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A STUDY OF THE TRENDS IN THE MALTESE BOVINE HUSBANDRY SECTOR FOLLOWING EUROPEAN UNION ACCESSION

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Summary

The creation of one centralised National Livestock Database (NLD) for the islands of Malta and Gozo was of crucial importance in the identification and traceability of bovines from 2002 to date. It was also important in covering legal obligations following Malta's accession to the European Union (EU) in May 2004. This thesis describes how the processes of identification, registration and traceability of bovines have changed following Malta's accession to the EU. The validation and integration of data originating from the different departmental sections such as the Identification and Registration section, the slaughterhouse and the National Veterinary Laboratory ensures that any discrepancies are highlighted and can be investigated. The various events recorded on the database allow for the cross-checking of compliance and eligibility of bovine producers applying for EU benefits. The main drawbacks and weak points of the system include financial costs for the government department, potentially late notification of births and deaths of new born calves and the insufficient uptake in the use of the latest technology by bovine producers for the notification of events such as births, deaths and movement of bovines.

The fact that the NLD is a computerised and centralised system has made collection, management and analysis of data possible. As a result principles of data mining have been used in this thesis to study in detail ten year trends in the number of bovine dairy holdings together with the bovine population on these holdings and to compare these trends with those reported in other European countries. Six trends related to the number of bovine dairy holdings and their bovine population were analysed in the study: the trend in the number of dairy holdings on the Maltese Islands; the trend in the total number of bovines on dairy holdings; the trend in the number of female bovines over two years of age (F>2y); the trend in the average bovine population (average herd size) on dairy holdings; the trend in the average number of female bovines over two years of age; the trend in the number of female and male bovines and their ratios.

The general trends showed that there was a significant decrease in the number of dairy holdings, in the bovine population and in the number of female bovines greater than 2 years of age on dairy holdings during the study period. The average herd size and the average number of females greater than 2 years of age on the individual dairy holdings

showed no statistically significant changes. On the other hand, a significant increase in the ratio of female to male bovines was registered on these holdings.

In the final part of this thesis, data on calf deaths was used to determine the overall mortality rates of live born calves up to 180 days of age in dairy herds on the islands of Malta and Gozo. This is the first time that data using the NLD is being used to determine the calf mortality rates from the whole dairy population of Malta and Gozo. Furthermore, five risk factors namely the island of birth, sex of calf, average herd size, the year and the season of birth were also studied. The data set used in the study consisted of a total of 44,078 calves born between 1 January 2004 and 31 December 2011.

From this dataset, 28,848 calves were born in Malta and 15,230 in Gozo. In total 2,821 calves were registered as having died before reaching 180 days of age. The overall calf mortality rate in live born calves up to 180 days of age was found to be 7.08%. In Malta the overall mortality rate was 6.05% and in Gozo 8.80% ($P<0.001$). The overall mortality rate was 8.50% for male calves and 6.00% for females ($P<0.001$). Holdings with a lower average herd size had a significantly lower calf mortality rate ($P = 0.01$) whereas no significant difference was found when the season of birth was taken into consideration. A significant difference ($P<0.001$) was present when calf mortality was stratified by the year of birth, with the last three years of the study having a lower mortality rate than the first five years.

Riassunto

La creazione di un database nazionale centralizzato per bovini (NLD: National Livestock Database) per le isole di Malta e Gozo è risultato di importanza cruciale per l'identificazione e la rintracciabilità dei bovini dal 2002 ad oggi. Divenne inoltre un obbligo legislativo a seguito dell'adesione di Malta all'Unione Europea (UE) nel maggio 2004.

La presente Tesi descrive come i processi di identificazione, registrazione e tracciabilità dei bovini siano cambiati dopo l'adesione di Malta all'UE. La validazione e l'integrazione dei dati provenienti da diverse sezioni dipartimentali, come la sezione di identificazione e registrazione dei bovini, il macello ed il laboratorio veterinario nazionale, assicurano che le eventuali discrepanze siano evidenziate e possano essere investigate. I vari eventi registrati nel database consentono inoltre il controllo incrociato di conformità ed ammissibilità degli allevatori ai benefici previsti dall'EU. I principali svantaggi ed i punti deboli del sistema sono rappresentati dagli alti costi finanziari per il dipartimento del governo, dalle notifiche di nascite e morte talvolta tardive e dalle difficoltà di implementazione tecnologica da parte degli allevatori, necessaria per la notifica degli eventi come nascite, decessi e movimentazione dei bovini stessi.

Tuttavia, la gestione computerizzata e centralizzata della NLD ha permesso un'efficiente raccolta, elaborazione ed analisi dei dati. Pertanto, con la presente Tesi è stato possibile studiare l'evoluzione nel numero di aziende di bovine da latte in tali popolazioni negli ultimi 10 anni, la numerosità di capi nelle aziende stesse e confrontare questi dati con quelli segnalati in altri paesi Europei. Nello studio sono stati analizzati 6 fattori legati alla numerosità degli allevamenti ed al numero di capi per allevamento: il trend del numero di aziende di bovine da latte sulle isole maltesi; il trend del numero totale dei bovini da latte nelle aziende; il trend del numero di bovine femmine superiori ai due anni di età (F > 2y); il trend delle dimensioni medie delle mandrie; l'andamento del numero medio di bovine femmine superiori ai 2 anni di età su ogni allevamento; l'andamento del numero di bovine femmine e maschi e il rapporto femmine-maschi.

I risultati generali indicano che durante il periodo di studio si è verificata una diminuzione significativa del numero di aziende di bovine da latte come pure della popolazione bovina complessiva, ed in particolare nel numero di bovine superiori ai 2 anni di età. Le dimensioni delle mandrie ed il numero medio di femmine superiori ai 2 anni di età su ogni allevamento non hanno mostrato variazioni statisticamente significative. D'altra parte, un aumento significativo del rapporto femmine-maschi è stato registrato in queste aziende.

Nella parte finale della presente Tesi sono stati presentati i dati sui decessi, necessari per evidenziare il tasso di mortalità fino ai 180 giorni di età dei vitelli nati vivi in allevamenti presenti nelle isole di Malta e Gozo; tali elaborazioni sulla mortalità risultano ancor più rilevanti dal momento che questi risultati rappresentano i primi dati elaborati e presentati da quando è presente il NLD in tali popolazioni di Malta e Gozo. Sono stati inoltre analizzati 5 fattori di rischio: isola di nascita, sesso del vitello, dimensione media della mandria, anno di nascita e stagione di nascita. Il set di dati utilizzato nello studio era composto da un totale di 44.078 vitelli nati tra il 1 gennaio 2004 ed il 31 dicembre 2011.

Da questo dataset, 28.848 vitelli sono nati a Malta e 15.230 a Gozo. In totale, 2.821 vitelli sono stati registrati come morti prima di raggiugere i 180 giorni di età, con un tasso di mortalità complessivo in vitelli nati vivi fino a 180 giorni di età pari al 7.08%, con una differenza statisticamente significativa ($P< 0.001$) tra Malta e Gozo, 6.05% ed 8.80%, rispettivamente. Il tasso di mortalità generale è risultato del 8,50% per vitelli maschi e 6,00% per le femmine. Aziende con una dimensione della mandria relativamente bassa hanno presentato un tasso di mortalità dei vitelli significativamente inferiore ($P = 0.01$) a quelle piu numerose. Nessuna differenza significativa è stata riscontrata in merito alla stagione di nascita, mentre delle differenze sono state evidenziate in merito alla mortalità a seconda dell'anno di nascita, dove gli ultimi 3 anni dello studio hanno mostrato un tasso di mortalità piu basso rispetto ai precedenti 5 anni.

List of Abbreviations

ANOVA:	Analysis of variance
BC:	Before Christ
BSE:	Bovine Spongiform Encephalopathy
DEFRA:	Department of Environment, Food and Rural Affairs of the United Kingdom
DNA:	Deoxyribose Nucleic Acid
EBL:	Enzootic bovine leucosis
EC:	European Commission
ELISA:	Enzyme-linked immunosorbent assay
EU:	European Union
EU-27:	All member states excluding Croatia which joined the European Union on the 1st of July 2013
GB:	Great Britain
GDP:	Gross Domestic Product
I&R:	Identification and Registration Section (Malta)
IT:	Information Technology
KPĦ:	Kooperativa Produtturi tal-Ħalib
MDP:	Malta Dairy Products Limited
MMU:	Milk Marketing Undertaking
MSDEC:	Ministry for Sustainable Development, the Environment and Climate Change (Malta)
M1:	Method 1
M2:	Method 2
M3:	Method 3
NLD:	Maltese National Livestock Database
NS:	Not significant
NSO:	National Statistics Office (Malta)
NVL:	National Veterinary Laboratory (Malta)
OIE:	World Organisation of Animal Health
OV:	Official Veterinarian
SD:	Standard Deviation
SPSS:	Statistical Package for the Social Sciences

STATA:	Statistics and data
USA:	United States of America
VPRD:	Veterinary and Phytosanitary Regulation Department
VSO:	Veterinary Support Officer

Chapter 1

Introduction

1.1 The Maltese Islands and its history relating to livestock

Malta is made up of an archipelago of five islands located in the middle of the Mediterranean Sea, 93 km to the south of Sicily and 290 km to the north of Libya. The Northern latitude is 36°00′00″ and the Southern latitude is 35°48′00″. The total area of the islands is 316 km^2. Malta is the largest island having an area of 247 km^2 and a population of approximately 385,000. Gozo has an area of 66 km^2 with a population of approximately 31,000 whilst Comino is only 3 km^2 (National Statistics Office Malta (NSO), 2012). The two other islands of Filfla and Cominotto are very small and uninhabited. This adds up to a total population of approximately 416,000 and a population density of 1,317 persons per km^2. Due to this high population density all livestock breeding including bovine husbandry systems are of the intensive type.

Livestock (mainly swine) were present on Comino in the past, but during the period under review in this study no bovines were registered as being present on Comino and therefore all the results presented in this work refer to data collected on the islands of Malta and Gozo.

The presence of livestock and in particular sheep, goats, pigs and cattle has been established in archaeological findings at Skorba in Malta from the Neolithic age (c. 5000 – 1400 BC) (Savona Ventura, 1997).

The tenth century Arab chronicler Ibn Hauqal writes that during this period the islands were inhabited only by savage donkeys, numerous sheep and bees. Furthermore, in the twelfth century Al Idrisi, the Arab geographer of the Norman King Roger II reports that pasture, sheep, fruit and honey abounded in Malta (Cassar, 2000).

In one of his works Wettinger, 1981 reports that in the 1400s the lack of rain led to the drying up of pasture used for grazing resulting in high mortality rates in cattle and other livestock. During this period oxen were mainly present on the islands and used as draught animals for the ploughing of fields and for treading wheat. During the fifteenth century common grazing ground was still present and important for the survival of livestock. Pasture land is not available nowadays and only small flocks of sheep and goats can occasionally be seen grazing on small parcels of land in a few villages. It is interesting to note that in the same work the author writes that the earliest documented sale of cattle present in Malta is from 1467.

In the late nineteenth century, Godwin (1880) a chaplain to the English forces based in Malta, reports that around 6000 head of cattle were present on the Maltese Islands. These are described as being of two types. The first type is described as a large, strong, fawn coloured animal used to till the land, producing little milk but commonly having two calves at a time. The second type is called the Barbary ox, a smaller animal imported from Africa, stall fed on green barley, clover, cotton seed and even leaves of the prickly pear and then slaughtered for its meat. Animal husbandry and the products obtained from these animals particularly meat and milk contributed significantly towards the survival of the Maltese population during these times and also during the first and second World Wars when these commodities were scarce (Galea & Debono, 2014).

In more recent times the agricultural sector is seen to play a relatively small role with regards to its contribution to the gross domestic product (GDP) of the islands. In fact the contribution of the agricultural and fisheries sector towards GDP in 2009 amounted to only 2% (Briguglio, 2011). The agricultural labour force has been an ageing one but following EU accession, the availability of EU funds has attracted the younger generation (Briguglio, 2011). The number of students reading for an agricultural degree is also relatively small. In 2010/2011 the number of students graduating from the University of Malta in the fields of agriculture, forestry and fisheries was only 15 representing 0.52% of the total number of graduates (NSO, 2013b). One has to keep in mind that no faculty of Veterinary Medicine is present on the islands and as a result students wishing to take up this field of study have to enrol in a university overseas.

The agricultural and fisheries sector, albeit being very small is important from a social and economic point of view since it provides the Maltese population with a certain degree of self-sufficiency in certain food items such as fresh milk (Briguglio, 2011).

1.2 The main characteristics of agricultural holdings in Malta and Gozo

The majority of agricultural holdings including dairy holdings in Malta and Gozo are relatively small and run by a sole-holder or by members of the same family. In a farm structure survey carried out by the NSO in 2013, it is reported that agricultural holdings belonged to a sole-holder in 98.6% of the holdings in Malta and Gozo. 1.1% belonged to a group of holders or were in partnership whereas 0.3% belonged to a company (NSO, 2014).

In the case of sole-holder agricultural holdings, the manager was the sole-holder in 96.9% of these holdings. In 1.3% the manager was the sole-holder's spouse and in 1.7% the manager was a family member of the sole-holder (NSO, 2014). These values are important especially when considering the running of dairy holdings since they imply that in the great majority of cases the owner or a close family member is also the manager of the holding. This is a factor which has been shown to influence the survival of calves especially during the first few weeks of life (Hartman et al., 1974; Jenny et al., 1981; James et al., 1984; Gulliksen et al., 2009) and this is discussed in detail in the section relating to the study of calf mortality rates at chapter 4.

Another important detail is the fact that 92.8% of the agricultural holdings on the Maltese islands are run on a part-time basis. This denotes that most holdings are relatively small. A detailed study of the trends in the number of dairy holdings, the dairy bovine population and how it is made up is found in chapter 3.

1.3 The dairy sector on the Maltese Islands

The primary aim of dairy holdings in Malta and Gozo is the production of fresh milk for human consumption. The leading dairy processing plant in the Maltese Islands is Malta Dairy Products Ltd (MDP). It is part-owned by the milk producers who are

members of the milk producing co-operative called Kooperativa Produtturi tal-Ħalib (KPĦ). KPĦ has a 70% shareholding of MDP whilst the Government of Malta has a 30% shareholding (Benna, 2014). It dates back to 1938 when a government department than known as Malta Marketing Undertaking (MMU) was set up with the main aim of pasteurising mainly goat's milk to reduce the incidence of brucellosis in humans consuming fresh milk (Wyatt, 2009). In 1986 the responsibilities of MMU were taken up by MDP (Benna, 2014).

The presence of brucellosis especially in goat herds in the 1800s was of great concern to the local authorities. It was reported that about 10% of goats in Malta were actively excreting the bacterium in their milk which could lead to what was termed "Malta Fever" (Wyatt, 2009). It was in 1887 that Sir David Bruce isolated the bacterium *Micrococcus melitensis,* later renamed *Brucella melitensis,* from a British soldier who died from the disease while stationed in Malta (Godfroid et al., 2005). In 1905 Sir Themi Zammit isolated the bacterium from goat's milk thus showing the zoonotic nature of this disease (Wyatt, 2005). The eradication process of brucellosis in Malta and Gozo included amongst other things a scheme in the 1950s where farmers having goats slaughtered during the eradication campaign, were compensated with a cow for every twelve goats slaughtered (Rizzo Naudi, 2005). From this period onwards the goat population decreased progressively and fresh milk for human consumption is nowadays derived from cow's milk with goat's milk being used mainly for the production of local cheeselets.

The quantity of fresh milk sold by dairy producers in *000 of litres for the years 2003 to 2012 (NSO, 2006; NSO, 2009; NSO, 2013b) is shown in Table 1.

Table 1: Quantity of fresh milk sold by dairy producers in *000 of litres for the years 2003 to 2012

Year	Quantity of milk sold in *000 of litres
2003	38,854
2004	39,924
2005	40,266
2006	40,049
2007	39,410
2008	38,863
2009	38,301
2010	40,895
2011	40,474
2012	42,092

During this period the mean value of fresh milk sold by the producers per year was 39,912,800.00 litres (SD 1,117,828.00). The rapid decrease in milk production during the years 2007 to 2009 (Fig. 1) can be attributed to a decrease in the number of milking cows due to the enzootic bovine leucosis eradication campaign carried out on the Maltese Islands during this period (Government of Malta, 2009).

The national milk quota for Malta and Gozo is currently capped at 51,177 tonnes of milk a year (European Commission, 2012). In 2012 the milk production in Malta and Gozo achieved around 82% of this quota.

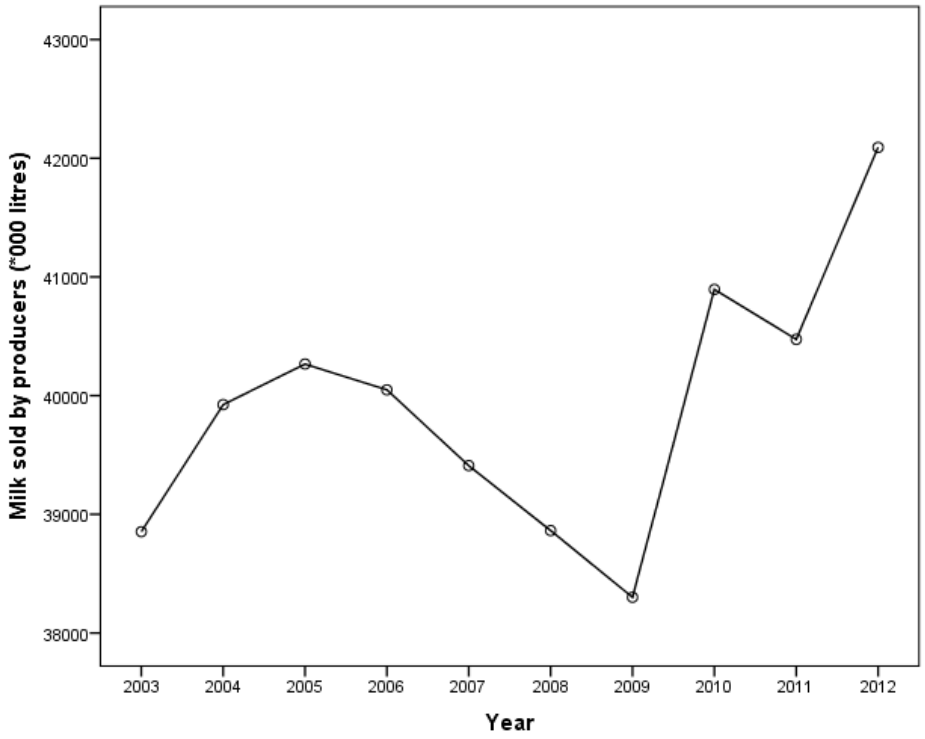


Figure 1: Line graph showing the quantity of milk sold by producers (in *000 litres) per year from 2003 to 2012

1.4 The importance of traceability of animals and their products

The importance of traceability of animals and their products on the Maltese Islands is of great importance especially following all the hardships due to the long presence of brucellosis in milk herds in the past. Traceability of animals and their products has become a priority for governments of many countries due to the demands by consumers for more comprehensive and integrated food safety policies (Caporale et al., 2001). This is especially so following the BSE crisis in Europe starting in the late 1980s (Cherfas, 1990) and the *Escherichia coli* O:157 infections in the USA in 1993 (Rangel et al., 2005). Moreover, consumers nowadays want more information about their source of food and also details regarding the various production systems from which livestock is sourced. Efficient animal identification systems, animal movement records and food chain data are crucial for traceability and food supply chain management (Pettitt, 2001). Different systems are used in different countries to ensure this traceability. In Malta and

Gozo the National Livestock Database (NLD) is at the core of such a traceability system.

The term "traceability" can be defined in many ways depending on the area of interest. According to the Oxford Dictionary the verb 'trace' is derived from the Latin *tractus* and has a number of meanings which include:

a) To find or discover by investigation;
b) To find or describe the origin or development of;
c) A procedure to investigate the source of something (Oxford Dictionaries, 2014).

If one had to define traceability with regards to animal health and food safety, a number of related definitions can be found. These highlight the various aspects of the long chain of events which make up such traceability systems. For example, the World Organisation for Animal Health (OIE) defines animal traceability in its Terrestrial Animal Health Code as "the ability to follow an animal or group of animals during all stages of its life" (OIE, 2014). Caporale et al., 2001 define traceability in the fields of animal health and food safety as the ability to document movements, processes and controls which are needed to define an animal or an animal product life history.

Traceability would not be possible without animal identification and an appropriate and efficient animal identification system. Records related to animal movements are of particular importance because animal movements are considered a risk factor for disease transmission (Bajardi et al., 2012). The OIE defines animal identification in its Terrestrial Animal Health Code as "the combination of the identification and registration of an animal individually, with a unique identifier, or collectively by its epidemiological unit or group, with a unique group identifier" (OIE, 2014). Furthermore in the same code it defines an animal identification system as "the inclusion and linking of components such as identification of establishments/owners, the person(s) responsible for the animal(s), movements and other records with animal identification" (OIE, 2014). How the NLD includes and links these components to ensure an efficient identification and registration system for bovines on the Maltese Islands is found in Chapter two.

By means of Resolution XXX of the 27 May 2004 the OIE recognised the importance of animal identification and traceability in the sphere of animal health, public health and trade. Furthermore by means of this resolution the OIE resolved to determine a common definition of animal traceability, to propose guidelines for the development of identification and traceability systems, to disseminate updated information with the latest advances in the field of animal identification and traceability and to collaborate with international organisations to facilitate the design and implementation of animal identification and traceability systems (OIE, 2004). Some of the different traceability systems found in EU and non-EU countries are described in Chapter two together with the advantages and disadvantages of such systems.

In an editorial from 2008 entitled "Animal identification and product traceability from the farm to the fork must be progressively implemented worldwide" Bernard Vallat, Director General of the OIE writes that "Traceability constitutes the link between animal health, food safety and the organoleptic characteristics of food linked to its origin" (OIE, 2008).

With regard to food safety, traceability is important in preventing food contamination and to respond promptly and effectively in the event of a crisis. An efficient traceability system can also help to eliminate any unjustified trade barriers since it can provide trading partners with assurances regarding the safety of any products they import (OIE, 2008).

Apart from the benefits mentioned above, other benefits reported in various countries can be listed with regards to bovine traceability systems. One such benefit of the setting up of a bovine traceability system is that shown by the Bovine Traceability Unit in the Dominican Republic which was reported as leading to a significant reduction in the theft, illegal sale and purchase of cattle in the country (The Beef Site, 2013b).

Another benefit obtained where a livestock traceability system was implemented was in China. A system for keeping track of livestock and poultry was reported to be implemented throughout the Zhejiang province in order to prevent the dumping of animal carcasses in the Huangpu River (The Beef Site, 2013a).

