before the completeness is improved by other means, a possible way to increase the completeness of the data used in research would be to only use data from groups identified as having the highest level of completeness. However, this would call for an analysis of the representativeness of such a study sample, with regards to breed composition, herd size and other factors.

- The most influential step in the recording process, next to notification, was the registration of manual records. This step needs to be further evaluated in order to differentiate between events lost because the record was not reported and those that were lost in the scanning process or because the animal's identity was incorrect.

7 Populärvetenskaplig sammanfattning

7.1 Bakgrund

En förutsättning för en etiskt försvarbar och ekonomiskt lönsam mjölkproduktion är att man söker minska och förebygga förekomsten av sjukdomar. De produktionssjukdomar som drabbar mjölkkorna är ofta multifaktoriella, dvs. flera bakomliggande orsaker samverkar till sjukdom. För att studera förekomst och orsaker till dessa sjukdomar kan man använda epidemiologisk metodik, med vilken man kan klarlägga orsakssamband med hjälp av observationer och mätningar på individer i deras naturliga miljö. Epidemiologisk forskning kräver stora material och insamling av information är i sin tur både tid- och kostnadskrävande. Därför kan befintlig information som samlats in för något annat ändamål än forskning (så kallade sekundära data) vara användbara. Sådan information finns för våra svenska mjölkkor.

I Sverige registreras information om mjölkkor på individnivå. Informationen inbegriper bland annat sjukdomsuppgifter, produktionsmått från månatliga provmjölkningar (avkastning, celltal i mjölken, fett- och proteinhalt i mjölken), fertilitetsuppgifter (inseminering, kalvning, undersökning och behandling) samt orsaker till utslagning. Dessa data registreras i Svensk Mjölks Kodatabas och används idag till underlag för rådgivning, avelsvärdering, statistik och forskning. Nyckeln mellan de olika uppgifterna i Kodatabasen är varje djurs unika identitetsnummer.

De sjukdomsuppgifter som registreras baseras framförallt på veterinärbehandlade sjukdomsfall. För att ett sjukdomsfall ska registreras måste djurägaren upptäcka sjukdomsfallet och därefter bestämma sig för att kontakta veterinären. Veterinären ska i sin tur föra journal och rapportera till Jordbruksverket. På Jordbruksverket registreras sjukdomsfallen och skickas till Svensk Mjölk där uppgifterna kontrolleras innan de registreras i databasen. Om sjukdomsfall rapporteras som gruppbehandlingar utan djurens identiteter eller om djuridentiteten är felaktig kan sjukdomsfallet inte registreras.

När sekundära data används i forskning är det viktigt att göra en kvalitetsbedömning av informationen. Om informationen är bristfällig riskerar man att få felaktiga resultat. Syftet med avhandlingen var att utvärdera hur stor del av observerade (av lantbrukaren) respektive veterinärbehandlade sjukdomsfall som registreras i Kodatabasen (täckningsgrad) samt om det skiljer sig mellan olika grupper av djur. För att i framtiden kunna förbättra täckningsgraden ville vi också identifiera var i registreringskedjan de största bortfallen sker.

7.2 Sammanfattning av studier och resultat

Två fältstudier genomfördes under 2004 i 177 respektive 112 besättningar. Informationen från fältstudierna jämfördes med informationen i Kodatabasen för samma besättningar. I första studien rapporterade lantbrukare in sjukdomshändelser till oss under fyra månader. Som sjukdomstillfälle räknades de fall då djuret verkade sjukt och lantbrukaren/djurskötaren antingen avvaktade, behandlade djuret själv, kontaktade veterinär eller slaktade djuret. I andra studien samlade vi in djurägarnas kopior av veterinärjournaler (851 journaler). Olika statistiska beräkningar användes för att pröva om det fanns skillnader mellan fältmaterialet och Kodatabasen.

Utifrån materialet i första studien skattades andelen sjukdomsfall som kom under veterinärvård. Vidare jämfördes djurägarregistrerad sjukdomsförekomst (både total sjuklighet och endast de fall som veterinärbehandlats) med informationen i Kodatabasen. Andelen av de sjukdomsfall som djurägarna rapporterat veterinärbehandlade som även återfanns i Kodatabasen beräknades. Slutligen analyserades om faktorer på besättningsnivå (t.ex. besättningens medelavkastning) eller individnivå (t.ex. djurets ålder eller avkastningsnivå) påverkade om ett djur med sjukdomssymptom blev veterinärbehandlat eller inte. I den andra studien undersöktes täckningsgraden av veterinärbehandlade sjukdomsfall i Kodatabasen. Vi kontrollerade även var i registreringskedjan bortfallen skedde samt om täckningsgraden varierade på grund av regionala skillnader, skillnader mellan privata och statligt anställda veterinärer samt skillnader mellan djur (t.ex. djur i olika åldersgrupper). Resultaten från båda studierna användes slutligen till att skatta sannolikheten för att ett observerat sjukdomsfall skulle registreras i Kodatabasen för fem olika sjukdomar (klinisk juverinflammation, kalvningsförlamning, hosta, hälta och diarré). Analysen tog hänsyn till varje del i rapporteringskedjan, dvs. från att djurägaren noterat ett sjukdomsfall till det registrerats i Kodatabasen.

Andelen sjukdomsfall som veterinärbehandlades skiljde sig för olika sjukdomar, exempelvis veterinärbehandlades 90% av alla kalvningsförlamningar och 78% av juverinflammationerna men bara 53% av fallen av hosta. Vi såg också att sjukdomsförekomsten var högre för djurägarregistreringarna (även icke veterinärbehandlade fall) jämfört med i Kodatabasen för flera av sjukdomarna (exempelvis klinisk mastit och hälta). Sannolikheten för att en veterinär skulle tillkallas påverkades av vilken ras som var vanligast förekommande i besättningen, om flera djur hade sjukdomsfall samma dag, vilken sjukdom djuret hade symptom på, djurets laktationsstadium, ålder (för kalvar eller ungdjur) samt under vilken studiemånad som fallet rapporterades.

I första studien där Kodatabasen jämfördes med djurägarregistreringar var täckningsgraden för veterinärbehandlade fall 71%. Baserat på materialet i andra studien skattades täckningsgraden till 75%. Täckningsgraden var högre för distriktsveterinärer än för privatpraktiserande veterinärer. Sannolikheten för att ett observerat sjukdomsfall skulle registreras i Kodatabasen (oavsett om fallet var veterinärbehandlat eller inte) varierade mellan 0.30 (för diarré) och 0.72 (för kalvningsförlamning). Om djurägaren kontaktat veterinär eller inte visade sig vara det steg i rapporteringskedjan som hade störst betydelse för registreringen.

Beräkning av sjukdomsförekomst baserade på Kodatabasen blir konservativa. Underrapporteringen berodde på flera faktorer och var även olika stor mellan olika grupper av djur och besättningar. När sjukdomsregistrering från Kodatabasen används i forskning är det viktigt att ta hänsyn till hur underrapporteringen kan påverka forskningsresultaten. Detta måste göras med utgångspunkt i det aktuella fallet.

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