Traceability is also important in ensuring adequate animal welfare standards by being able to trace individual animals to their herds or holdings of origin. Concern on the part of the consumer on animal welfare started off when animals started being kept in confinement production systems in the 1970s (Fraser et al., 2013).

The description of the setting up of the Maltese National Livestock Database, which represents the unique identification and registration system on the Maltese islands, together with a detailed appraisal of the system following ten years of its implementation and the way all the points discussed above are integrated into this system may be found in Chapter two of this thesis.

1.5 The importance of data collection, analysis and interpretation

In the parts of this study which are found in chapter three and four, data mining techniques were used for the collection of data, its analysis and interpretation. Garcia, 2013 states that data collection, its analysis and interpretation are of great importance in the implementation of food safety controls and in animal and public health programmes.

The use of Data Mining which is also referred to as Knowledge Discovering in Databases is an important method of analyses for the identification of relationships between different data collected and its use in increasing knowledge and to support decision making in the animal, food and health industries (Garcia, 2013).

Data mining has been defined by Larose, 2005 as the process of analysing large amounts of stored data to discover useful correlations, patterns and trends by using either mathematical or statistical methodologies and is predicted to be one of the most important emergent technologies in recent times.

The main data mining techniques are used mainly for two purposes, descriptive as has been used in this study, and those for predictive purposes (Garcia, 2013). It is important to keep in mind that the results obtained from data mining depend on the availability of the data, its accuracy and quality (Garcia, 2013). Centralising data as is the case with

the Maltese NLD helps to improve data consistency. This, together with the availability of the data, its accuracy and quality are discussed in Chapter two.

Garcia (2013) argues that cattle farmers should be informed regarding the benefits of keeping useful data for analysis. This should be promoted and supported by government, universities and professionals working with the farming community. Moreover, this author also reports that in developed countries, dairy farmers seem to be more familiar with computerised data collection and data analyses than beef farmers.

The main purposes for the use of data mining in bovine databases are in analyses of animal production, health and welfare and disease control. According to Garcia, 2013 any important results should be reported to the industry, the scientific community and the press so that even society at large can be made aware of interesting outcomes. A case in point is the interest generated when the Maltese NLD was mentioned in a news article by one of the local newspapers. The role of the database was questioned following reports of the dumping of slurry on agricultural fields (Times of Malta, 2014).

Vertical integration in the dairy and beef industries together with the use of individual animal identification systems are generating large amounts of data. As a result the use of data mining techniques is now necessary to improve animal production, health and welfare and to comply with current legislation (Garcia, 2013). In this specific study data mining was made use of in chapters three and four to determine the trends in the number of dairy holdings in Malta and Gozo over a ten year period, the trends in the bovine population on these holdings over the same time period and to establish for the first time the mortality rates of live born calves up to 180 days of age on dairy holdings in Malta and Gozo.

1.6 Objectives of this research project

The main aim of this research project was to make use of data in the National Livestock Database in use on the Maltese Islands as from 2002 i.e. two years before Malta's accession to the European Union (EU), to attain a number of objectives.

The objectives of this research were:

a) To describe and assess how the processes of identification, registration and traceability of bovines have changed just prior to and following Malta's accession to the EU.
b) To describe the setup of the NLD with regards to the registration of bovine holdings and bovine identification and registration on the Maltese Islands.
c) To identify the merits and weak points of the NLD and give suggestions on how it can be improved.
d) To compare and contrast the Maltese NLD with other traceability systems present in the EU and in some non-EU countries.
e) To use data mining techniques using the NLD to produce datasets which were then analysed statistically to assess the trends in the number of bovine dairy holdings and their bovine population over a ten year period from 2003 to 2012.
f) To produce datasets, using the NLD, which were then used in a benchmark study of calf mortality rates from 2004 to 2011.
g) To determine the mortality rate of calves up to 180 days of age and investigate five risk factors which may have an effect on the mortality rate of these calves present on dairy holdings on the islands of Malta and Gozo.

This thesis has been divided into five chapters. The first chapter is the general introduction containing background information important in the better understanding of the research project. For ease of reference, the research part of the thesis is divided into three main chapters (chapters 2, 3 and 4).

Chapter two includes a detailed discussion of the setup and legal basis of the NLD and then describes the different sections of the database and the interaction between the different parts together with an appraisal of the system and comparison with traceability systems found in other EU and non-EU countries.

Chapter three contains the study of the ten year trends (2003 - 2012) in the number of bovine dairy holdings on the Maltese Islands together with detailed analyses of the changes in the bovine population during this period. Chapter four is a comprehensive benchmark study, carried out locally for the first time, to investigate dairy calf mortality rates up to 180 days of age on the Maltese Islands and a study of five risk factors which

may influence calf mortality rates. Some of these risk factors have been reported by various authors (Jenny et al., (1981); Waltner-Toews et al., (1986a, b); Wells et al., (1996); Svensson et al., (2006); Gulliksen et al., (2009)) to influence calf mortality rates. The aim of this latter part of the study was to investigate how calf mortality rates differ when the various risk factors were taken into consideration and to compare these rates with those already described by the authors mentioned. The main research findings of each section are listed in point form at the end of each chapter respectively.

The general conclusions of the thesis are found in Chapter five.

Chapter 2

The setup, legal basis and appraisal of the Maltese National Livestock Database with regards to bovine traceability following ten years of its implementation

2.1 Introduction

Identification of livestock has been considered an important issue since man started keeping livestock. Evidence regarding the identification of live animals, by means of body markings, can be found as far back as 3,800 years ago in the Code of Hammurabi (King, 1910). Marking of live animals to identify ownership was especially important with regards to valuable livestock. Later on, the use of branding had particular importance for disease control purposes in livestock (Blancou, 2001).

Freeze branding and ear tagging have been practiced on the Maltese Islands for permanent marking of bovines. These two identification systems were useful for two main purposes: to claim ownership of bovines and to identify bovines during the brucellosis and tuberculosis surveillance and eradication programmes. Legislation dating back to 1924 empowered the Superintendent for Public Health to order that cows, goats or sheep be branded, wear a marked collar, ear stud or other mark for the purpose of identification (Government of Malta, 1924). The same legislation also required the Director of Agriculture and Fisheries to keep a register of farms and of any persons working therein, and for every keeper to keep a farm book.

Prior to Malta's accession to the European Union on the 1st of May 2004, no centralised computerised system was used to store data pertaining to the bovine husbandry systems in Malta and Gozo. Any data generated by the Department of Veterinary Services within the Ministry of Agriculture and Fisheries, such as data relating to the ongoing disease surveillance programmes, was stored mainly in the form of paper records. Copies of movement permits relating to the movement of bovines, ovines and caprines from one holding to another were stored in individual files for each holding. However,

although these records were quite comprehensive, any tracing forwards or backwards of animals required during epidemiological studies, was a long and laborious process requiring analyses of paper records present in the various files.

During the run up of Malta's accession to the EU, the identification of bovines and the way data generated in this area was stored and analysed changed radically. One of the main reasons for this change was the introduction of the National Livestock Database to store, manage and analyse data.

The aim of this part of the research project is to describe how identification, registration and traceability, with regards to the bovine sector, are managed via the NLD on the Maltese Islands since EU accession. A comparison of the Maltese NLD to other traceability systems in EU countries and also in non-EU countries is carried out. The study also lists the merits and drawbacks arising from ten years of implementation of the NLD.

2.1.1 Present situation: Plastic ear tags and herd registers

As from 2002, plastic ear tags started being used on new-born calves and to replace the metal ear tags on adult bovines. Subsidiary Legislation 437.84 published as Legal Notice 311 of the 2nd of September 2005 of the Laws of Malta was enacted to cover the use of these ear tags (Government of Malta, 2005a). In practice, EC Regulation 1760/2000 (EC, 2000) and EC Regulation 911/2004 (EC, 2004b) were implemented. As a result, bovines started being identified by an ear tag number which is unique to each individual animal and which accompanies it throughout its life. Each ear tag is made up of: the two letter country code (MT) of Malta, the Maltese Coat of Arms, a bar code and a seven digit number, the last digit of which is a check digit (Fig. 2).

Figure 2: Bovine plastic ear tags

Furthermore, owners of bovines were now legally obliged as per Regulation (EC) No 1760/2000, to keep more comprehensive records regarding their herds on their herd register. The date of birth, death and movement of all bovines on the holding should be listed on the register. The ear tag number of calves together with the identification of the mother is also recorded. When animals are bought, details of the holding of origin are listed and in the case of bovines sold, details of the holdings to which the animals are sold must be recorded for traceability purposes.

2.2 Traceability and the National Livestock Database

In recent times the issue of traceability, especially during disease outbreaks, has become more important (Wismans, 1999; James, 2005; Anderson, 2010). This can be achieved through the three pillars of traceability namely:

a) Animal identification;
b) Premises identification;
c) Tracking of animal movements (Carlberg, 2010).

From a practical point of view this would require that:

a) All animals are permanently identified with a unique number;

b) All livestock holdings together with their location are registered;
c) Herd registers containing information regarding the herd are kept on all holdings;
d) Records of movements in and out of holdings are kept;
e) One or more databases are set up to provide a link between points (a) to (d) mentioned above and to give real-time traceability of all livestock present on the holdings.

Traceability is difficult to implement and control without the necessary legislation. In Malta, Subsidiary Legislation 437.78 (Government of Malta, 2005b) and the previously mentioned 437.84 (Government of Malta, 2005a) published as Legal Notices 292 and 311 of 2005 respectively were enacted. The scope of these laws was to give power to "the competent authority for the territory of Malta", in this case the Veterinary Services of Malta, to implement these rules according to the relevant EU legislation. This also ensures the mandatory participation by all the stakeholders in Malta and Gozo. Anderson, 2010 and Stanford et al., 2001 describing bovine identification systems in the United States and Canada respectively, acknowledge the importance of mandatory participation by all producers and have highlighted the problems related to different identification systems such as their ease of use, reliability, costs and acceptance of the system by all stakeholders.

2.2.1 The setting up and legal basis of the NLD

The setting up of the NLD has played a crucial role in the recording, management and analysis of livestock data. The use of the NLD together with the inputting of data started gradually in 2002 as a pre-requisite for Malta to join the EU.

Consequently, the Commission of the European Communities recognised the fully operational character of the Maltese database for bovine animals stating by means of Article 1 of Commission Decision 2004/588/EC of the 3rd of June 2004 that "the Maltese database for bovine animals is recognised as fully operational from 1 May 2004" (EC, 2004a).

Furthermore, Article 1 of Commission Decision 2005/415/EC of the 1st of June 2005 authorising Malta to make use of the system established by Title I of Regulation (EC) No 1760/2000 states that "Malta is hereby authorised to replace the surveys of bovine animals provided for by Directive 93/24/EC (EC, 1993) by using the system for the identification and registration of bovine animals as referred to in Title I of Regulation (EC) No 1760/2000 to obtain all the statistical data required to comply with the obligations arising out of the said Directive" (EC, 2005). In practice, following this decision, Malta was authorised to replace the surveys of bovines provided for by Directive 93/24/EC by using the NLD to obtain all the statistical data required to comply with the obligations arising from the said directive.

Starting from its implementation in 2002, the Department of Veterinary Services which is now the Veterinary and Phytosanitary Regulation Department (VPRD) is responsible for managing and running the database. As a result, the NLD is national and centralised and fragmentation in the collection of data is kept to a minimum. The different sections within the Department dealing with caprines and ovines, the swine section, the poultry section, the equine section and the National Veterinary Laboratory (NVL), all input and manage data pertaining to their sections. Other government departments or entities are given authorised access to the database but adding or editing data is only allowed following authorisation from the database administrator.

The NLD can manage data in three main areas:

a) Data regarding animal identification, registration and traceability of animals and/or their products;
b) Data regarding animal health records such as disease surveillance programmes and their control;
c) Data regarding production information which is particularly useful to producers and breeding organisations.

Data regarding the first two areas are utilised mainly by government departments involved in veterinary affairs and in managing payments of EU livestock premiums. Data listed in the first area are also utilised by the National Statistics Office of Malta. This office is responsible for drawing up the yearly cattle census, such as the NSO Cattle Survey (NSO, 2013a) in accordance with Commission Regulation (EC)

1165/2008 (EC, 2008a).

Producers and breeding organisations can be allowed access to the data in the third area. In fact the NLD is structured in such a way so as to allow various entities using it to be able to request programmes they might require from the database developers. Producers can also be given authorisation to utilise certain on-line applications such as visualisation of data pertaining to their herd. This can be used as an important data validation tool and in fact, in some countries such as Switzerland users have to check their own data and report back any errors so that action can be taken to ensure that the database contains only accurate data (MAF Biosecurity New Zealand, 2009). The NLD also allows for the online application for animal movement permits by the producers.

Additional facilities for breed societies and production recording agencies can allow the recording of lactation data, individual milk tests, linear assessments, etc. Currently the NLD is not being utilised to manage data in the third area.

2.2.2 Training of Departmental staff and stakeholders

Apart from the setting up of the actual database and making sure that all the necessary information technology (IT) infrastructure and legislation was in place, training of all Departmental staff and stakeholders in the bovine sector was necessary. Internally organised training of Official Veterinarians (OVs) and staff involved in data entry commenced in 2002. Veterinary Support Officers (VSOs) responsible for the tagging of bovines were also trained on how to apply the EU approved ear tags and on how to prepare all the necessary paper work involved. Bovine producers were instructed on their legal obligations, on how to keep records on their farm register and on how to liaise with the Department regarding notification of births, deaths and movements. OVs were also trained on how to audit data on herd registers and on how to carry out a random or targeted census to verify that data held by the database reflected the actual population status on the holdings. This is another important point in the validation of data present in the NLD since any discrepancies can be flagged and action taken accordingly.

2.2.3 The recording of data on the NLD

The NLD is of value only as long as the data it contains covers the totality of bovine holdings present in Malta and Gozo together with their respective herd populations. For such a system to be comprehensive, the following data are collected:

a) Registration of all holdings containing bovines in Malta and Gozo;
b) Registration of all ear tags applied to bovines;
c) Registration of all movements of bovines from one holding to another, to a slaughterhouse or a temporary exhibition.

2.2.3.1 Registration of all holdings containing bovines in Malta and Gozo

All holdings of bovines are required by law to be registered with the Veterinary Services Department of Malta as at article 3 (1) (a) of Subsidiary Legislation 437.78. The scope of this law is to implement the rules found under the following EU laws: Directive 92/102 (EC, 1992a), Decision 89/153 (EC, 1989), Directive 91/496 (EC, 1991), Regulation 3508/92 (EC, 1992b), Directive 90/425 (EC, 1990), Directive 88/661 (EC, 1988) and Directive 64/432 (EC, 1964).

On the Maltese Islands, all bovine holdings irrespective of the area of production or the number of heads, are registered on the NLD. Apart from being given a unique code, the longitude and latitude of these holdings are also recorded in the database. In the ten year period under review starting from the 1st of January 2003 to the 31st of December 2012, 358 active holdings were registered in Malta and 61 in Gozo giving a total of 419 holdings. These holdings include both dairy holdings and also non-dairy holdings mainly keeping bovines for fattening and slaughter. The latter are normally run on a part-time basis by family members. Active holdings are defined in this study as those holdings having an average of at least one bovine on the holding throughout the 10 year period under review.

Out of 126 dairy holdings registered in Malta, 89 holdings had less than 100 bovines (71%) and out of 232 non-dairy bovine holdings in Malta, 216 had a herd of less than 20 bovines (93%). In Gozo, out of 49 dairy holdings registered during the ten year

period under study, 27 holdings had less than 100 bovines (55%) and out of the 12 non-dairy bovine holdings, all had less than 20 bovines on the premises (100%). This data, together with data presented further on in this chapter are shown in Table 2. Even though the smaller holdings keep very few bovines, since they are also involved in the buying and selling of stock, their registration is required for traceability purposes.

Table 2: Summary of the main data groups generated for the bovine sector over a ten year period starting 1st of January 2003 till 31st December 2012

Main bovine data groups	Malta	Gozo	Total
Number of towns where active bovine holdings are registered	48	12	60
Number of holdings registered as active milk producers	126	49	175
Number of active holdings keeping bovines for fattening and slaughter	232	12	244
Average number of bovines on all the active milk producing holdings	10,395	5,609	16,004
Average number of bovines on all active fattening holdings	1,719	55	1,774
Number of events registered on bovine premises	6,703	1,718	8,421
Number of events registered on bovines	272,473	150,944	423,417
Number of bovine births registered	38,255	19,081	57,336
Number of EU imports registered	3,105	453	3,558
Number of bovine mortalities registered on holdings	6,410	3,967	10,377
Number of bovines slaughtered (including emergency slaughter)	50,044	1,566	51,610
Number of bovine movements to other holdings	19,712	2,898	22,610
Number and percentage ( ) of active milk producing herds having an average herd size of < 100 bovines	89 (71%)	27 (55%)	116
Number and percentage ( ) of active milk producing holdings having an average herd size of > 100 bovines	37 (29%)	22 (45%)	59
Number and percentage ( ) of active holdings keeping bovines for fattening and slaughter having an average herd size of < 20 bovines	216 (93%)	12 (100%)	228
Number and percentage ( ) of active holdings keeping bovines for fattening and slaughter having an average herd size of > 20 bovines	16 (7%)	0 (0%)	16

2.2.3.2 Registration of all bovine ear tags

The ear tagging of bovines on the Maltese Islands is carried out by the VSOs from the Department. Whenever an animal is born, the owner has to inform the Department within seven days of birth as per article 7 (1) (b) of Subsidiary Legislation 437.84 of the Laws of Malta and the VSOs are then sent to tag the animal within the 20 day period required as per article 4 (2) of the same law (Government of Malta, 2005a). When ear tagging is performed, the farmer signs a form confirming the event and the details given, and this is taken by the team back to the office where data entry is carried out either on the same day or the following working day.

The ear tag number, breed, sex, date of birth, the holding number and the identification of the dam are inserted in the database.

When an animal loses an ear tag the owner informs the Department and a new ear tag with the same number is re-ordered from the manufacturer. When this arrives at the Department, the VSOs will visit the holding, verify that the tag is missing and re-tag the animal. The event is then recorded in the database. A record is kept in the database on the number of times an animal is re-tagged and also the number of re-tagging events carried out on any particular holding. If the number is deemed high, the holding is flagged and if necessary an OV can be sent to investigate such an event.

A total of 57,336 bovine births were registered on the Maltese Islands during the study period. Of these, 38,255 were births registered in Malta and 19,081 were births registered in Gozo (Table 2).

2.2.3.3 Registration of movements of bovines between holdings or to a slaughterhouse

Movement permits are required whenever bovines are moved from one holding to another. This is not required when bovines are transported from the holding directly to the slaughterhouse. However, a pre-slaughter form containing the details of the animals transported to the slaughterhouse is required and has to be presented on arrival. The importance of tracking animal movements on and off holdings is well known, since one

of the first exercises carried out when serious contagious diseases are discovered is the tracing back and forward of animals from the index holding. It is therefore important that all animal movements are registered and that the information is entered into the database as soon as possible after the movement has taken place.

Whenever a producer wants to introduce or remove bovines from a holding, a movement permit has to be requested beforehand. The ear tag number of the bovine/s to be moved is given together with the holding registration number of the buyer and the seller. An OV will carry out the necessary checks on the database and verify that all details given are correct. If movements are temporarily blocked due to infringements or because of a positive disease status, this is flagged by the database and the movement permit cannot be issued by the OV. If there are no objections to the movement, a movement permit is issued by the Department and given to the producer. Once movement has taken place a copy of the permit signed by both the buyer and the seller has to be handed in to the Department within seven days as per article 7 (1) (b) of S.L. 437.84 of the Laws of Malta and the movement is then confirmed in the database (Government of Malta, 2005a).

In the ten year period under review a total of 22,610 movements between premises were registered. 19,712 movements were registered as originating in Malta and 2,898 originated in Gozo (Table 2).

When bovines are transported from a holding to the slaughterhouse in Malta or Gozo, the pre-slaughter form is presented on arrival, their ear tags are registered and the relevant details are automatically entered into the database. *Ante-mortem* and *post-mortem* inspection findings are recorded to the database directly from the slaughter line. This ensures in real time that the number of bovines registered on the database for any particular holding at any day, reflects the actual situation on the holding. This is of importance since whenever an official census or inspection is carried out on a holding the OV can download the list of animals present on the holding on the same day and cross check if any discrepancies are present when the inspection is carried out thus further validating the data present for the particular holding present on the database. This ensures that there is full compliance by livestock holders in notifying the Department of any births, deaths or movements in or out of the holdings.

The number of bovines registered as being slaughtered during the period under review is 50,044 at the abattoir in Malta and 1,566 at the abattoir in Gozo giving a total of 51,610 (Table 2). These figures also include emergency slaughtering. The huge discrepancy between the number of bovines slaughtered in Malta and Gozo is due to the fact that the slaughterhouse in Gozo was not operating for the majority of the ten year period due to re-structuring.

2.3 Analysis of the National Livestock Database setup on the Maltese Islands

The NLD of the Maltese Islands is under the control of the VPRD. The Department has a main office on the island of Malta and one on the island of Gozo. The NLD is managed from the main office in Malta. The Gozo division has an internet link to the main database in Malta. The NLD is implemented in Microsoft SQL Server and it is located on a central server managed by the Government IT services. The server is a virtual machine utilising resources from the pool maintained for all Government servers. These are protected against power interruptions and, in case of catastrophic failure, a second independent pool is maintained in a different location, allowing all operations to continue without interruption. In addition to the standard data backup procedures of the Government IT service, an automatic backup of the NLD is generated on an independent disk drive each night. Periodically, these backups are copied to DVD ROM and stored in a secure location. There is therefore a copy of the database as it was on every day since 2004. As the database is used to validate subsidy claims, these backups are from time to time required by auditors to verify that the claims were correctly processed at the time that they were processed.

All data collected in Gozo is entered by Department officials at the office in Gozo and the central server in Malta is updated in real time. The fact that only one database is used is an advantage since the limited resources present on the islands can be made use of more efficiently and fragmentation of resources and man power is kept to a minimum. Moreover, this set-up is possible due to the relatively small number of holdings and bovine population present on the Islands. During the ten year period under review the average yearly bovine population registered on all active bovine holdings in Malta was 12,114 and 5,664 on those in Gozo giving a total yearly average of 17,778

bovines (Table 2).

Data is stored in three main data registers. These are the:

- Premises Register;
- Producers Register;
- Animal Register.

There are no practical limits to the number of registers that can be maintained in the database and these can be increased or decreased as required.

Filters can be used to limit the large volume of records down to very specific subsets of data. This is especially useful whenever data is being compiled for surveys or census purposes. Filters can also be applied to records according to the different premises type, producers, species, age, etc. Moreover, user defined reports can be produced in the form of a rich text format file. Reports such as results of disease surveillance tests, monthly slaughtering reports and lists of calves born per month can be produced in this format. A screenshot of the NLD Main Menu is shown in Figure 3.

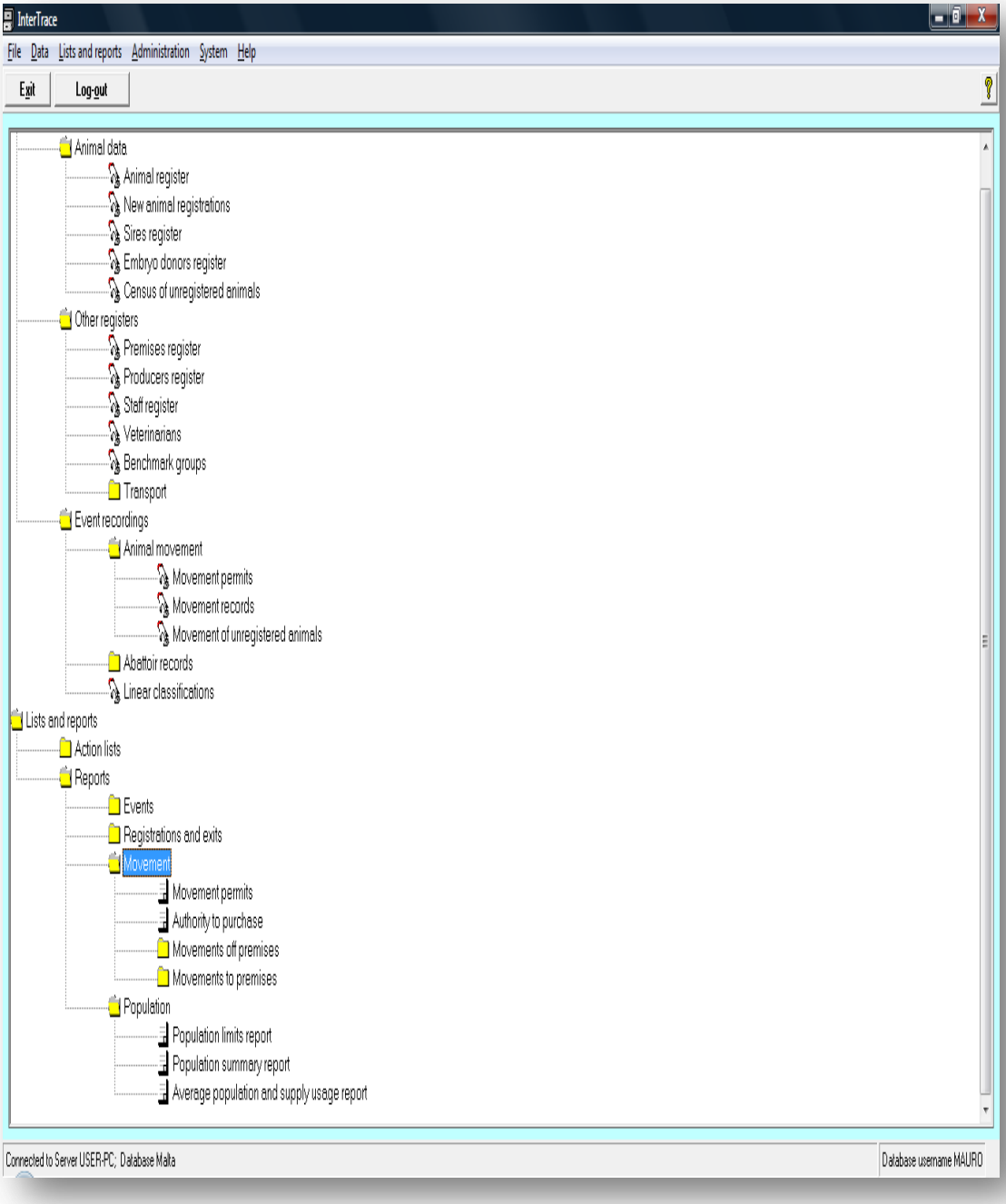


Figure 3: Screenshot of the NLD Main Menu

Security and auditing of the system is one key area of significant importance considering the volume of data stored and the potential implications of losing any of the data or having data stolen or tampered with. As a result a number of precautionary measures are in place to reduce the risks of such events happening. All users having access to the database are registered by the administrator of the database. They can

access the database by means of a user name and password. They must also be authenticated to the Government CORP domain. Each user's level of permission to control and edit data is determined by the administrator of the database. Data entered by all users are recorded, together with the date, time and workstation used. Any edited or deleted records are in fact retained by the database and the date and time of editing or deletion together with the username and workstation used are recorded. Furthermore, all connections to the database are recorded including the date and time of connection, disconnection, the username and the workstation used.

2.3.1 Premises Register

The Premises Register includes details of all holdings where animals are kept. Apart from holdings these can include slaughterhouses and quarantine areas. The data fields included in this register are:

- Premises code, which is a unique code by which each holding is identified;
- Producer name;
- Premises type, describes the type of activity carried out. In the case of bovines this refers to dairy herds and non-dairy herds. The latter are herds where fattening of calves is the main activity;
- Location denotes the town in which the holding is located. During the review period, active bovine holdings were registered in 48 towns in Malta and in 12 towns in Gozo giving a total of 60 throughout the Maltese Islands (Table 2);
- Longitude and latitude give the exact position of the holdings. This is a very useful tool as maps with the exact location of the holdings can be produced when disease outbreaks are being investigated.

Other variables can be created to record details of events for each type of holding. These can include inspections, disease incidents, and herd tests carried out. These events can be recorded either as events carried out defined on the NLD as 'Done' or future events yet to take place defined as 'Scheduled'. As a result, action lists for scheduled events during a specified time period are issued to the responsible OV or VSO so that action can be taken as necessary. Lists of events, such as number of brucellosis or tuberculosis tests carried out during any specified period of time can also

be produced for evaluation by managers or directors at the Department.

2.3.2 Producers Register

The Producers Register holds data on the persons or firms legally responsible for livestock. In the majority of cases one producer is associated with each holding but in certain instances such as a partnership between family members, more than one producer is associated with each holding. On the other hand, a producer may be associated with any number of holdings.

The data in this register includes the:

- Producer code, which is unique and is the Identity Card number of the owner/s;
- Producer name/s;
- Address and contact details for correspondence.

2.3.3 Animal Register

The Animal Register records details of individual animals according to species. It also includes their complete movement history. Moreover, the NLD can record batches of animals such as a litter of pigs or poultry coming from a common source. Batches can be split into sub-batches which can then be recorded independently of each other. A sub-batch inherits the movement and event history of its parent batch. Up to ten generations of split batches is currently supported, and batches can be split to individual animals if required such as for carcass classification data. If the animal products derived from animal batches are marked with the final sub-batch code, the product can be traced back through all movements to the first registration of the original parent batch. This is a very import point in the whole traceability chain as reported by Golan et al., 2004, since it links the animal identification to the products derived from it.

The data in this register includes the following:

- Premises number;
- Species;

- Breed;
- Sex;
- Date of birth;
- Age;
- Present from: This indicates the date when the animal entered the premises where it is currently located. If it was born on the premises it will indicate the date of birth. If the animal was bought, it will indicate the date when the animal was introduced into the herd;
- Origin: This field gives an annotation of the 'Present from' field described above. If the animal was born on the holding it will have as a comment 'Birth'. If the animal was bought it will have the premises code from which it was bought. If it was imported from an EU country the field will have 'IMP-EU' as a comment. If for any reason the origin of the animal on the holding could not be verified as being by birth or bought, the comment 'First' is inserted in the field till further investigations are carried out.
- Left on: This field gives the date at which a particular animal would have left the holding under review.
- Destination: This gives the destination of the particular animal if it has left the holding. This field can have 'AM' as a comment meaning that the animal was taken to a slaughterhouse, it can have a premises code denoting that it has been sold, or it can have 'DEAD' as a comment meaning that it was registered by the owner as having died on the holding. 6,410 bovines were registered as having died on the holdings in Malta and 3,967 in Gozo giving a total for the ten year period of 10,377 (Table 2).

Using the above data, various lists can be produced. The most common lists used are those showing all the animals present at a specified premises and between specified dates, and lists of all the animals registered to specified producer/s irrespective of the premises at which they are kept. Moreover, the parentage and offspring of different livestock species can be recorded to an unlimited number of generations.

It is also possible to link various registers together and to link a particular animal identification with other information such as dam and sire of the animal and any offspring produced.

Lists of movements on and off the premises is another option available and is generally utilised during epidemiological studies when disease outbreaks need to be investigated and tracing of animals is required within a very short period of time.

By making use of the NLD it is now possible to determine the number of holdings active at a particular date or during a particular time frame, together with the number of bovines or the average population on any particular holding, and all the relevant data at any particular date or during a particular time frame.

2.4 The Data Management Section

The Data Management Section of the NLD is the main data management and analysis interface. It is used to issue the various reports requested on a day to day basis by the managers or OVs of the Department and also for audit purposes and to draw up the necessary statistical reports. The Data Management Section is divided into three further sections as shown in Figure 4.

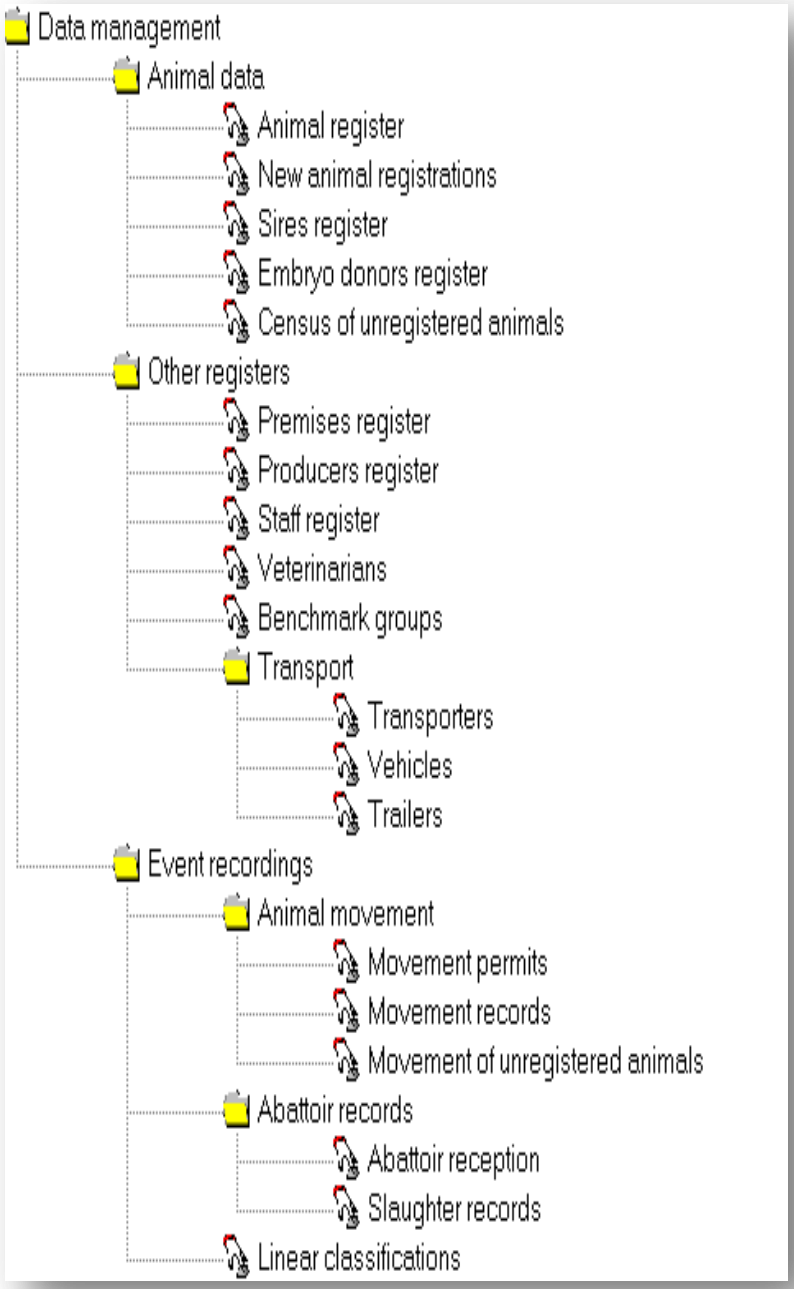


Figure 4: Screen shot showing the Data Management Section of the Maltese National Livestock Database

2.4.1 The Animal Data Section

The Animal Data Section includes data pertaining to the various animal species held on the database. These are arranged in registers, as follows:

- Animal Register: This register contains lists of bovines on a particular holding during a specified date or over a specified period of time. This list also includes details on each animal present on the holding such as date of birth, origin, movement dates, any offspring etc.
- New Animal Registrations: This register contains lists of new registrations of bovines over a specified period of time. New registrations can be due to birth, importation from EU Countries or from third countries. During the review period, a total of 3,558 bovines were imported from EU countries. No imports from third countries were registered during this period. In certain cases a new registration with no birth history can be inserted for traceability purposes till the case is investigated.
- Sire Register: This facility is currently not being used by the Department but can be of value to producers or producer associations involved in the recording and issuing of pedigrees.
- Embryo Donors Register: This facility, which can be used to register any embryo donors used on bovine holdings, is currently not being utilised by the Department.
- Census of unregistered animals: This section is of use whenever unregistered animals are discovered during inspections or census on holdings. All the animals are registered to keep track of their presence till investigations and the necessary action is taken.

2.4.2 The Other Registers Section includes six registers:

- Premises Register: This includes details of all the premises registered;
- Producers Register: This register includes all the producer details such as name, address, contact numbers etc.
- Staff Register: This lists all the staff involved in any way with data collection, analysis and management. Its function is to link and record the data inputted or edited with the person who actually carries out the action. This is important for validation, auditing and security of data;
- Veterinary Register: Lists of OVs visiting the holdings and carrying out official testing and inspections;
- Benchmark groups Register: This register is not used for bovine data collection.

- Transport Register: Lists of livestock transporters together with data on vehicles used such as type of vehicle, identification number etc.

2.4.3 The Event Recordings Section includes three registers:

- Animal Movement Register: This register includes all the movement permits issued and records information such as details of buyer and seller, date of issuing of permit, issuing officer, date of movement, animal identification, sex, breed and age of the animal. A section for the issuing of a movement permit for unregistered animals is also present in this register. This is necessary to allow traceability of all animals even those that for some reason might not have been previously registered according to law. This is done till the required investigations are carried out and any necessary action is taken;
- Abattoir Records Register: This register includes details of the identification of the animal slaughtered, breed, sex, age, origin of the animal, the arrival date/time at the abattoir, abattoir reference number, fate of the carcass such as if it is considered fit for human consumption or condemned, date/time of slaughter, slaughter week, live weight, dead weight, abattoir document number, carcass classification when applicable, and the identification of the assessor of this classification;
- Linear Classifications Register: This register is not currently used for bovine data collection.

A summary of how the Data Management Section is set up together with a brief description of the contents of each register is shown in Table 3.

Table 3: Summary of the Data Management Section together with a brief description of the contents of each register

Data Management Section	Type of Register	Contents of Register
Animal Data Section	Animal Register	Lists of bovines on holdings together with details such as date of birth, origin, movement dates, etc.
	New Animal Registrations	Lists of births and importations from EU or third countries
	Sire Register	Details of sire (Of use to producers for pedigree purposes)
	Embryo Donors Register	Details of embryo donors (Not currently in use by the Department)
	Census of unregistered animals	Details of any unregistered animals discovered during inspections and pending investigations
Other Registers Section	Premises Register	Details of premises
	Producers Register	Details of producers
	Staff Register	Lists all staff involved in data collection and management. Links data input with the person carrying out the action
	Veterinary Register	Lists all OVs involved in inspections and official testing
	Benchmark groups Register	Benchmarks (not used for bovine data collection)
	Transport Register	Details regarding livestock transporters together with data on vehicles used
Event Recordings Section	Animal Movement Register	Details regarding all movement permits issued
	Abattoir Records Register	Details on the animals slaughtered together with data on date of slaughter, fate of carcass, classification, etc.
	Linear Classifications Register	(Not currently in use for bovine data collection)

2.5 Lists and Reports Section

The Lists and Reports Section includes the Action List Register and the Reports Register as shown in Figure 5.

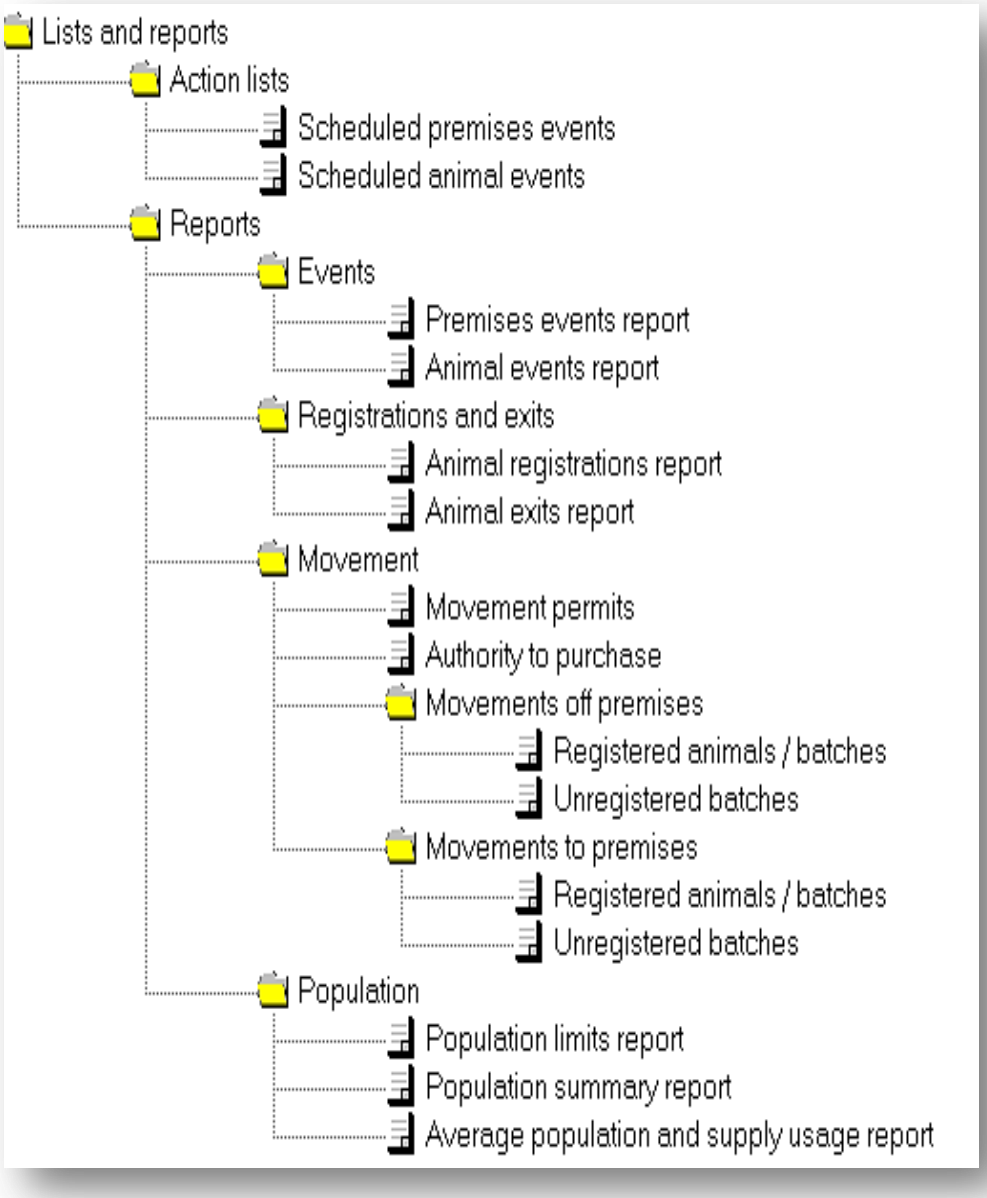


Figure 5: Screen shot showing the Lists and Reports Section of the Maltese National Livestock Database

2.5.1 Action List Register

This register is made up of the Scheduled Premises Events and the Scheduled Animal Events.

2.5.1.1 Scheduled Premises Events Register

The Scheduled Premises Events Register holds details of any events which are scheduled to be carried out on the holdings. These may include bluetongue disease testing, brucellosis, leucosis and tuberculosis testing, leucosis milk tests, milk ring tests for brucellosis, milking hygiene inspections, animal welfare inspections and welfare inspection re-checks. From the 1st of January 2003 to the 31st of December 2012 a total of 8,421 premises events were registered on bovine holdings. These included 6,703 events on holdings in Malta and 1,718 in Gozo (Table 2).

2.5.1.2 Scheduled Animal Events Register

The Scheduled Animal Events Register holds details of any events carried out or scheduled to be carried out on livestock. The events carried out and those still scheduled can be listed according to the specified periods of time imposed by the database user. These include any events carried out on the animals themselves and/or on any of their products and in the case of bovines include bluetongue disease testing, brucellosis, leucosis and tuberculosis testing, leucosis milk test, milk ring tests for brucellosis and retagging when necessary. A total of 423,417 events were registered on bovines during the 10 year review period. 272,473 were registered on bovines in Malta and 150,944 on bovines in Gozo (Table 2).

In both the scheduled premises events and scheduled animal events registers, all the results and combinations of this data can be viewed by the database user in a number of tabular summary tables. It is possible to obtain lists of tests carried out by month, by holding, by OV or VSO etc.

2.5.2 Reports Register

The Reports Register contains four categories of data: events, registrations and exits, movement and population data. This register is used to collect and analyse data and issue reports regarding the four categories of data listed. Even in this case, this can be done for a particular time frame and in different tabular forms.

2.5.2.1 Events File

The Events File includes the Premises Events Report File and the Animal Events Report File. These files manage data held in the Scheduled Premises Events Register and Scheduled Animal Events Register as described at point 2.5.1.1 and 2.5.1.2 respectively. Tabular summaries by month, operator, type of activity and premises can be produced.

2.5.2.2 Registration and Exits File

The Registration and Exits file has two sub-sections namely the Animal Registrations Report File and the Animal Exits Report File.

Animal Registrations Report File: This file contains the data of all the registered animals on each of the premises. One of the data fields is the 'Origin Code'. This field will show animals which have been registered as Births, Imports from EU or third countries, and first registrations where birth data is missing thus still allowing traceability of the animal until investigations and any necessary action is taken.

Animal Exits Report File: The Animal Exits Report File contains all the data on the fate of every registered animal. The 'Fate Code' includes a number of scenarios such as 'DEAD' i.e. an animal which is reported as having died on the holding or 'SL' an animal which has been slaughtered or 'EXP' an animal which has been exported.

A tabular summary can be produced for both the Animal Registrations Report File and the Animal Exits Report File for any predefined period of time by cross tabulation

according to Month, Administrative Unit, Premises, Species, Breed, Sex, Fate, Destination and Origin.

2.5.3 Movement File

The Movement File has four sub-sections:

- Movement Permits;
- Authority to purchase;
- Movement off premises;
- Movement to premises.

The Movement Permits file and Authority to purchase file are administrative control files used to limit permits and movement in case of infringements, illegal movements etc. Access to this part of the database is restricted and only the database administrator or Department Officials given the necessary authorisation can add, remove or edit data in this section.

2.5.3.1 Movement off premises

This file is divided into the Registered animals/batches file and the Unregistered batches file.

Registered animals and registered batches file: This file contains data on all the registered animals or batches of animals and information regarding their movements off a premises and their destination.

A tabular summary can also be constructed producing a cross tabulation according to month, administrative unit, premises, species, breed, sex and destination. A specified period of time can be chosen and data will be generated accordingly.

Unregistered batches file: This file is not used in the collection of data on bovines.

2.5.3.2 Movement to premises

The movement to premises file contains data on the movement of animals onto premises.

This file is divided into the Registered animals/batches file and the Unregistered batches file.

Registered animals and registered batches file: This file contains data on all the movements on to premises of all registered animals or batches of animals.

A tabular summary for both the movement off and movement to premises can be produced according to month, administrative unit, premises, species, breed, sex and origin or destination for any specified period of time.

The movement off premises and movement to premises section of the database are of particular importance in the tracing back and forward of animal movements during epidemiological studies or during inspections and auditing of herd books.

Unregistered batches file: This file is not used in the collection of data on bovines.

2.5.4 Population File

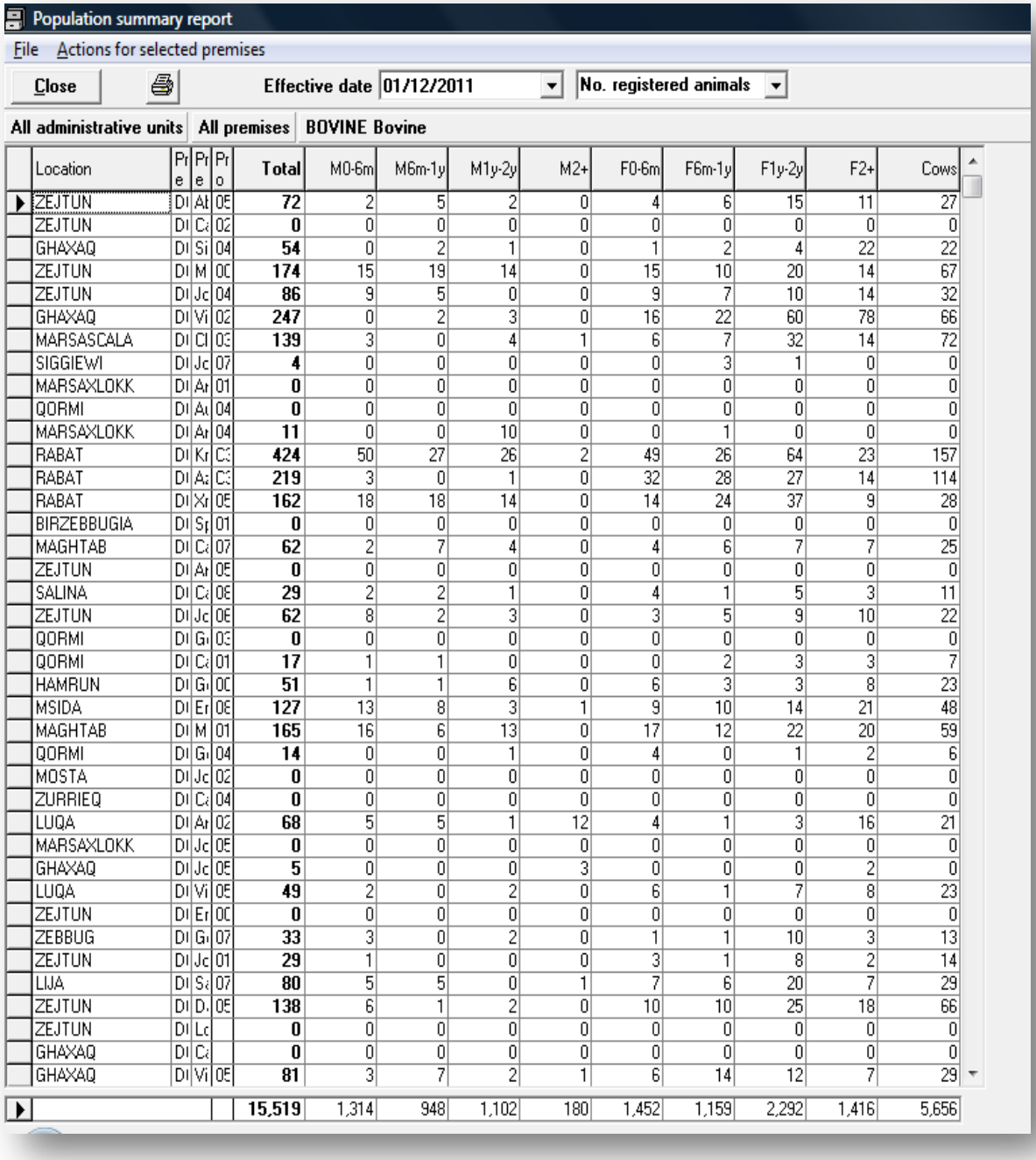
The Population file contains three sections: the Population limits report, Population summary report and the Average population and supply usage report.

2.5.4.1 Population limits report

The Population limits report shows any limits which might be imposed on the holding population. This can be visualised according to any day of the year under study and in tabular form by different data fields.

2.5.4.2 Population Summary Report

This report is one of the most utilised and it gives a summary of the population on any holding or group of holdings on any particular date selected by the user. Furthermore, the total number of animals on each of the premises can be divided into eight categories according to the output required. These eight categories are: males 0-6 months; males 6 months to 1 year; males 1 to 2 years; males 2 years and over; females 0-6 months; females 6 months to 1 year; females 1 to 2 years; females 2 years and over. This is shown in the population summary report screenshot in Figure 6.



Location	Pre	Pre	Pro	Total	M0-6m	M6m-1y	M1y-2y	M2+	F0-6m	F6m-1y	F1y-2y	F2+	Cows
ZEJTUN	DI	At	05	**72**	2	5	2	0	4	6	15	11	27
ZEJTUN	DI	Ca	02	**0**	0	0	0	0	0	0	0	0	0
GHAXAQ	DI	Si	04	**54**	0	2	1	0	1	2	4	22	22
ZEJTUN	DI	M	00	**174**	15	19	14	0	15	10	20	14	67
ZEJTUN	DI	Jc	04	**86**	9	5	0	0	9	7	10	14	32
GHAXAQ	DI	Vi	02	**247**	0	2	3	0	16	22	60	78	66
MARSASCALA	DI	Cl	03	**139**	3	0	4	1	6	7	32	14	72
SIGGIEWI	DI	Jc	07	**4**	0	0	0	0	0	3	1	0	0
MARSAXLOKK	DI	Ar	01	**0**	0	0	0	0	0	0	0	0	0
QORMI	DI	Au	04	**0**	0	0	0	0	0	0	0	0	0
MARSAXLOKK	DI	Ar	04	**11**	0	0	10	0	0	1	0	0	0
RABAT	DI	Kr	03	**424**	50	27	26	2	49	26	64	23	157
RABAT	DI	Az	03	**219**	3	0	1	0	32	28	27	14	114
RABAT	DI	Xr	05	**162**	18	18	14	0	14	24	37	9	28
BIRZEBBUGIA	DI	Sp	01	**0**	0	0	0	0	0	0	0	0	0
MAGHTAB	DI	Ca	07	**62**	2	7	4	0	4	6	7	7	25
ZEJTUN	DI	Ar	05	**0**	0	0	0	0	0	0	0	0	0
SALINA	DI	Ca	05	**29**	2	2	1	0	4	1	5	3	11
ZEJTUN	DI	Jc	05	**62**	8	2	3	0	3	5	9	10	22
QORMI	DI	Gi	03	**0**	0	0	0	0	0	0	0	0	0
QORMI	DI	Ca	01	**17**	1	1	0	0	0	2	3	3	7
HAMRUN	DI	Gi	00	**51**	1	1	6	0	6	3	3	8	23
MSIDA	DI	Er	05	**127**	13	8	3	1	9	10	14	21	48
MAGHTAB	DI	M	01	**165**	16	6	13	0	17	12	22	20	59
QORMI	DI	Gi	04	**14**	0	0	1	0	4	0	1	2	6
MOSTA	DI	Jc	02	**0**	0	0	0	0	0	0	0	0	0
ZURRIEQ	DI	Ca	04	**0**	0	0	0	0	0	0	0	0	0
LUQA	DI	Ar	02	**68**	5	5	1	12	4	1	3	16	21
MARSAXLOKK	DI	Jc	05	**0**	0	0	0	0	0	0	0	0	0
GHAXAQ	DI	Jc	05	**5**	0	0	0	3	0	0	0	2	0
LUQA	DI	Vi	05	**49**	2	0	2	0	6	1	7	8	23
ZEJTUN	DI	Er	00	**0**	0	0	0	0	0	0	0	0	0
ZEBBUG	DI	Gi	07	**33**	3	0	2	0	1	1	10	3	13
ZEJTUN	DI	Jc	01	**29**	1	0	0	0	3	1	8	2	14
LIJA	DI	Sa	07	**80**	5	5	0	1	7	6	20	7	29
ZEJTUN	DI	D.	05	**138**	6	1	2	0	10	10	25	18	66
ZEJTUN	DI	Lc		**0**	0	0	0	0	0	0	0	0	0
GHAXAQ	DI	Ca		**0**	0	0	0	0	0	0	0	0	0
GHAXAQ	DI	Vi	05	**81**	3	7	2	1	6	14	12	7	29
				15,519	1,314	948	1,102	180	1,452	1,159	2,292	1,416	5,656

Figure 6: Screenshot from the NLD showing an example of the Population Summary Report

The database user can also choose to visualise a number of different population statistics in this report. These include: number of registered animals, livestock unit registered animals, number of census animals and livestock units census animals.

2.5.4.3 Average Population and Supply usage Report

The Average Population and Supply usage Report is another tool which is mainly used during surveys or statistical analysis of the herds. This report gives the average population on any premises requested over a defined period of time specified by the database user.

This method was used to generate the data regarding the yearly average number of bovines on the holdings over the ten year period under review shown in Table 2 and also to generate the data used in the statistical analyses carried out in chapters three and four.

The data fields which are given in the Average Population and Supply usage report include the following:

- Location;
- Premises Code;
- Premises Name;
- Number of bovines at start date;
- Number of bovines at end date;
- Bovine Average Population.

The Population statistic can be visualised as: number of registered animals, number of census animals, or livestock units census animals.

The set-up of this section together with a brief description of the contents of each register is shown in Table 4.

Table 4: Summary of the Lists and Reports Section together with a brief description of the contents of each register

Lists and Reports Section	Sub-Register	Contents of Register
Action List Register	Scheduled Premises Events	Details of events such as testing and inspections carried out on each holding
	Scheduled Animal Events	Details of events such as tests carried out or scheduled to be carried out on each animal
Reports Register	Events File	Details of premises and animal events grouped by type of activity, month, premises, operator, etc.
	Registrations & Exits File	Details of all the registered animals on each holding and data on the fate (died on farm, slaughtered etc.) of every registered animal
	Movement File	Details of all animal movements on and off the holdings. Important in tracing back and forward during epidemiological studies. Editing of data in this section is restricted
	Population File	Summarises data regarding population of each holding according to database user's needs

From the 1st of January 2003 to the 31st of December 2012 a total of 8,421 premises events were registered on bovine holdings. These included 6,703 events on holdings in Malta and 1,718 in Gozo. Moreover, a total of 423,417 events were registered on bovines during the same period. 272,473 were registered on bovines in Malta and 150,944 on bovines in Gozo (Table 2).

A tabular summary can be constructed producing a cross tabulation according to month, administrative unit, premises, species, breed, sex, destination etc. A specified period of time can be chosen and data will be generated accordingly.

2.6 Integration of data between the National Veterinary Laboratory (NVL) and the Identification and Registration Section (I&R)

The National Veterinary Laboratory and the Identification and Registration Section, which both fall under the VPRD, share information and data via the NLD. This step is important since integration and validation of data together with any further checks are carried out whenever data from the laboratory is added to the database.

When the OV or the VSO has to visit a holding for testing such as tuberculosis, brucellosis, leucosis or bluetongue disease testing, a field sheet containing the identification number of all the bovines present on the holding is printed. This printout also contains labels with the identification number and corresponding bar code of each bovine present on the holding on that date. These labels will then be attached to the sampling tubes collected during testing on the relevant holding. As a result, any labels which are not used or bovines whose identification is not on the field sheet is noted thus validating the data present on the database with the actual situation on the holding. The OV or VSO will then notify the I&R Section and investigations can be initiated accordingly.

The samples together with a copy of the testing sheet are then handed in at the NVL. Here the identification of each bovine is entered on the respective test template folder according to the test being carried out. Once the results are obtained these are imported onto the relevant file and then transferred onto the NLD. With regards to tuberculosis testing, the VO will input the results directly on the NLD.

Where enzyme-linked immunosorbent assay (ELISA) tests are carried out, the test template together with the results are automatically updated onto a file at the NVL. After this is checked by a member of staff at the NVL, it is sent to the NLD. If any positive results are obtained, the health status of the animal and also of the holding on which it is found is updated accordingly. E-mails are also sent by the I&R Section to the responsible OVs to inform them of any positive cases found, so that the necessary action can be taken.

2.7 Comparison of the Maltese NLD with cattle tracking systems in other countries

The extent of the impact of EU accession on the traceability system of the Maltese bovine husbandry sector has been considerable since it has evolved from an incomplete, paper based system to a centralised, computerised system. As a result traceability from farm to fork with regards to the bovine sector is now possible. This is significant since in some countries like the United States of America (USA) one of the biggest challenges is co-ordinating and linking different animal and meat traceability systems together (Golan *et al.*, 2004).

Although the database in itself is not unique to the Maltese Islands since the presence of a database is required by all EU member states (EC, 2000), some aspects of management, funding and day to day running of the system in Malta and Gozo are different to those found in other EU member states. Livestock databases can also be found in non-EU member states were the bovine industry is economically important such as Australia, Canada, Switzerland, USA, Japan, South Korea, Argentina, Brazil and New Zealand (MAF Biosecurity New Zealand, 2009). The main objective remains the traceability of bovines and in some cases, as is the case for the Maltese Islands, other livestock species. The extent of this traceability, the specifications of the different systems and the way they are operated may differ from country to country. Differences are also present in:

- who is responsible for the management of the database;
- the funding of the database;
- the ordering of ear tags, tagging of animals and cost of the tags;
- the notification period of births, deaths and movement of animals;
- the way data is submitted to the database;
- who is responsible for the inputting of data to the database;
- the extent to which data can be accessed by third parties.

Different scenarios regarding the responsibility for the management of the database are present. In Malta and Gozo the government department is responsible for the management of the NLD. This is also the case for Great Britain (GB) and the Netherlands (MAF Biosecurity New Zealand, 2009). In Denmark and Finland the

database is managed by private companies (National Audit Office, 2003). The system in Australia is a joint industry-government partnership (MAF Biosecurity New Zealand, 2009).

In Malta the NLD is funded by government. This is similar to the situation in GB. In Switzerland the funding for the setting up of the system was provided by the government but the operating costs of the system are covered by the users of the database (MAF Biosecurity New Zealand, 2009). In Denmark (National Audit Office, 2003) and the Netherlands (MAF Biosecurity New Zealand, 2009) the database is funded by the farmers.

Another difference between the set-up on the Maltese Islands to other countries is that bovine keepers do not order ear tags from the approved manufacturers themselves as happens in other countries like GB (British Cattle Movement Service, 2014), but these are ordered directly by VSOs at the Department. The VSOs then carry out the tagging of the calves themselves with no cost to the keepers. When the cost of the ear tags, the salaries of the officers responsible for the ear tagging and the cost of transport and fuel used are taken into consideration, it is estimated that the cost of each ear tag adds up to approximately €7.00.

On the Maltese Islands the keeper is obliged by law to inform the Department of any births of calves within seven days of birth and these are then tagged within a maximum of 20 days of age (Government of Malta, 2005a). Movement has to be notified within seven days (Government of Malta, 2005a). This notification and tagging period is different in some other EU member states. In the Netherlands ear-tagging and notification of births, including still births has to be carried out within three days of birth and movement of animals has to be notified within three days (MAF Biosecurity New Zealand, 2009). In GB, dairy farmers have to ear tag calves within 36 hours of birth whereas beef farmers have to tag their calves by 20 days of age. Any calves dying before these deadlines do not need to be tagged and movement of bovines has to be notified within three days (British Cattle Movement Service, 2014). In Malta and Gozo the movement notification is a joint notification where both the details of the buyer and seller are present on the movement notification. This is also the case in the Netherlands (MAF Biosecurity New Zealand, 2009). In GB the buyer has to notify movement in

and the seller has to notify movement out of the holding. This double notification has been found to increase the number of incomplete movement histories (National Audit Office, 2003).

The way data is submitted to the database can also vary between different countries. In Malta, notification of births, deaths and movement to the database is carried out after paper records have been submitted to the responsible staff at the Department. The use of paper records which are then used to input data into the database has been found in other countries such as GB to increase the chances of errors taking place during the data input phase. The direct inputting of data via electronic data submission is preferable and leads to fewer errors (MAF Biosecurity New Zealand, 2009). The exchange of data between the Maltese NLD and the NVL is an important link in the verification process of data with regards to the identification, registration and traceability of bovines. In the Netherlands data submission via paper records has been replaced by submission of data via the internet or through interactive telephone systems (MAF Biosecurity New Zealand, 2009). Switzerland requires users to check their own data and report back any errors or discrepancies so that action can be taken to ensure that the database contains only accurate data (MAF Biosecurity New Zealand, 2009).

In Malta and Gozo it is only staff from the Department who input data directly into the NLD. This is similar to the situation in Northern Ireland where staff from the Agriculture Department input the data supplied by farmers at markets, slaughterhouses and local offices (National Audit Office, 2003). In other countries such as Denmark, Finland and Germany, data inputting is carried out by private companies or farmer associations (National Audit Office, 2003). The presence of a large number of slaughterhouses and animal markets tend to increase the chances of error in data submission. This is reduced in the case of Malta and Gozo where only one slaughterhouse on each island is present and where no animal markets are present.

The extent to which data can be accessed by third parties also varies in different countries. On the Maltese Islands access to the NLD is restricted although bovine keepers can have access to the data pertaining to their holding. In Switzerland data present in the database is made available to industry related organisations thus maximising data use and generating revenue, whilst in South Korea and Japan,

consumers are able to access information online on the specific animal from which a beef product is derived (MAF Biosecurity New Zealand, 2009). This is important since the perceived importance of animal traceability systems is that of providing consumer confidence in food safety and to control animal disease outbreaks (Sugiura & Onodera, 2008). In fact, many of the traceability systems present in various countries such as GB, Canada, Switzerland, Japan and South Korea were implemented or gained more importance following the discovery of bovine spongiform encephalopathy (BSE) and the consequent lack of consumer confidence in beef and beef products (MAF Biosecurity New Zealand, 2009). The farm to fork traceability system in some countries such as Japan is comprehensive; the final beef product can be traced back to the individual animal, by means of its ear tag. Moreover, Deoxyribose Nucleic Acid (DNA) samples are taken from each carcass to verify trace back when required (Sugiura & Onodera, 2008).

Due to the small size of the country and the relatively short distance between holdings, the primary driving force to maintain accurate data in the Maltese NLD must be the risk involved if a serious contagious disease is introduced into the country. In this scenario, once discovered, the ability to identify all at-risk animals and premises as fast as possible is of utmost importance. This has been recognised as being important in other countries such as the USA (United States Department of Agriculture, Animal and Plant Health Inspection Service, 2005). In this respect, reducing the notification period of birth, deaths and movement to three days, on the Maltese Islands, as present in some other EU member states may be of benefit. The fact that the Maltese NLD is used to store and manage data regarding a number of livestock species such as sheep, goats, poultry, pigs and horses, is advantageous from an epidemiological point of view.

The compliance of bovine keepers with the regulations is very important and this can only be possible by means of incentives and disincentives (MAF Biosecurity New Zealand, 2009). In Malta and Gozo the main incentives are that the system of identification of bovines is entirely funded by the government. Availability of EU subsidies is only possible following compliance with all the relevant laws and the NLD is used to validate these subsidy claims. On the other hand the main disincentives are the possibility of fines, the imposition of movement restrictions and loss of EU subsidies if compliance is lacking.

2.8 Discussion

2.8.1 Merits of the system

Golan et al., 2004 describe the importance of breadth, depth and precision in traceability systems used in food supply systems. These authors describe the breadth as the amount of information recorded, the depth is how far back or forward the system can track and the precision as the degree of assurance by which the system can accurately recall the movement of a particular product. These three factors can also be applied to the NLD since the usefulness and reliability of the Maltese NLD in fact depends on the breadth, depth and precision of the information recorded. The amount of information recorded, apart from covering legal obligations, allows for an accurate representation of livestock actually present on bovine holdings thus giving breadth to the system. The links between the different data registers together with the type of data collected allow for the depth required of the system. The precision of the data collected allows for accurate traceability of bovines from the time they are born and ear tagged till slaughtering. Precision of data is ensured by means of proper validation of data.

The fact that there is one centralised database, managed by officials all working within the same Department, has led to a number of advantages. These include the following:

a) Greater efficiency;
b) Savings on the cost of entering data;
c) Improved reliability and greater accuracy of information since staff follow common guidelines on the entry of data;
d) The fact that the staff responsible for the inputting of data may also be involved in farm visits and liaising with producers, leads to a holistic vision of the whole system and allows the staff to be aware of any incongruence or pitfalls in the data collection and inputting process;
e) Another important aspect is the fact that Department officials are also responsible for the ordering of ear tags and the actual tagging of all livestock. This ensures better traceability since the flow of information from when the ear tag is ordered, to the moment it is applied to the animal, is under direct control of the Department;

f) The short distances between holdings, considering that the Maltese Islands have a total land area of 316 km^2 (NSO, 2012), allows this set-up to be efficient and economically viable as large distances would render this system unfeasible from an economic point of view since the ear tagging team would have to travel over the whole island from one central position. Due to the distance between the two islands and to ensure that tagging takes place within the time required by legislation (Government of Malta, 2005a) ear tagging teams are present on both the islands of Malta and Gozo;

g) Another advantage is that since ear tags are applied by staff from the Department, ear tags do not have to be posted or distributed to farmers beforehand as happens for example in the UK (Department of Environment, Food and Rural Affairs, 2013). This reduces the chances of ear tags being misplaced, applied to animals and not registered with the database or used in any other fraudulent manner;

h) Notifications of births, deaths or movements of bovines can be carried out very easily. The Department happens to be located within the same area as the slaughterhouse in both Malta and Gozo. As a result most producers who would visit the slaughterhouse on a weekly basis can very easily notify the staff regarding these events. Notifications can also be carried out by phone or via e-mail. This ensures that at all times the Department has an accurate picture of the animal population on all holdings on both islands. This is very important since due to the relatively small distances between holdings, tracking animal movements is of fundamental importance in the case of the presence of any serious contagious diseases;

i) Animals may leave the holding to be transported to the slaughterhouse. This event has to be recorded so as to keep records of the actual population on holdings up to date. All slaughtering records are entered into the database directly from the slaughterhouse floor. If the ear tag and last holding location do not match with what is listed on the database, the event is flagged up and the carcass will not be released for human consumption until the event is investigated by Department officials. This chain of events occurs within a very short time frame as only one slaughterhouse is present on each island and they are both linked to the NLD. Furthermore, slaughtering of cattle takes place once a week and this facilitates the investigation of any queries;

j) Since the recording of activities carried out on holdings such as inspections regarding animal health and welfare and the respect of environmental and hygiene regulations by Department officials are all recorded on the database, these events can be used to cross check the compliance and eligibility of producers applying for EU benefits;

k) Any herd tests due to be carried out are scheduled in the database. This ensures that managers within the Department can verify subsequently that the scheduled events have in fact taken place;

l) The integration of the data generated by the NVL allows for the continuous validation of data inputted by the I&R section. Any discrepancies will be brought to light and action can be taken accordingly;

m) In those cases where a lot of data has to be inputted manually, systems are in place to reduce this. As a practical example, in the case of tuberculosis testing whereby the OV inputs results on the field worksheet, the records of negative results are inputted by default and only the results of positive or inconclusive results have to be entered manually on the database. Any positive results, animals not tested or anomalies in animal movement records are flagged up and can be acted upon as necessary by the OVs.

2.8.2 Drawbacks and weak points of the system

As in all database systems there are also a number of drawbacks and weak points in the system. These include the following:

a) If the barcodes on the ear tags are covered with dirt, these can be rendered unreadable by the barcode scanners. As a result the number would have to be inputted manually increasing the chances of incorrect inputting of data;

b) Producers do not contribute financially towards the ear tagging expenses. The costs are incurred solely by the Department except when very frequent re-tagging is flagged up;

c) The ear tagging teams are members of staff of the Department and as a result their salaries are paid by government and no contribution is made directly by the producers themselves;

d) The fact that the producers do not tag their calves themselves means that if

they do not keep an accurate and timely record of births, errors can arise in the registration of date of births and identification of the dam. This is especially so since a period of seven days is allowed for notification and up to twenty days from the day of birth for the application of the ear tag (Government of Malta, 2005a). However, this would still remain a weak point of the system even if tagging is carried out by producers themselves;

e) Another weak point is the notification of deaths of new-born calves. Since, as reported by Agerholm et al., 1993, the highest risk of death in calves occurs during the first four weeks of life, producers would not necessarily notify the Department of calf deaths occurring, especially if its birth has not been already notified and it has not been officially ear tagged. As a result when the collected data is used to calculate perinatal mortality rates of young calves it will lead to an underestimation of the real number since in all probability there is a lack of notification of such events as has been described in England by Brickell et al., 2009;

f) A number of producers are not computer literate or may lack internet connectivity on their holdings and as a result cannot make efficient use of this technology to notify the Department of any births, deaths or movements of bovines;

g) During the period under review the NLD has generated a lot of data which can be used to analyse production on each individual holding. Neither the producers themselves nor their co-operative is currently making efficient use of the data available.

2.9 Conclusions

The realities which are found on the Maltese Islands with regards to livestock production, and in this specific case bovine production systems, may be unique since the majority of holdings are relatively small on both islands. This part of the research project has described the ten year transition from a pre-EU accession period when, although bovine traceability was to some extent present on the Islands of Malta and Gozo, it was based mainly on paper records, to the post-EU accession period during which a centralised National Livestock Database was set up and utilised. This has

resulted in better identification, registration, traceability and accountability of livestock present on holdings together with more efficient use of all the animal health data generated on a daily basis. It is now possible to have a day by day breakdown of all the bovines present on each registered holding on both Islands. Moreover, apart from the benefits of the tracing back necessary to guarantee food safety and quality already described, the implementation of this database can lead to other benefits such as the improvement in the supply management, and the differentiation and marketing of certain products as described by Golan et al., 2004.

The merits of the system have been described and these should be kept in mind whenever any changes to the system itself are required. On the other hand the drawbacks and weak points have to be carefully studied and ways to overcome the problems mentioned should be sought. Other countries setting up a livestock traceability system may find the advantages and disadvantages discussed in this study useful during the preliminary phase of implementation. The further education and training of livestock owners is crucial in tackling the problems mentioned above. Once the main stakeholders understand the importance of the collection and analysis of accurate data in a timely manner, this will invariably lead to a more comprehensive and efficient use of the database.

Key Findings of Chapter 2

- ✓ ***The creation of one centralised National Livestock Database for the islands of Malta and Gozo has been of crucial importance in the identification, registration and traceability of bovines and in covering Malta's legal obligations in this field following EU accession.***

- ✓ ***The NLD has been recognised by the EU Commission as fully operational from 1 May 2004 and Malta has been authorised to use the NLD to obtain all statistical data regarding bovines to comply with the obligations arising from EU legislation.***

- ✓ ***The NLD can manage data in three main areas namely: (a) data regarding animal identification, registration and traceability; (b) data regarding animal health records; (c) data regarding production information.***

- ✓ ***Training of departmental staff and stakeholders was of fundamental importance since the different duties and obligations had to be clearly understood.***

- ✓ ***Data can only be entered into the database by authorised staff from the relevant government department reducing chances of error in data submission.***

- ✓ ***Bovine ear tags are ordered and placed by department officials and the relevant data is also entered into the database by staff from the department. This ensures better traceability and a more efficient and accurate flow of information.***

- ✓ ***The small size of the islands together with the close proximity of the department and the slaughterhouse on both islands allows for easy notification of births, deaths and movements of bovines.***

- ✓ ***The NLD is comprehensive since data is collected on all bovine holdings, on all bovine ear tags applied and on all movements of bovines.***

- ✓ ***All the necessary steps have been taken to ensure security and auditing of the system together with protection of all collected data on a daily basis.***

- ✓ ***The validation and integration of data in the NLD which takes place during inter-departmental use of the same data ensures that discrepancies are highlighted and investigated.***

- ✓ ***The various recorded events allow for cross-checking of compliance and eligibility of bovine producers for EU benefits.***

- ✓ ***Although the use of similar databases is present in other EU countries, the characteristics of the bovine husbandry system in Malta together with the particular setup and the running of the database by government staff within the same department make this system unique.***

Chapter 3

The study of the ten year trends in the number of bovine dairy holdings together with the analyses of the changes in the bovine population on these holdings from January 2003 to December 2012

3.1 Introduction

Data collection with regards to the number of dairy holdings and the number of bovines takes place regularly in every European country. This is necessary, amongst other things, to allow for the monitoring and comparison of the various parameters related to dairy farming in EU countries (European Commission, 2013). These parameters include data on the number of dairy holdings, number of dairy cows, milk production but also milk prices, farm revenues, costs etc.

Jongeneel et al. (2011) report that the number of dairy holdings in the EU has been gradually declining from the year 2000. Furthermore, Nowicki et al. (2009) reported that this trend was expected to continue.

In this chapter the ten year trends in the number of dairy bovine holdings together with the population of bovines on these holdings are studied. These trends are also compared to those reported in other European countries. Three methods were used in the study to collect three datasets which are then analysed statistically.

The period of study was from 1st January 2003, a year before Malta's accession to the EU on the 1st of May 2004 (Government of Malta, 2003), to 31st December of 2012. This part of the study involved retrieval of data from the National Livestock Database.

The NLD is managed by the Veterinary and Phytosanitary Regulation Department (VPRD) within the Ministry for Sustainable Development, the Environment and

Climate Change (MSDEC). This database was recognised as being fully operational by the EU as stated by Commission Decision 2004/588/EC of the 3rd of June 2004 (European Commission, 2004a). Furthermore, by means of Commission Decision 2005/415/EC (European Commission, 2005), Malta was authorised to make use of the NLD and replace surveys of bovine livestock as required by Directive 93/24/EC (European Commission, 1993).

All bovine herds are obliged by Maltese law to be registered with the VPRD. Two important laws in this regard are Subsidiary Legislation 437.78 published as Legal Notice 292 of 2005 (Government of Malta, 2005b) and Subsidiary Legislation 437.84 published as Legal Notice 311 of 2005 (Government of Malta, 2005a).

The obligation of identification and registration of each bovine together with the collection of all the data in one centralised and computerised system has now made it possible to collect and analyse data regarding bovines on holdings present on the islands of Malta and Gozo at any point in time.

Bovine dairy holdings are the subject of this part of this study due to the fact that 85.43% (SD = 2.50) of bovines in Malta and 98.91% (SD = 0.17) of bovines in Gozo are present on these holdings respectively. The rest of the bovines are present on small holdings mostly run on a part time basis with the main aim of fattening male bovines for slaughter.

3.2 Materials and Methods

3.2.1 Study design

A retrospective longitudinal study was conducted on the entire population of dairy herds present on the islands of Malta and Gozo registered in the NLD. No bovines were registered on the island of Comino during the study period. Six trends related to the number of dairy holdings and the dairy bovine population were analysed in Malta, Gozo and jointly. These included:

a) The trend in the number of dairy holdings on the Maltese Islands
b) The trend in the total number of bovines on dairy holdings
c) The trend in the number of female bovines over two years of age (F>2y)
d) The trend in the average bovine population (average herd size) on dairy holdings
e) The trend in the average number of female bovines over two years of age
f) The trend in the number of female and male bovines and their ratios.

Bovine holdings on the Maltese Islands fall into two categories. These are the dairy holdings and the non-dairy holdings. The dairy holdings are licensed to produce and sell their milk to a dairy processing plant and their main objective is the production of fresh milk.

The non-dairy holdings are those bovine holdings which are not licensed to produce and sell milk and their main activity is buying-in young calves mostly from the dairy holdings and then fattening these animals till slaughter. These holdings are relatively small, family run and generally managed on a part-time basis.

The aim of the study was to obtain data from the whole bovine population which represented the actual day to day composition of the holdings during the study period and to analyse the data accordingly rather than rely on figures collected sporadically or via questionnaires. Only the herd composition of holdings which were active during the study period was considered in this study. This was done to ensure that the results obtained were a true reflection of the national dairy population. Due to the dynamic nature of the livestock population on holdings, different results can be obtained depending on what is considered as being an active holding. As a result three methods were used in this study. Depending on the method used, a holding is considered to be active if the presence of at least one bovine is present on the holding on the reference data of each year of the study (Method 1), if at least an average of one bovine is registered on the holding during the year under study (Method 2) or, especially in the case of dairy holdings, if at least one female bovine over 2 years of age (F>2y) is present on the reference date of each year of the study (Method 3).

Apart from recording all the animals found on the holdings under study on a particular reference date (Method 1) as is usually done when collecting data for the National Cattle Surveys carried out by the NSO (NSO, 2013), the other two methods (Method 2 & 3) make use of the data recorded on the NLD on a daily basis and which can be analysed accordingly. The results obtained by these three methods were then used in the statistical analyses to verify if any significant differences were present. The following is a description of the three methods used in the study.

3.2.2 Method 1 (M1)

Using this method, an active bovine holding was defined as being a holding on which at least one bovine was registered at the reference date of the 1st of December of the year under study.

3.2.3 Method 2 (M2)

This method considers an active holding as one on which at least an average of one bovine is registered on the holding throughout the year. This method takes into account the average population on the holding per year, starting from the 1st of January to the 31st of December of each year. The calculation of the average population is in principle the average of the number of animals present for each day in the period. For computational efficiency, the database locates all the animals that were present at any time during the period. It then calculates the number of days that each animal was present during the period (animal-days). The total number of animal-days is then divided by the number of days in the period to obtain the average population on any particular holding. The holding is inserted in the study if animal-days/365 is ≥ 1.

3.2.4 Method 3 (M3)

Using this method, a holding was considered as being active when at least one female bovine older than 2 years of age (F>2y) was present on the holding on the 1st of December of each year of the study. In this case it is assumed that dairy holdings

having female bovines greater than 2 years of age are still involved in milk production since nearly all of these bovines would be cows in the various phases of milk production. This consideration was made since a number of dairy holdings winding down their activities would still have a number of bovines on the holding, such as young heifers and male calves or bulls, but in actual fact they would not be actively involved in milk production. This is especially so since during the period 2007 to 2012 an eradication programme for enzootic bovine leucosis (EBL) was underway (Government of Malta, 2009). The fact that at least one F>2y is present on a holding licensed as being a dairy holding assumes that it contains dairy cows and therefore is still involved in milk production.

The 1st of December of each year was chosen as the reference date in order to follow the guidelines of the National Statistics Office of Malta which uses the 1st of December as its reference date when compiling the yearly cattle census as per Commission Regulation (EC) 1165/2008 (European Commission, 2008a) and Commission Regulation (EC) 1166/2008 (European Commission, 2008b).

3.2.5 Statistical Analyses

The data collected from the NLD was transferred to Excel files where data verification and validation was carried out. In all cases data from 2003 to 2012 were used in the statistical analyses. However during the verification process, the data fields concerning the number of F>2y of age for the year 2003, were not considered to be sufficiently accurate. This is due to the fact that when inputting data for animals born prior to 2003 in the database, the date of birth had to be transposed from pre-existing paper records which at times had incomplete or inaccurate data. As a result, in some of the statistical analyses, data regarding certain trends for F>2y in 2003 were omitted from the statistical computations. This was done to ensure uniformity and reliability of any results obtained. Whenever this data was removed from the analysis, it was pointed out in the relevant section.

The data used in the statistical analyses was then transferred to SPSS version 21, a statistical package that permitted the descriptive statistics, correlation analysis and

analysis of variance to be carried out. Correlation coefficient results (r) were interpreted as follows: 0.90 – 1.00 = very strong correlation; 0.70-0.89 = strong correlation; 0.50-0.69 = moderate correlation; 0.30-00.49 = low correlation; 0.00-0.29 = little correlation.

3.3 Results and Discussion

Before presenting and discussing the results regarding dairy holding data, a brief analysis of non-dairy bovine holdings follows at point 3.3.1. This is done to ensure a better understanding of the Maltese bovine husbandry system in its totality.

3.3.1 The non-dairy bovine holdings

The number of non-dairy holdings in Malta is relatively high however, the total bovine population on these holdings and the average herd size is small (Table 5).

Table 5: Descriptive statistics of the total number of non-dairy bovine holdings in Malta and Gozo, the total bovine population on these holdings and the average herd size from 2003 to 2012 as calculated using data obtained by Method 2

	No of non-dairy bovine holdings Malta	Bovine pop. Malta	Average herd size Malta	No of non-dairy bovine holdings Gozo	Bovine pop. Gozo	Average herd size Gozo
Mean	206.40	1761.20	8.49	13.70	62.00	4.68
Median	202.50	1746.00	8.44	12.00	58.50	4.80
SD	21.82	330.20	0.91	4.06	10.90	0.69
Range	69.00	1116.00	3.58	11.00	30.00	1.93
Minimum	169.00	1249.00	6.57	10.00	51.00	3.71
Maximum	238.00	2365.00	10.15	21.00	81.00	5.64
25th Percentile	189.50	1485.00	8.20	10.00	53.00	3.88
50th Percentile	202.50	1746.00	8.44	12.00	58.50	4.80
75th Percentile	227.75	2024.25	8.97	17.50	72.75	5.30

The figures in Table 5 and the line diagram in Fig. 7 show that the number of non-dairy bovine holdings in Malta increased from 190 in 2003 to reach a maximum of 238 in 2008. Their number than shows a gradual decrease, reaching a minimum of 169 in

2012. In Gozo the number of holdings is much lower ranging from a minimum of 10 to a maximum of 21 holdings during the study period.

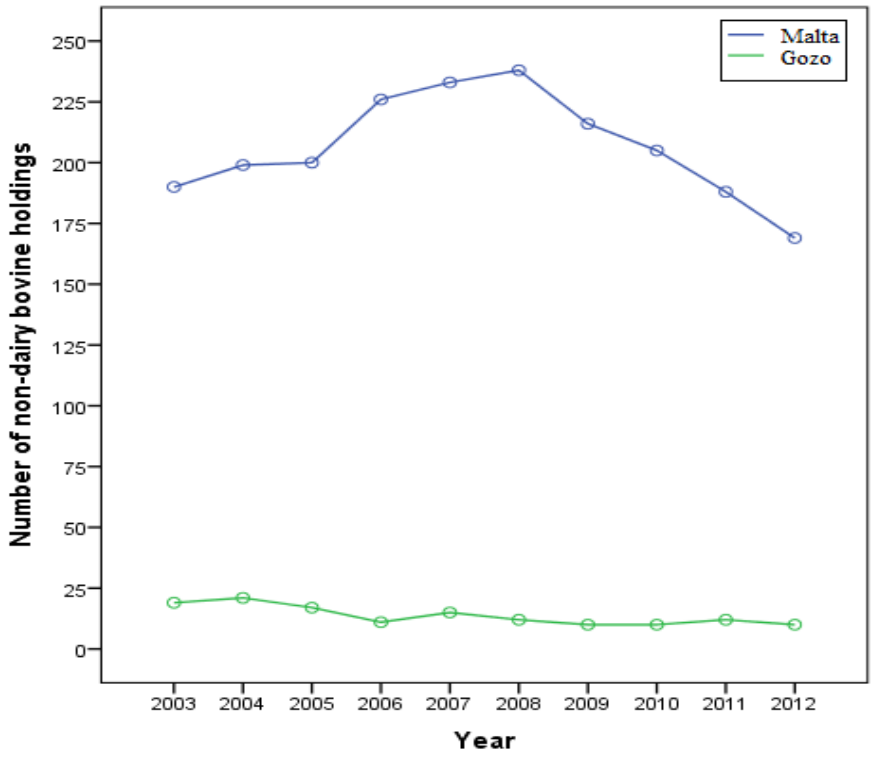


Figure 7: Line diagram showing the number of non-dairy bovine holdings in Malta and Gozo per year from 2003 to 2012 as calculated using data obtained by Method 2

The trend in the total bovine population on the non-dairy bovine holdings in Malta is also different from the one in Gozo (Fig. 8).

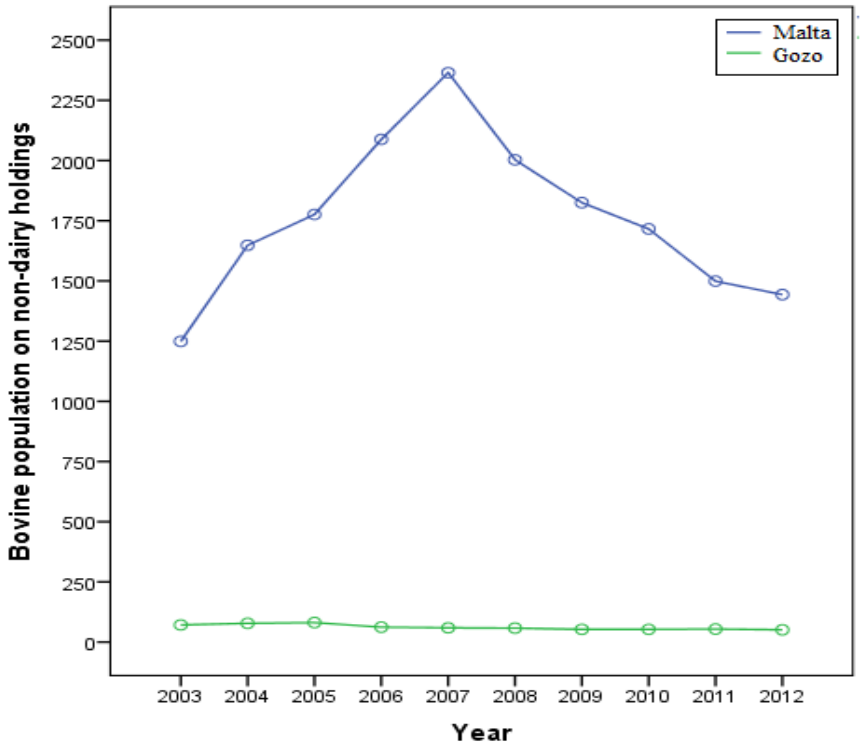


Figure 8: Line diagram showing the bovine population on non-dairy holdings in Malta and Gozo per year from 2003 to 2012 calculated using data obtained by Method 2

The population increased significantly from 1,249 in 2003 to reach a maximum of 2,365 in 2007. It then decreased progressively to 1,443 in 2012. The mean total bovine population on the non-dairy holdings during the ten year period in Malta was 1761.20 (SD = 330.20). The bovine population on the same type of holding in Gozo showed significantly less variation with a minimum of 51 bovines registered in 2012 and a maximum of 81 in 2005. The mean total bovine population here was 62.00 (SD = 10.90).

The mean number of active non-dairy holdings per year throughout the ten year period under study as calculated by M2 was 206.40 (SD = 21.82) in Malta and 13.70 (SD = 4.06) in Gozo. The holdings in Malta had an average herd size of 8.49 (SD = 0.91) and those in Gozo had an average herd size of 4.68 bovines (SD = 0.69). The non-dairy

holdings in Malta are relatively greater in number than those in Gozo. Moreover, the average herd size of the Maltese holdings is nearly double that of Gozo.

The percentage bovine population on non-dairy holdings in Malta compared to the dairy holdings is relatively small. In fact the non-dairy holdings in Malta contained 14.57% (SD = 2.50) of the total bovine population of Malta. In Gozo this percentage is even smaller with non-dairy holdings containing only 1.09% (SD = 0.17) of the total bovine population of Gozo (Table 6).

Table 6: Descriptive statistics of the percentage population on dairy and non-dairy bovine holdings in Malta and Gozo from 2003 to 2012 calculated using data obtained by Method 2

	% population on dairy holdings Malta	% population on non-dairy holdings Malta	% population on dairy holdings Gozo	% population on non-dairy holdings Gozo
Mean	85.43	14.57	98.91	1.09
Median	84.72	15.28	98.99	1.02
SD	2.50	2.50	0.17	0.17
Range	8.30	8.30	0.40	0.40
Minimum	82.30	9.40	98.60	0.90
Maximum	90.60	17.70	99.10	1.40
25th Percentile	83.58	13.04	98.70	0.95
50th Percentile	84.72	15.28	98.99	1.02
75th Percentile	86.96	16.42	99.05	1.30

It can be concluded that although a relatively large number of non-dairy holdings in Malta was registered during the study period, the average herd size was found to be relatively small. In Gozo this sector is even smaller than in Malta with a very small number of holdings and very small average herd size. As a result about 99% of the population of bovines in Gozo is present on dairy holdings.

3.3.2 The trend in the number of dairy holdings on the Maltese Islands

The trend in the total number of dairy holdings on the Maltese Islands per year during the period 2003 to 2012, calculated using data obtained by the three methods described, is shown by the line diagram in Fig. 9.

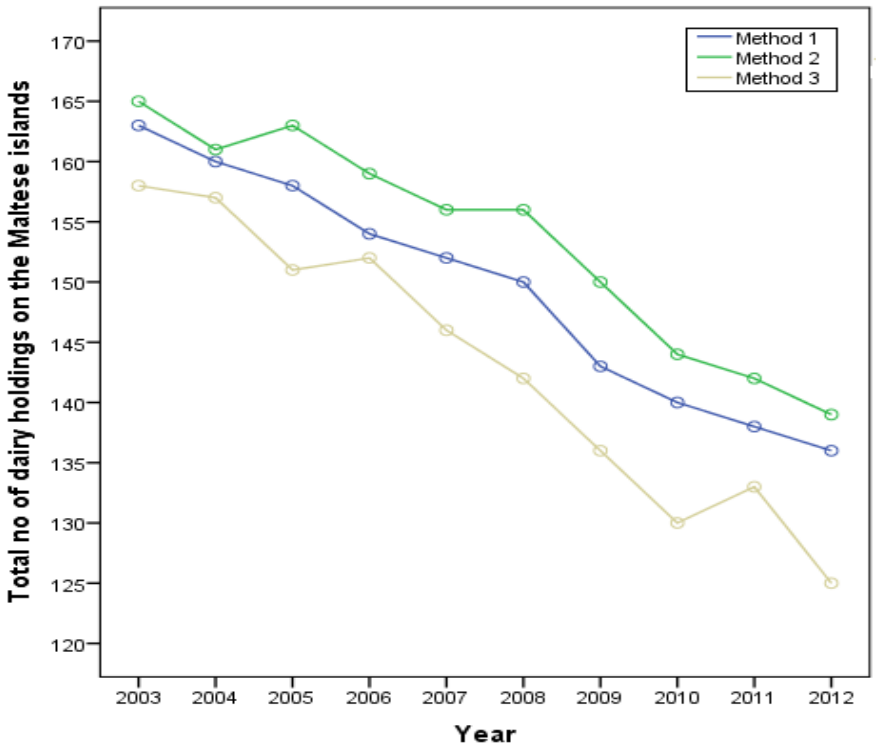


Figure 9: Line diagram showing the total number of dairy holdings on the Maltese Islands per year from 2003 to 2012 calculated using data obtained by the three methods described

All three methods used in the data collection show a decrease in the total number of dairy holdings on the Maltese Islands from maximum peaks in 2003 of 163, 165 and 158 holdings to minimum numbers in 2012 of 136, 139 and 125 holdings for methods 1, 2 and 3 respectively (Table 7).

Table 7: Descriptive statistics of the number of dairy holdings in Malta, Gozo and Malta + Gozo (M+G) from 2003 to 2012, calculated using data obtained by the three methods described

	No of holdings (M1)			No of holdings (M2)			No of holdings (M3)		
	Malta	Gozo	M+G	Malta	Gozo	M+G	Malta	Gozo	M+G
Mean	105.70	43.70	149.40	109.00	44.50	153.50	100.10	42.90	143.00
Median	107.00	44.00	151.00	110.00	45.50	156.00	100.50	43.50	144.00
SD	7.03	2.71	9.65	6.46	2.92	9.23	8.40	3.25	11.63
Range	20.00	7.00	27.00	19.00	8.00	26.00	24.00	9.00	33.00
Minimum	96.00	40.00	136.00	99.00	40.00	139.00	87.00	38.00	125.00
Maximum	116.00	47.00	163.00	118.00	48.00	165.00	111.00	47.00	158.00
25^{th} Percentile	98.75	40.75	139.50	102.00	41.50	143.50	92.50	39.75	132.25
50^{th} Percentile	107.00	44.00	151.00	110.00	45.50	156.00	100.50	43.50	144.00
75^{th} Percentile	112.25	46.25	158.50	114.25	47.00	161.50	107.75	45.50	153.25

This gives a decrease in the number of dairy holdings from 2003 to 2012 in Malta + Gozo of 16.56% when using M1, 15.76% when using M2 and 20.89% when using M3. In Malta alone, the decrease was of 17.24% (M1), 16.10% (M2) and 21.62% (M3). In Gozo the same trend showed a decrease of 14.89% (M1), 16.67% (M2) and 19.15% (M3). The average decrease of 18.32% in the number of dairy holdings in Malta was more pronounced than the average decrease of 16.90% registered in Gozo.

The mean number of dairy holdings in Malta during the study period was significantly higher than in Gozo (Fig. 10). The number varied from 105.70 (SD = 7.03) when using M1, 109.00 (SD = 6.46) when using M2 and 100.10 (SD = 8.40) when using M3. The mean number of holdings in Gozo calculated by M1 was 43.70 (SD = 2.71). When calculated using M2 and M3 the values were 44.50 (SD = 2.92) and 42.90 (SD = 3.25) respectively. The range in the number of holdings over the ten year period in Gozo is smaller than the range in Malta. This denotes that the number of dairy holdings in Gozo over the ten year period was more uniform than the number of dairy holdings in Malta.

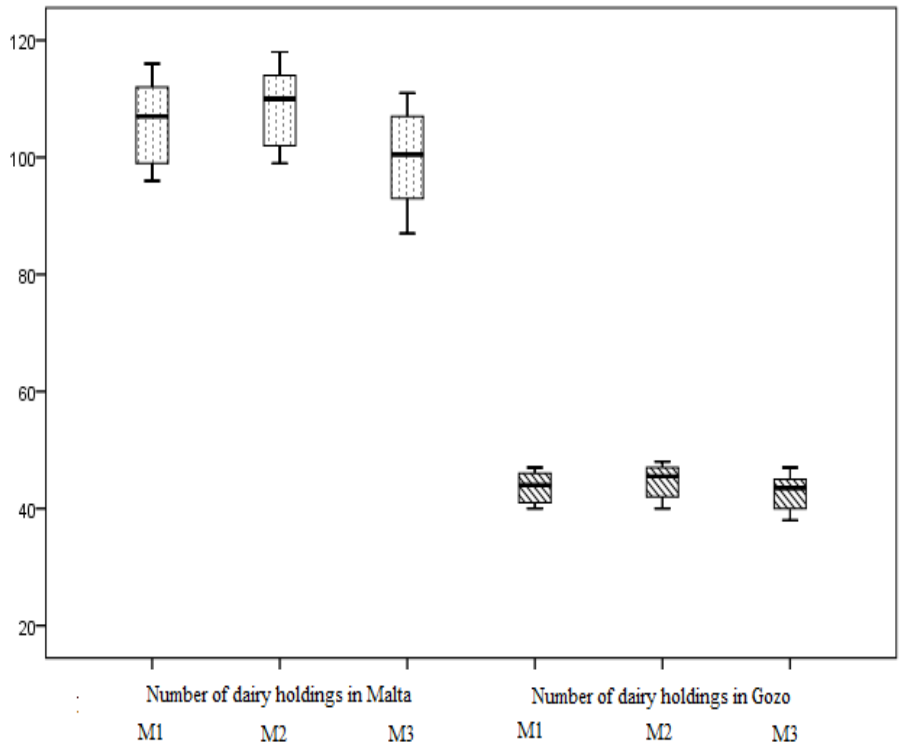


Figure 10: Box and whisker plot of the number of dairy holdings in Malta and Gozo as calculated using data obtained by Method 1, 2 and 3

The biggest difference in the number of holdings in Malta, Gozo or Malta + Gozo is obtained when using M3. This method is more appropriate in calculating the actual number of active dairy holdings producing milk from their herds since it is only dairy holdings having at least one F>2y of age which are taken into consideration in the statistical analysis. M1 gives a mean number of dairy holdings of 149.40 (SD = 9.65) which is higher than 143.00 (SD = 11.63) obtained when using M3. This is due to the fact that M1 would include some holdings which were closing down their activity during the ten year period and no females greater than two years of age were present on the holding. However some males and/or younger female bovines would still be present on these holdings. This also applies to M2 where the mean number of holdings was found to be 153.50 (SD = 9.23). In this case the mean is even higher than that reported when using M1 and M3 since the average calculated by this method over a one year period would take a longer time to fall below the cut-off point of at least one bovine present on the holding.

The decrease in the number of holdings present on both islands and confirmed by all three methods, although less pronounced, is similar to trends registered in EU-27 member states. The EU-27 member states include all member states excluding Croatia which joined the European Union on the 1st of July 2013. The total number of holdings with dairy cows in the EU-27 member states fell by 32% from 2007 to 2010. The decrease amounts to 47% if values for 2003 and 2010 are compared (Marquer, 2013). Very strong negative correlations ranging from r = -0.913 to r = -0.992 (n = 10) are present between the total number of dairy holdings and the year, when analysed separately on both islands and as a total number of holdings in Malta plus Gozo (Table 8). This applies to the three methods used and in all cases the correlations have a significance of $p < 0.0005$.

Table 8: Correlation coefficients between the number of dairy holdings in Malta, Gozo and Malta + Gozo and the year, as calculated using data obtained by the three methods described, from 2003 to 2012

		Correlation coefficient
No of dairy holdings Malta Method 1	Pearson Correlation	-0.985**
	Sig. (2-tailed)	0.000
No of dairy holdings Gozo Method 1	Pearson Correlation	-0.982**
	Sig. (2-tailed)	0.000
No of dairy holdings Malta + Gozo Method 1	**Pearson Correlation**	**-0.992****
	Sig. (2-tailed)	**0.000**
No of dairy holdings Malta Method 2	Pearson Correlation	-0.977**
	Sig. (2-tailed)	0.000
No of dairy holdings Gozo Method 2	Pearson Correlation	-0.913**
	Sig. (2-tailed)	0.000
No of dairy holdings Malta + Gozo Method 2	**Pearson Correlation**	**-0.972****
	Sig. (2-tailed)	**0.000**
No of dairy holdings Malta Method 3	Pearson Correlation	-0.981**
	Sig. (2-tailed)	0.000
No of dairy holdings Gozo Method 3	Pearson Correlation	-0.978**
	Sig. (2-tailed)	0.000
No of dairy holdings Malta + Gozo Method 3	**Pearson Correlation**	**-0.981****
	Sig. (2-tailed)	**0.000**

**. Correlation is significant at the 0.0005 level (2-tailed).

This implies that there has been a statistically significant decrease in the number of dairy holdings of about 18.32% in Malta, 16.90% in Gozo and 17.74% in Malta + Gozo during the period 2003 to 2012.

The yearly percentage of dairy holdings present in Malta compared to Gozo calculated using the three methods was 70.74% (SD = 0.40) when using M1, 71.02% (SD = 0.51) for M2 and 69.99% (SD = 0.25) for M3. This percentage does not show great variation during the 10 year period under study showing that the percentage distribution of dairy holdings in Malta and Gozo was relatively stable from 2003 to 2012 (Table 9).

Table 9: Descriptive statistics for the percentage of dairy holdings in Malta compared to Gozo from 2003 to 2012 calculated using data obtained by the three methods described

	% dairy holdings (M1) Malta	% dairy holdings (M2) Malta	% dairy holdings (M3) Malta	% dairy holdings (M1) Gozo	& dairy holdings (M2) Gozo	% dairy holdings (M3) Gozo
Mean	70.74	71.02	69.99	29.26	28.99	30.01
Median	70.75	70.82	69.96	29.25	29.18	30.04
Std. Deviation	0.40	0.51	0.25	0.40	0.51	0.25
Range	1.40	1.32	0.79	1.40	1.32	0.79
Minimum	69.93	70.51	69.60	28.67	28.17	29.61
Maximum	71.33	71.83	70.39	30.07	29.49	30.40
25th Percentile	70.54	70.54	69.82	28.95	28.44	29.79
50th Percentile	70.75	70.82	69.96	29.25	29.18	30.04
75th Percentile	71.05	71.56	70.21	29.46	29.46	30.18

3.3.3 The trend in the total number of bovines on dairy holdings

The trend in the total number of bovines on dairy holdings on the Maltese Islands during the study period is shown in Fig. 11.

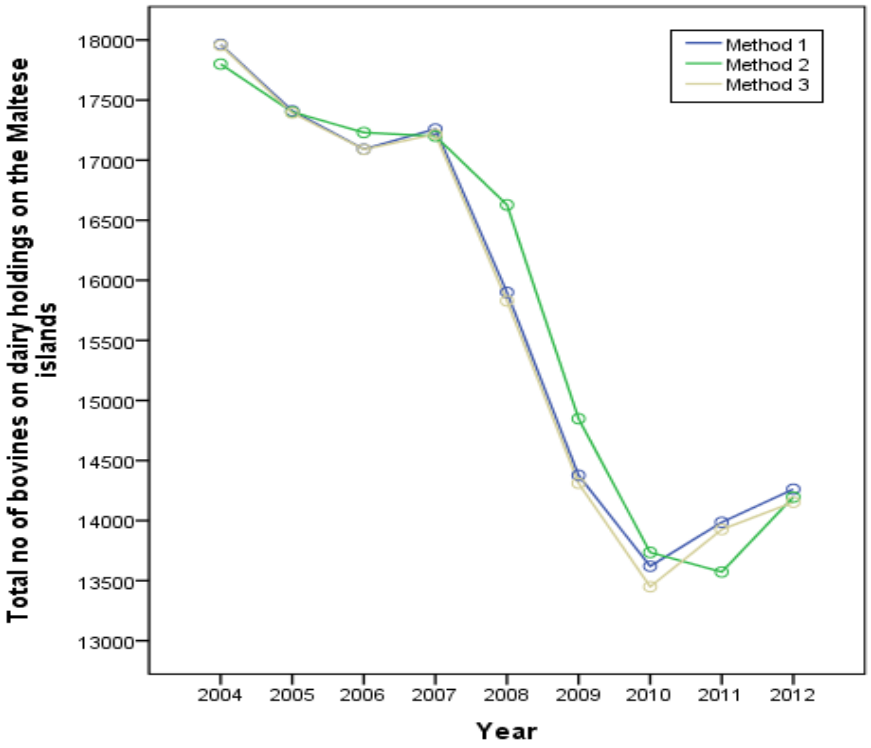


Figure 11: Line diagram showing the total number of bovines on dairy holdings on the Maltese Islands from 2004 to 2012 calculated using data obtained by the three methods described

The data analysed is from year 2004 to 2012 since data concerning the number of F>2y of age for year 2003 were not deemed to be sufficiently reliable and were removed from the statistical analysis. A small decrease in the total number of bovines on dairy holdings on the Maltese Islands was registered from 2004 to 2007 using the three methods. The decrease was of 3.92% when calculated using M1, 3.37% using M2 and 4.12% using M3. A sharp decrease in the bovine population then follows till 2010 and this is again demonstrated by all three methods. The decrease from 2007 to 2010 is of 21.08% using M1, 20.15% using M2 and 21.88% using M3. An increase of 4.71% and 5.23% is then present from 2010 to 2012 as calculated using M1 and M3 respectively, whereas M2 shows a further slight decrease of 1.19% till 2011 with an increase of 4.60% from 2011 to 2012.

The overall decrease in the number of bovines on dairy holdings on the Maltese Islands from 2004 to 2012 is of 20.61%, 20.25%, and 21.18% as calculated using methods 1, 2 and 3 respectively. This is considerably higher than the decrease of around 4% reported in the EU-27 member states from 2004 to 2012 (Marquer, 2013).

When data regarding the number of bovines on dairy holdings is analysed separately for both islands, it can be seen that the percentage decrease in the number of bovines on dairy holdings in Malta is nearly double the percentage decrease in Gozo. In fact from 2004 to 2012 the decrease in Malta was of 24.50% (M1), 24.24% (M2) and 25.24% (M3). The decrease in Gozo as calculated using method 1, 2 and 3 was of 12.47%, 11.81% and 12.69% respectively. Furthermore, in Gozo an increase of approximately 8.20% was registered from 2004 to 2007. This trend is shown in Fig. 12.

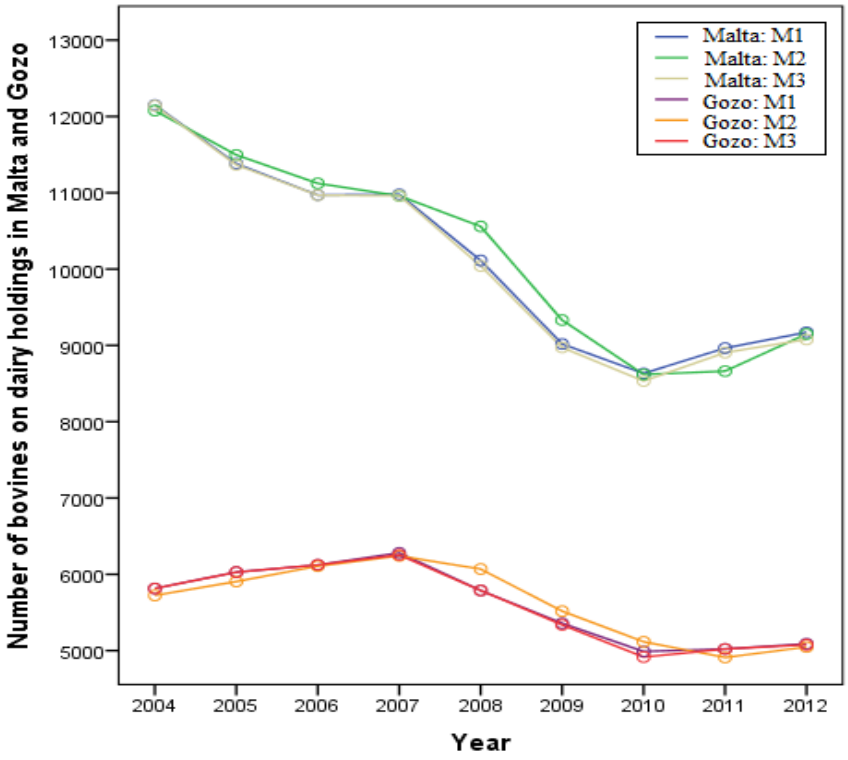


Figure 12: Line diagram showing the number of bovines on dairy holdings in Malta and Gozo from 2004 to 2012 calculated using data obtained by the three methods described

The mean number of bovines on all dairy holdings on the Maltese Islands from 2004 to 2012, as calculated using M1 was 15,763.00 (SD = 1,714.12). M2 gave a value of 15,845.56 (SD = 1,729.97) and M3 15,702.33 (SD = 1,758.47). When analysed separately, the mean number of bovines on all dairy holdings in Malta is seen to be nearly double the number on dairy holdings in Gozo (Table 10).

The number in Malta from 2004 to 2012, as calculated using M1 was 10,153.00 (SD = 1,265.76). M2 gave a value of 10,219.44 (SD = 1,298.12) and M3 10,107.00 (SD = 1,297.41). The values for Gozo were 5,610.00 (SD = 503.70) for M1, 5,626.11 (SD = 501.62) for M2 and 5,595.33 (SD = 513.77) for M3.

Table 10: Descriptive statistics of the total number of bovines on dairy holdings in Malta, Gozo and Malta + Gozo (M+G) from 2004 to 2012 calculated using data obtained by the three methods described

	No of bovines (M1)			No of bovines (M2)			No of bovines (M3)		
	Malta	Gozo	**M+G**	Malta	Gozo	**M+G**	Malta	Gozo	**M+G**
Mean	10,153.00	5,610.00	**15,763.00**	10,219.44	5,626.11	**15,845.56**	10,107.00	5,595.33	**15,702.33**
Median	10,112.00	5,788.00	**15,900.00**	10,559.00	5,723.00	**16,628.00**	10,041.00	5,788.00	**15,829.00**
SD	1,265.76	503.70	**1,714.12**	1,298.12	501.62	**1,729.97**	1,297.41	513.77	**1,758.47**
Range	3,517.00	1,292.00	**4,343.00**	3,458.00	1,331.00	**4,228.00**	3,608.00	1,338.00	**4,506.00**
Min	8,632.00	4,988.00	**13,620.00**	8,619.00	4,910.00	**13,572.00**	8,533.00	4,916.00	**13,449.00**
Max	12,149.00	6,280.00	**17,963.00**	12,077.00	6,241.00	**17,800.00**	12,141.00	6,254.00	**17,955.00**
25th Percentile	8,991.50	5,055.00	**14,123.50**	8,905.50	5,081.50	**13,965.50**	8,938.50	5,048.50	**14,039.50**
50th Percentile	10,112.00	5,788.00	**15,900.00**	10,559.00	5,723.00	**16,628.00**	10,041.00	5,788.00	**15,829.00**
75th Percentile	11,180.00	6,076.00	**17,334.50**	11,309.50	6,088.00	**17,315.50**	11,166.00	6,075.50	**17,304.50**

The box and whisker plot in Figure 13 shows that, apart from the fact that the mean number of bovines on dairy holdings in Malta is nearly double that of Gozo, the range is also significantly larger. This implies that the dairy herds in Gozo during the study period were relatively more stable than those in Malta.

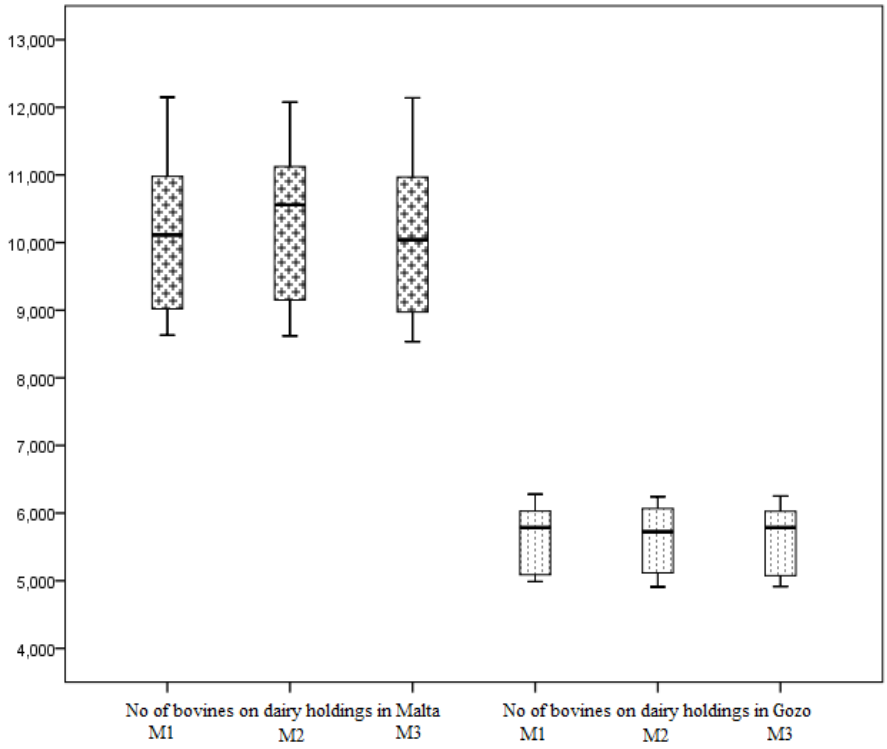


Figure 13: Box and whisker plot of the number of bovines on all dairy holdings in Malta and Gozo as calculated using data obtained by Method 1, 2 and 3

Very strong negative correlations of r = -0.930, -0.930 and -0.929 (n = 9) are present between the total number of bovines on dairy holdings and the year, calculated using methods 1, 2 and 3 respectively. These correlations are highly significant at a value of $p < 0.0005$ denoting that there has been a significant decrease in the total number of bovines on dairy holdings on the Maltese Islands during the study period (Table 11).

Table 11: Correlation coefficients between the total number of bovines on dairy holdings in Malta, Gozo and Malta + Gozo and the year, as calculated using data obtained by the three methods described, from 2004 to 2012

		Correlation coefficient
No of bovines on dairy holdings Malta Method 1	Pearson Correlation	-0.930**
	Sig. (2-tailed)	0.000
No of bovines on dairy holdings Gozo Method 1	Pearson Correlation	-0.826**
	Sig. (2-tailed)	0.006
No of bovines on dairy holdings Malta + Gozo Method 1	**Pearson Correlation**	**-0.930****
	Sig. (2-tailed)	**0.000**
No of bovines on dairy holdings Malta Method 2	Pearson Correlation	-0.944**
	Sig. (2-tailed)	0.000
No of bovines on dairy holdings Gozo Method 2	Pearson Correlation	-0.764*
	Sig. (2-tailed)	0.017
No of bovines on dairy holdings Malta + Gozo Method 2	**Pearson Correlation**	**-0.930****
	Sig. (2-tailed)	**0.000**
No of bovines on dairy holdings Malta Method 3	Pearson Correlation	-0.932**
	Sig. (2-tailed)	0.000
No of bovines on dairy holdings Gozo Method 3	Pearson Correlation	-0.826**
	Sig. (2-tailed)	0.006
No of bovines on dairy holdings Malta + Gozo Method 3	**Pearson Correlation**	**-0.929****
	Sig. (2-tailed)	**0.000**

** Correlation is significant at the 0.0005 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Statistically significant strong negative correlations ($p < 0.05$) ranging from -0.764 to -0.944 are also present when the bovine populations on dairy holdings on both islands are analysed separately showing that the decrease in the total number of bovines is present on both islands. The decrease however, is more pronounced in Malta than in Gozo.

When the percentages of the total number of bovines on all dairy holdings in Malta relative to Gozo are analysed, the values show that 64.32% (SD = 1.44), 64.40% (SD = 1.64) and 64.27% (SD = 1.45) of bovines, as calculated using methods 1, 2 and 3 respectively, are present on dairy holdings in Malta relative to Gozo (Table 12).

Table 12: Descriptive statistics of the percentage of bovines on dairy holdings in Malta and Gozo from 2004 to 2012 calculated using data obtained by the three methods described

	% bovine pop. (M1) Malta	% bovine pop. (M2) Malta	% bovine pop. (M3) Malta	% bovine pop. (M1) Gozo	% bovine pop. (M2) Gozo	% bovine pop. (M3) Gozo
Mean	64.32	64.40	64.27	35.68	35.61	35.73
Median	64.10	63.82	63.95	35.90	36.18	36.06
SD	1.44	1.64	1.45	1.44	1.64	1.45
Range	4.90	5.10	4.92	4.90	5.10	4.92
Minimum	62.73	62.75	62.70	32.37	32.15	32.38
Maximum	67.63	67.85	67.62	37.27	37.25	37.30
25th Percentile	63.49	63.17	63.44	35.16	34.69	35.24
50th Percentile	64.10	63.82	63.95	35.90	36.18	36.06
75th Percentile	64.84	65.31	64.76	36.51	36.83	36.56

The interquartile range of the percentages given by the three methods is around 1.60 meaning that they were quite stable during the study period. Only method 2 shows a significant correlation with $r = -0.692$, $n = 9$, $p = 0.039$ between the percentage bovine population and the year under review. This is due to the fact that since in method 2 the average number of animals per year is calculated by using the animal-days method, the percentage of bovines showed a decrease from 2004 to 2010 with an increase in the last two years, whereas methods 1 and 3 registered a decrease from 2004 to 2009 with an increase in the last three years. The fact that only one method gives a significant correlation, which is not very strong, also implies that the percentage distribution of bovines on dairy holdings in Malta relative to Gozo was relatively stable during the study period.

3.3.4 The trend in the number of female bovines over 2 years of age on dairy holdings

The trend in the number of F>2y of age on dairy holdings on the Maltese Islands was analysed since this data reflects the potential milk production on this type of holding. Method 3 was used in the analysis of this parameter. The trend for the period 2004 to 2012 is shown by the line diagram in Figure 14.

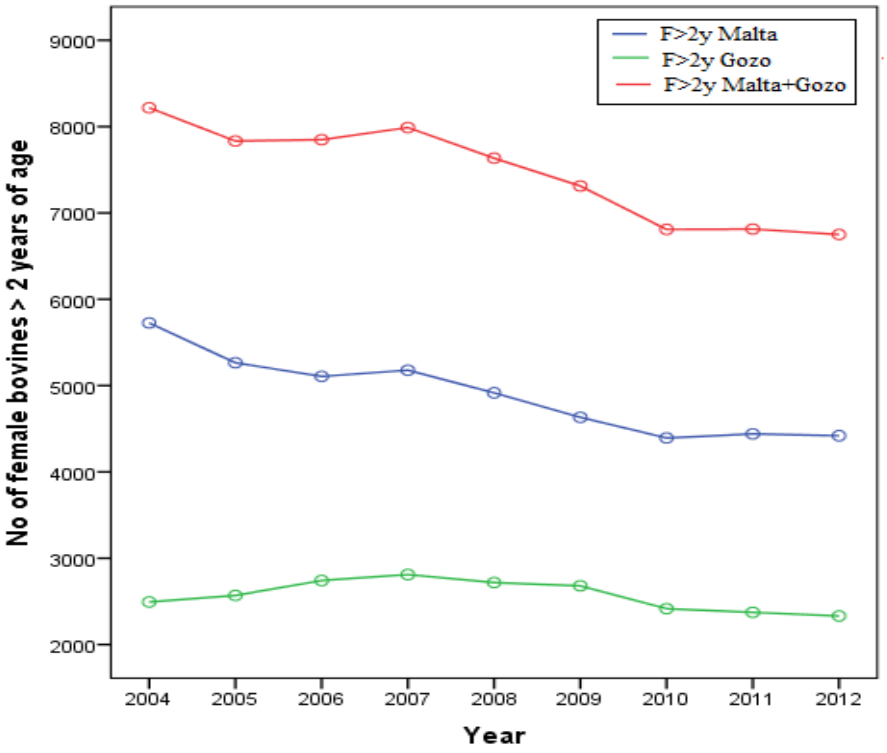


Figure 14: Line diagram showing the number of female bovines > 2 years of age on dairy holdings in Malta, Gozo and Malta + Gozo from 2004 to 2012

The number of F>2y of age on dairy holdings in Malta shows a decrease from 5,725 bovines in 2004 to 4,419 in 2012. This represents a decrease of 22.81%. The mean number of F>2y of age in Malta for the same period was 4,897.00 (SD = 461.63).

In Gozo, the number of F>2y of age increases slightly from 2,493 in 2004 to 2,811 in 2007. A slight decrease then follows to reach 2,331 in 2012. From 2004 to 2012 the number of F>2y of age on dairy holdings in Gozo decreased by only 6.50%. The mean number of F>2y of age in Gozo was 2,570.33 (SD = 175.80).

If the total number of F>2y of age on both islands is taken into consideration, a decrease of 17.86% from 8,218 in 2004 to 6,750 in 2012 can be seen. The mean number of F>2y of age on the Maltese islands was 7,467.33 (SD = 563.73) (Table 13).

Table 13: Descriptive statistics of the number of F>2y of age on dairy holdings in Malta, Gozo and Malta + Gozo from 2004 to 2012 using data obtained by Method 3

	F>2y Malta	F>2y Gozo	F>2y M+G
Mean	4,897.00	2,570.33	7,467.33
Median	4,916.00	2,569.00	7,634.00
SD	461.63	175.80	563.73
Range	1,332.00	480.00	1,468.00
Minimum	4,393.00	2,331.00	6,750.00
Maximum	5,725.00	2,811.00	8,218.00
25th Percentile	4,429.50	2,394.50	6,811.00
50th Percentile	4,916.00	2,569.00	7,634.00
75th Percentile	5,221.00	2,730.00	7,918.50

The decrease of 17.86% of F>2y of age on the Maltese Islands is very similar to the trend in the number of dairy cows on holdings in the European Union. Marquer (2013) reports a decrease of 20% in the number of dairy cows on the specialist dairying holdings in the EU-27 countries from 2007 to 2010. Specialist holdings are defined as deriving at least two thirds of their output from the dairy activity (Marquer, 2013). As described previously in some of the trends for Gozo, this parameter also shows a certain stability with a decrease of only 162 F>2y of age from 2004 to 2012.

A statistically significant, strong negative correlation is present between the number of F>2y of age in Malta and the period under study ($r = -0.956$, $n = 9$, $p < 0.0005$) showing that the number of F>2y of age in Malta decreased significantly during the study period. However, no significant correlation is present between the number of F>2y of age and the period under study in Gozo. This implies that their number in Gozo has remained relatively unchanged during the study period. When the trend for both islands is analysed together we obtained a statistically significant, strong negative correlation with $r = -0.946$, $n = 9$ and $p < 0.0005$.

The number of dairy cows in the EU stood at 22.9 million in 2011. Whilst Germany had the highest proportion of dairy cows, at 18.3% within the EU-27 countries (Marquer, 2013), the Maltese Islands with a dairy cow population of 6,813 in 2011, had the smallest proportion at 0.03 %.

An estimate of the average milk production in litres per cow per year can be calculated using the figures shown in Table 1 in the introduction. This is done by dividing the yearly figures by the number of female bovines greater than 2 years of age in each year. In this manner we are assuming that all female bovines greater than 2 years of age are producing milk during the majority of days in each year. Furthermore we are using figures for the milk sold to the dairy factory and not the actual total amount of milk produced by the dairy holdings. In all probability the actual total amount of milk produced would be slightly higher since it would also include any milk used on the holding itself. These assumptions had to be made since it was not possible to obtain exact data regarding the number of cows in lactation and the exact quantity of milk produced by each cow in every holding during the study period. Milk production per year in litres/Number of F>2Y was then divided by 305 (milking days per cow per year) to produce the final average milk produced per cow per day in litres.

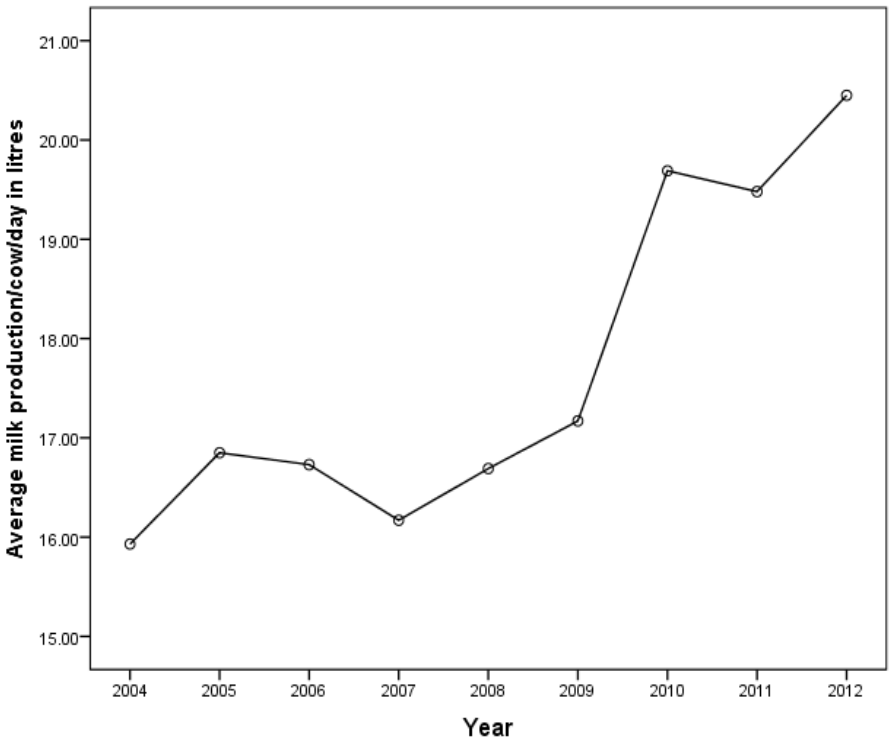


Figure 15: Line diagram showing the trend in the average milk production per cow per day in litres during the period 2004 to 2012

The average milk production/cow/day was 15.93 litres in 2004 and 20.45 in 2012 (Fig. 15). This represents an increase of 28.37%. The mean value for the same period is 17.68 litres (SD 1.70). Considering that the total number of F>2y of age on both islands

showed a decrease of 17.86% from 2004 to 2012, the increase in milk production is an indication of improved efficiency especially during the last four years of the study. The EBL eradication programme may have influenced such a trend since the imported stock may have improved the average milk yield. It would be interesting to further investigate if the restructuring of the holdings and any changes in herd management may have also contributed to this increase in average milk yield/cow/day.

3.3.5 The trend in the average bovine population (average herd size) on dairy holdings

This trend was included in the study to determine if the average herd size on dairy holdings on both islands was increasing to make up for the decreasing number of holdings. The trend is shown by the line diagram in Figure 16. In this instance data obtained by Method 3 was used in the analysis.

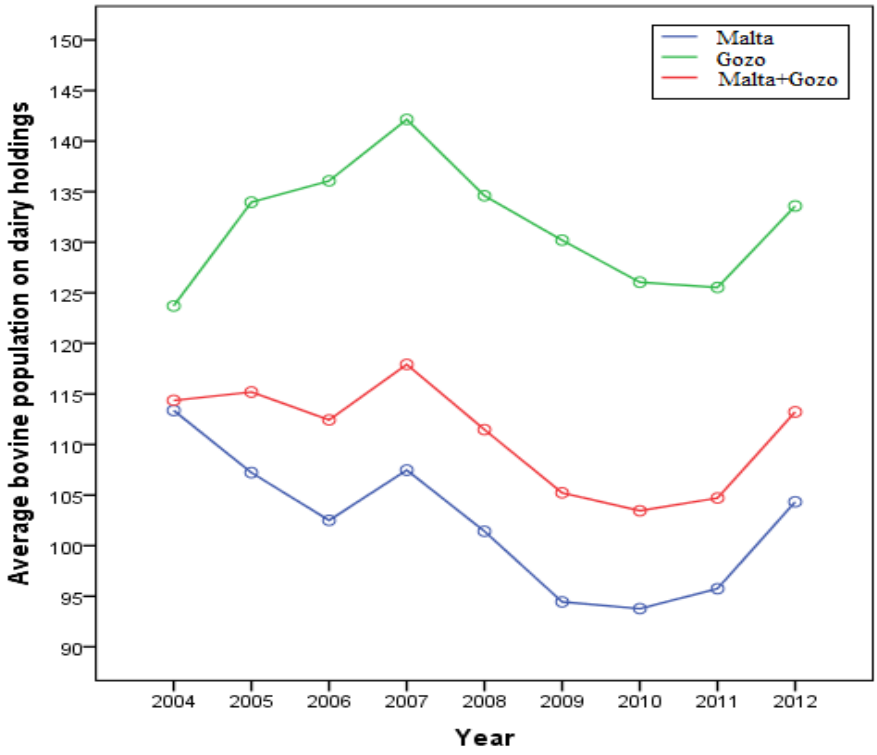


Figure 16: Line diagram showing the average bovine population (average herd size) on dairy holdings in Malta, Gozo and Malta + Gozo from 2004 to 2012

The average herd size on dairy holdings on the Maltese Islands was relatively stable from 2004 to 2006. This was mainly due to a decrease in the average herd size on dairy holdings in Malta from 113.37 in 2004 to 102.50 in 2006 and an increase in Gozo from 123.70 in 2004 to 136.07 in 2006. In 2007 an increase was registered in both Malta (107.47) and Gozo (142.14). In Malta the average herd size reached its minimum of 93.77 in 2010 whilst in Gozo a minimum of 125.53 was reached in 2011. An increase was then registered in both Islands in 2012 with values reaching 104.33 in Malta and 133.58 in Gozo (Table 14).

Table 14: Descriptive statistics of the average herd size on dairy holdings in Malta, Gozo and Malta + Gozo from 2004 to 2012 calculated using data obtained by Method 3

	Average herd size on dairy holdings Malta	Average herd size on dairy holdings Gozo	Average herd size on dairy holdings Malta + Gozo
Mean	102.25	131.76	110.89
Median	102.50	133.58	112.43
SD	6.67	5.93	5.17
Range	19.60	18.44	14.47
Minimum	93.77	123.70	103.45
Maximum	113.37	142.14	117.92
25th Percentile	95.10	125.79	104.97
50th Percentile	102.50	133.58	112.43
75th Percentile	107.35	135.34	114.78

The decrease on both islands from 2007 to 2010 was mainly due to the ongoing EBL eradication programme.

No statistically significant correlation is present between the average herd size and the year in Malta and Gozo ($r = -0.589$, $n = 9$, $p = 0.095$) or in Gozo alone ($r = -0.137$, $n = 9$, $p = 0.726$). A statistically significant, weak negative correlation is present between the average herd size on dairy holdings in Malta and the period under study ($r = -0.692$, $n = 9$, $p = 0.039$).

This implies that the average herd size on dairy holdings on both islands, although showing some fluctuations during the study period, remained relatively constant with a

mean value of 110.89 (SD = 5.17). The figures for the last three years of the study imply that the average herd size on these holdings is on the increase.

A statistically significant difference is present between the average herd size on dairy holdings in Malta and Gozo as determined by one-way ANOVA ($F(2, 24) = 58.42$, $p < 0.0005$). A Tukey post-hoc test shows that the average herd size on dairy holdings as calculated using M3 in Malta is statistically significantly lower (102.25 ± 6.67, $p < 0.0005$) than the average herd size on dairy holdings in Gozo (131.76 ± 5.93) for the period 2004 to 2012 (Fig. 17).

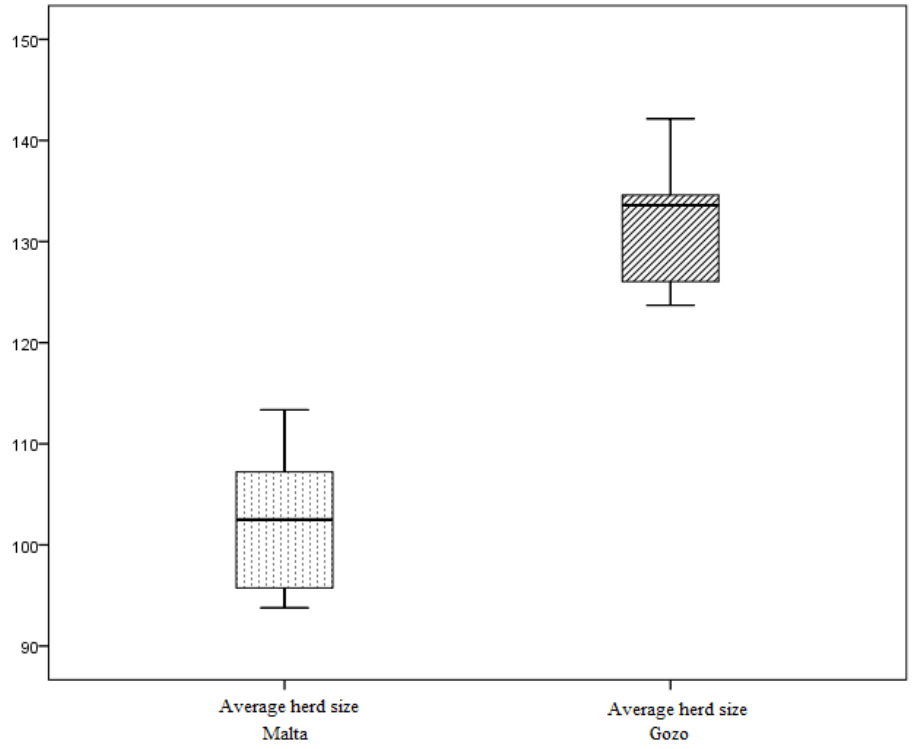


Figure 17: Box and whisker plot of the average herd size from 2004 to 2012 on dairy holdings in Malta and Gozo calculated using data obtained by Method 3

3.3.6 The trend in the average number of females greater than two years of age on dairy holdings

Apart from analysing the average herd size on dairy holdings, the trend in the average number of F>2y on dairy holdings on the Maltese Islands was also studied. This was considered important since any changes in this data group are very likely to affect the milk producing potential of the dairy holdings. The trend in the average number of F>2y of age on dairy holdings is shown in Figure 18.

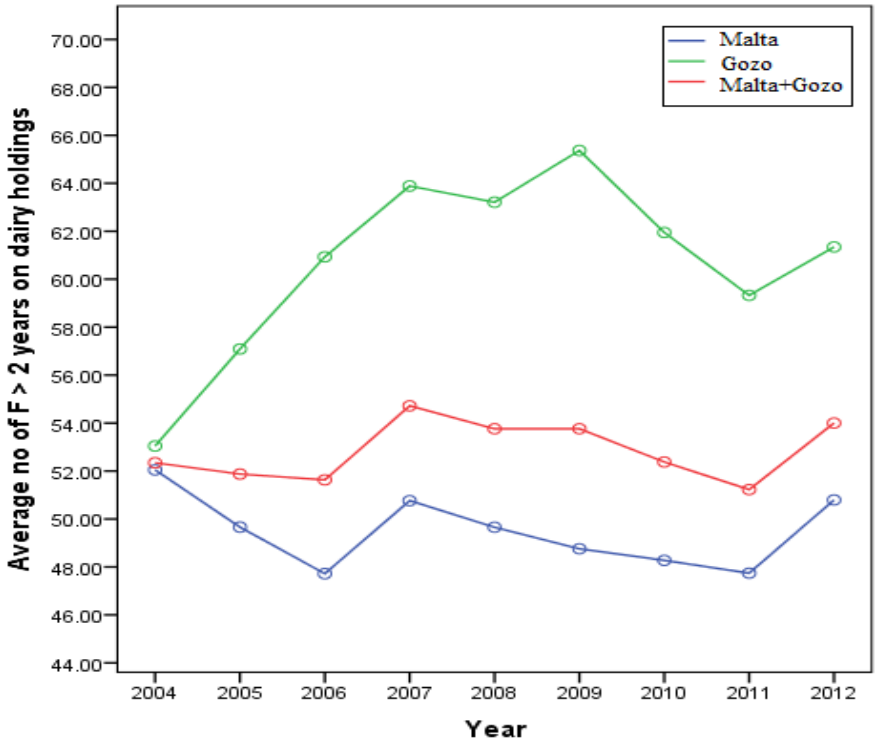


Figure 18: Line diagram showing the average number of F>2y on dairy holdings in Malta, Gozo and Malta + Gozo from 2004 to 2012

The trend on dairy holdings in Malta is quite different to that in Gozo. The trend in Malta is relatively stable throughout the period 2004 to 2012 with a mean of 49.49 (SD = 1.51) (Table 15).

Table 15: Descriptive statistics of the average number of F>2y on dairy holdings in Malta, Gozo and Malta + Gozo from 2004 to 2012 calculated using data obtained by Method 3

	Average F > 2y Malta	Average F > 2y Gozo	Average F > 2y Malta + Gozo
Mean	49.49	60.68	52.86
Median	49.65	61.34	52.38
SD	1.51	3.77	1.23
Range	4.33	12.32	3.49
Minimum	47.72	53.04	51.23
Maximum	52.05	65.37	54.72
25th Percentile	48.01	58.21	51.75
50th Percentile	49.66	61.34	52.38
75th Percentile	50.78	63.55	53.88

In Gozo the average number of F>2y on the holdings increases from a minimum value of 53.04 in 2004 to a maximum of 65.37 in 2009. The average then decreases to 59.33 in 2011 to increase again to 61.34 in 2012. The trend for the two islands together follows closely the trend shown for Malta and the trend line lies in between those for Malta and Gozo.

For the period under study, no statistically significant correlation was present between the average number of F>2y on dairy holdings and the year in Malta ($r = -0.354$, $n = 9$, $p = 0.350$), Gozo ($r = 0.525$, $n = 9$, $p = 0.146$), or on both islands taken together ($r = 0.194$, $n = 9$, $p = 0.617$). This implies that although there was an increase in Gozo from 53.04 to 65.37 during part of the study and which than levelled at 61.34, the average number of F>2y of age on both islands was relatively constant during the study period. This is in contrast to the trend in the EU-27 countries where the average number of dairy cows per holding has been reported to have increased (Marquer, 2013).

A statistically significant difference is present between the average number of F>2y on dairy holdings in Malta and Gozo from 2004 to 2012 as determined by one-way ANOVA ($F(2, 24) = 49.48$, $p < 0.0005$) (Fig. 19).

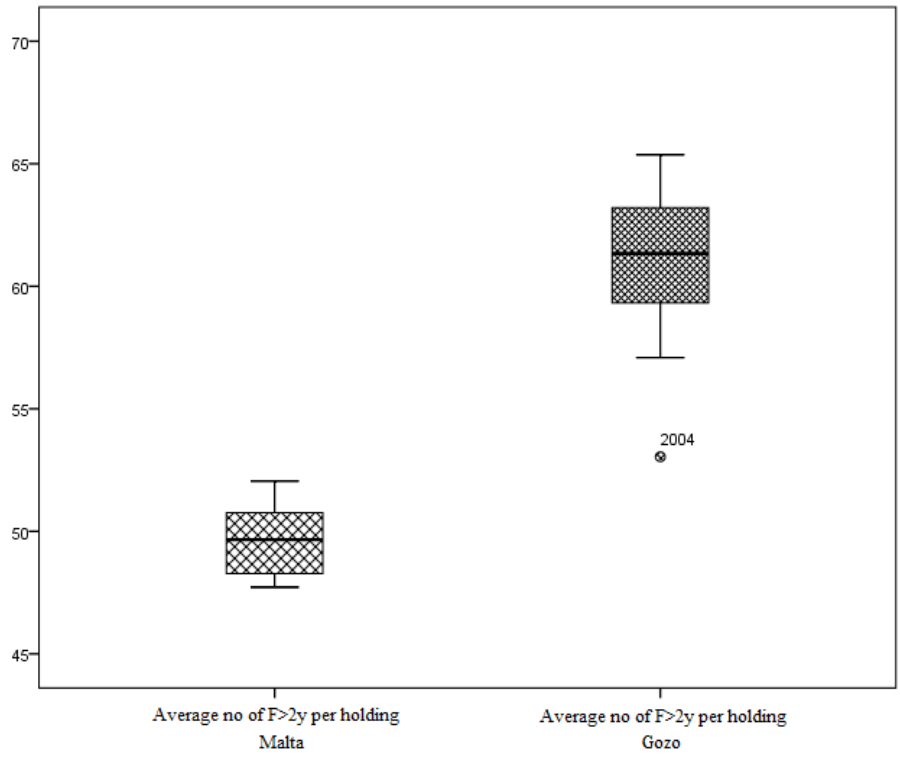


Figure 19: Box and whisker plot of the average number of females greater than two years of age (F>2y) on dairy holdings in Malta and Gozo calculated using data obtained by Method 3

A Dunnett T3 post-hoc test shows that the average number of F>2y on dairy holdings in Malta is statistically significantly lower (49.49 ± 1.51, $p < 0.0005$) than the average on dairy holdings in Gozo (60.68 ± 3.77). The average number of F>2y on dairy holdings in Malta and Gozo (52.86 ± 1.23) lies in between these two values. If we assume that the majority of female bovines over two years on dairy holdings are in fact dairy cows, than this average is higher than the average of around 28 dairy cows on EU-27 specialist dairying holdings where a maximum of 141 dairy cows per holding was reported in Denmark and a minimum of 3 cows per holding was reported in Romania (Marquer, 2013).

3.3.7 The trend in the number of female and male bovines and their ratio on dairy holdings

The trend in the number of female and male bovines on dairy holdings on the Maltese Islands from 2004 to 2012 is shown by the line diagram in Figure 20.

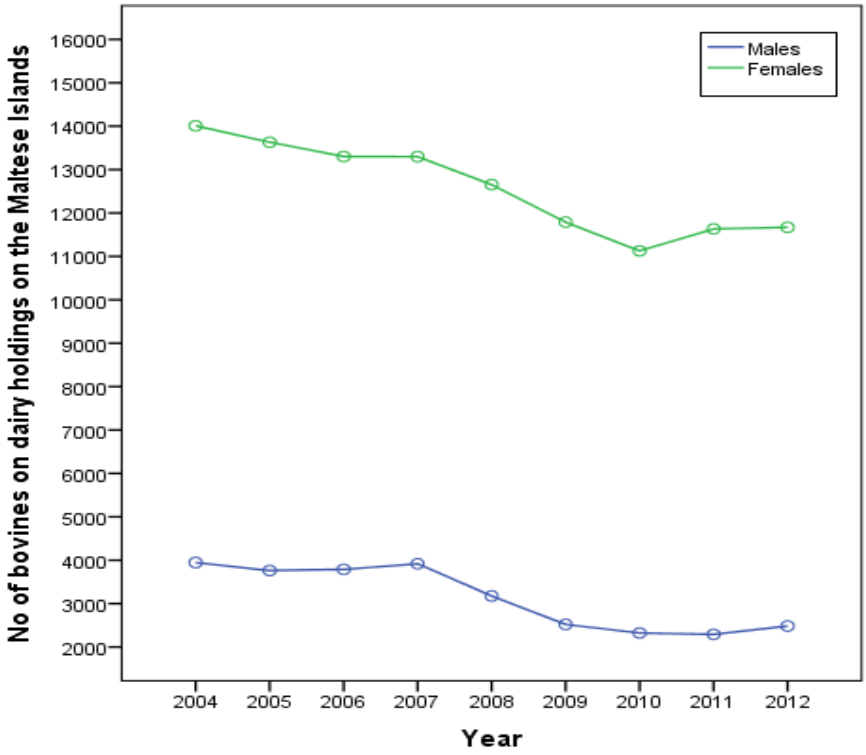


Figure 20: Line diagram showing the number of female and male bovines on dairy holdings on Malta + Gozo from 2004 to 2012 calculated using data obtained by Method 3

The mean number of female bovines on the Maltese Islands during the period 2004 to 2012 calculated using data obtained by M3 was 12,567.89 (SD = 1,039.70) whereas the mean number of male bovines was 3,134.44 (SD = 730.22) (Table 16). When the bovine populations on the two islands are analysed separately, the mean number of female bovines on holdings is Malta was found to be 8,228.32 (SD = 833.66) and the mean number of males was 1,878.78 (SD = 478.48). In Gozo the mean number of female bovines was nearly half that in Malta at 4,339.67 (SD = 269.66) whilst the mean number of males was quite similar to that found in Malta at 1,255.67 (SD = 258.89).

Table 16: Descriptive statistics of the number of male and female bovines and their ratios on dairy holdings in Malta, Gozo and Malta + Gozo from 2004 to 2012 calculated using data obtained by Method 3

	Males Malta	Females Malta	Ratio F to M Malta	Males Gozo	Females Gozo	Ratio F to M Gozo	Males Malta + Gozo	Females Malta + Gozo	Ratio F to M Malta + Gozo
Mean	1,878.78	8,228.22	4.55	1,255.67	4,339.67	3.56	3,134.44	12,567.89	4.14
Median	1,885.00	8,156.00	4.33	1,291.00	4,382.00	3.48	3,176.00	12,653.00	3.98
SD	478.48	833.66	0.78	258.89	269.66	0.56	730.22	1,039.70	0.66
Range	1,194.00	2,429.00	2.04	619.00	734.00	1.36	1,654.00	2,882.00	1.69
Min	1,320.00	7,198.00	3.71	972.00	3,929.00	2.93	2,292.00	11,127.00	3.39
Max	2,514.00	9,627.00	5.75	1,591.00	4,663.00	4.29	3,946.00	14,009.00	5.08
25th Percentile	1,401.00	7,522.50	3.80	998.00	4,054.00	3.02	2,403.00	11,651.50	3.53
50th Percentile	1,885.00	8,156.00	4.33	1,291.00	4,382.00	3.48	3,176.00	1,2653.00	3.98
75th Percentile	2,316.00	8,891.50	5.29	1,501.00	4,574.50	4.08	3,853.50	1,3466.00	4.75

Statistically significant, strong negative correlations are present between the number of male and female bovines and the period under study in both islands and when analysed together (Table 17). This indicated that the number of male and female bovines on both islands has decreased during the years from 2004 to 2012.

Table 17: Correlation coefficients between the number of male and female bovines (calculated by M3) and the year, on dairy holdings in Malta, Gozo and Malta & Gozo for the period 2004 to 2012

	No of Males Malta	No of Females Malta	No of Males Gozo	No of Females Gozo	No of Males Malta & Gozo	No of Females Malta & Gozo
Correlation coefficient	-0.927**	-0.919**	-0.859**	-0.750*	-0.912**	-0.931**
Sig. (2-tailed)	0.000	0.000	0.003	0.020	0.001	0.000

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

The ratio of female to male bovines on dairy holdings in both Malta and Gozo was relatively stable from 2004 to 2007. In Malta an increase in the ratio followed from 3.71 in 2007 to 5.75 in 2011. The ratio decreased slightly to 5.19 in 2012. In Gozo a marked increase was present from 2.93 in 2007 to 4.29 in 2009 and then the ratio remained relatively stable at 3.99 in 2012 (Fig. 21).

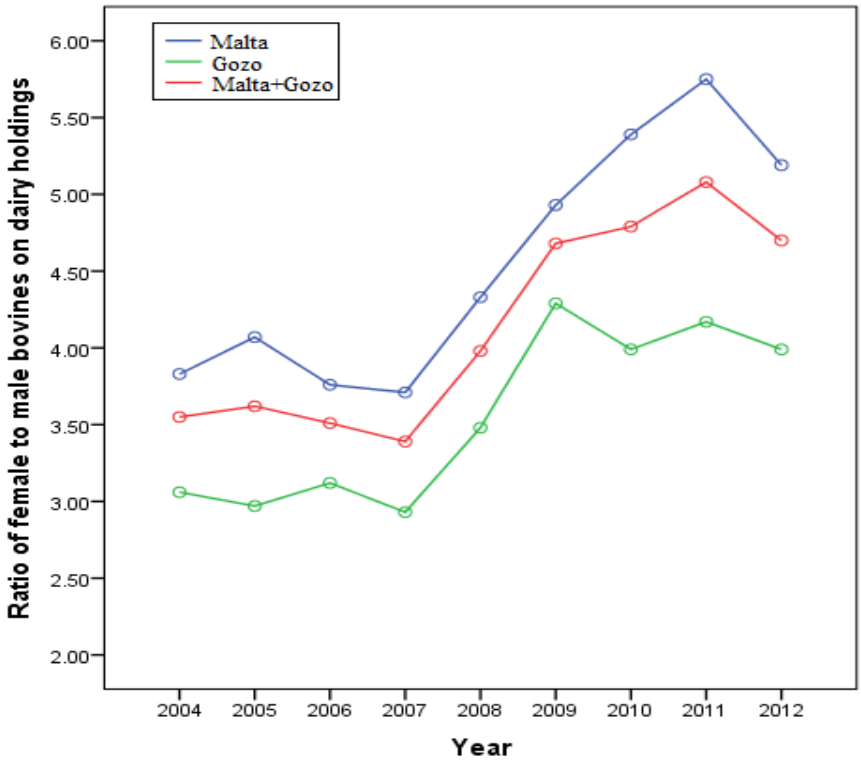


Figure 21: Line diagram showing the change in ratio between the number of female to male bovines on dairy holdings in Malta, Gozo and Malta + Gozo from 2004 to 2012

The increase in both cases is due to a proportionally larger decrease in the number of males on the holdings. This was possibly due to the slaughtering trends during the EBL eradication campaign.

Statistically significant, strong positive correlations are present between the ratio of female to male bovines and the year in Malta ($r = 0.879$, $n = 9$, $p < 0.05$), Gozo ($r = 0.856$, $n = 9$, $p < 0.05$), and Malta and Gozo ($r = 0.884$, $n = 9$, $p < 0.05$). This implies that the ratio of female to male bovines on dairy holdings in both Malta and Gozo increased during the period under study.

A statistically significant difference is present between the female to male bovine ratios on dairy holdings in Malta and Gozo calculated using data obtained by M3 during the period 2004 to 2012 as determined by one-way ANOVA ($F(2,24) = 5.01$, $p < 0.05$). A Tukey post-hoc test shows that the female to male bovine ratio on holdings in Malta is statistically significantly higher (4.55 ± 0.78, $p < 0.05$) than the ratio on dairy holdings in Gozo (3.56 ± 0.56) (Fig. 22).

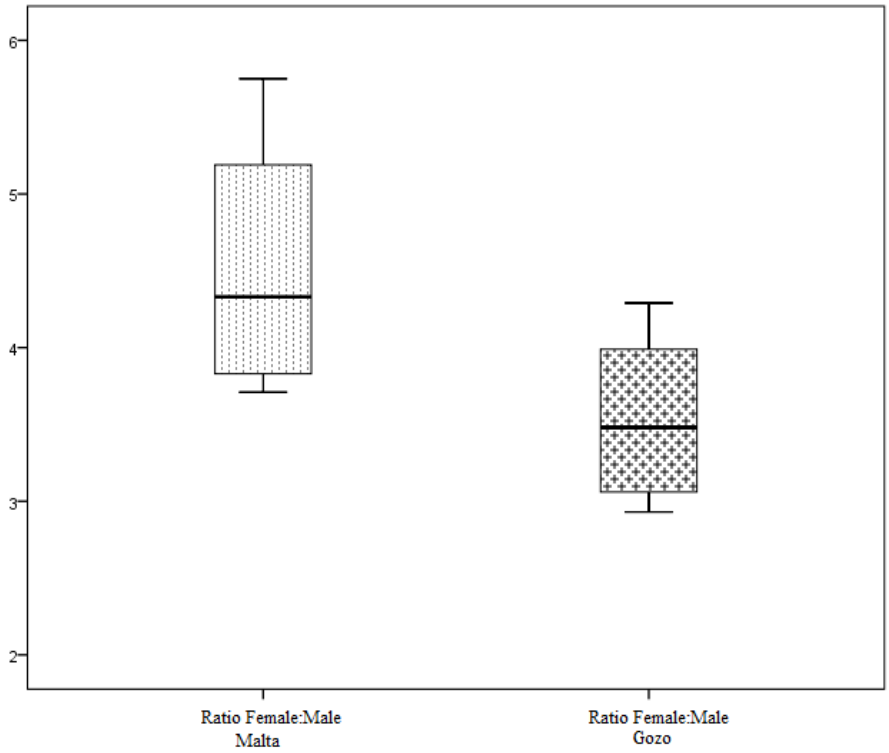


Figure 22: Box and whisker plot of the ratio of female to male bovines on dairy holdings in Malta and Gozo as calculated using data obtained by Method 3

This difference might be due to the fact that the number of non-dairy bovine holdings in Gozo and their average herd population is considerably lower than those in Malta and they contain only around 1.00% of the bovine population in Gozo (Table 6). As a result dairy holdings in Gozo tend to keep more male bovines up to slaughtering age rather than selling them to non-dairy holdings at an early age as happens in Malta.

3.4 Conclusions

This part of the research project has described and analysed six trends with regard to dairy holdings and their bovine population on the Maltese Islands from 2003, a year before Malta's accession to the European Union to 2012. The general trends on the Maltese Islands show that there was a significant decrease in the number of dairy holdings, in the total bovine population and in the number of F>2y of age during the study period. The number of dairy holdings and the total bovine population decreased by approximately 17.74% and 20.68% respectively, depending on the method used for

their calculation. The total number of F>2y on dairy holdings on the islands decreased by 17.86% from 2004 to 2012. On the other hand, the average herd size and the average number of F>2y on dairy holdings on the Maltese Islands showed no statistically significant changes during the study period. A significant increase in the ratio of female to male bovines from 3.55 to 4.70 was registered on these holdings. The fact that the average herd size and the average number of F>2y of age on the holdings showed no significant changes implies that the bovine population on the individual holdings still active during the study period was relatively stable.

Key Findings of Chapter 3

- ✓ ***The average decrease in the number of dairy holdings in Malta from 2003 to 2012 was of 18.32%.***

- ✓ ***The average decrease in the number of dairy holdings in Gozo from 2003 to 2012 was of 16.90%.***

- ✓ ***The average decrease in the number of dairy holdings in Malta + Gozo from 2003 to 2012 was of 17.74%.***

- ✓ ***The mean number of dairy holdings in Malta from 2003 to 2012 varied from 100.10 to 109.00 depending on the method used.***

- ✓ ***The mean number of dairy holdings in Gozo from 2003 to 2012 varied from 42.90 to 44.50 depending on the method used.***

- ✓ ***A statistically significant ($p < 0.0005$) and progressive decrease ($r = -0.913$ to -0.992 depending on the method used) in the number of dairy holdings was registered in Malta, Gozo and Malta + Gozo.***

- ✓ ***The percentage of dairy holdings per year in Malta compared to Gozo varies from 69.99% to 71.02% depending on the method used in the calculation.***

- ✓ ***This percentage was relatively stable during the 10 year study period.***

- ✓ ***The overall decrease in the total number of bovines on dairy holdings in Malta from 2004 to 2012 varied from 24.24% to 25.24% depending on the method used in the calculation.***

- ✓ ***The overall decrease in the total number of bovines on dairy holdings in Gozo from 2004 to 2012 varied from 11.81% to 12.69% depending on the method used in the calculation.***

- ✓ ***The overall decrease in the total number of bovines on dairy holdings in Malta + Gozo from 2004 to 2012 varied from 20.25% to 21.18% depending on the method used in the calculation.***

- ✓ ***The mean number of bovines per year from 2004 to 2012 on all dairy holdings in Malta varied from 10,107.00 to 10,219.44 depending on the method used in the calculation.***

- ✓ ***The mean number of bovines per year from 2004 to 2012 on all dairy holdings in Gozo varied from 5,595.33 to 5,626.11 depending on the method used in the calculation.***

- ✓ ***The mean number of bovines per year from 2004 to 2012 on all dairy holdings in Malta + Gozo varied from 15,702.33 to 15,845.56 depending on the method used in the calculation.***

- ✓ ***A statistically significant ($p < 0.0005$) and progressive decrease ($r = -0.930$ to -0.944 depending on the method used) was registered in the total number of bovines on dairy holdings in Malta from 2004 to 2012.***

- ✓ ***A statistically significant ($p < 0.05$) and progressive decrease ($r = -0.764$ to -0.826 depending on the method used) was registered in the total number of bovines on dairy holdings in Gozo from 2004 to 2012.***

- ✓ ***A statistically significant ($p < 0.0005$) and progressive decrease ($r = -0.929$ to -0.930 depending on the method used) was registered in the total number of bovines on dairy holdings in Malta + Gozo from 2004 to 2012.***

- ✓ ***The decrease in the total number of bovines on dairy holdings is more pronounced in Malta than in Gozo.***

- ✓ ***The percentage of the total number of bovines on dairy holdings in Malta relative to Gozo from 2004 to 2012 varied from 64.27% to 64.40% depending on the method used in the calculation.***

- ✓ ***The percentage of the total number of bovines on dairy holdings in Malta relative to Gozo was relatively stable during the study period.***

- ✓ ***The number of female bovines greater than two years of age on dairy holdings in Malta decreased by 22.81% from 2004 to 2012.***

- ✓ ***The mean number of female bovines greater than two years of age on dairy holdings in Malta was 4,897.00 (SD = 461.63).***

- ✓ ***The number of female bovines greater than two years of age on dairy holdings in Gozo decreased by 6.50% from 2004 to 2012.***

- ✓ ***The mean number of female bovines greater than two years of age on dairy holdings in Gozo was 2,570.33 (SD = 175.80).***

- ✓ ***The number of female bovines greater than two years of age on dairy holdings in Malta + Gozo decreased by 17.86% from 2004 to 2012.***

- ✓ ***The mean number of female bovines greater than two years of age on dairy holdings in Malta + Gozo was 7,467.33 (SD = 563.73).***

- ✓ ***A statistically significant decrease ($r = -0.956$, $p < 0.0005$) was registered in the number of female bovines greater than two years of age on dairy holdings in Malta from 2004 to 2012.***

- ✓ ***No statistically significant correlation was found between the number of female bovines greater than two years of age on dairy holdings in Gozo and the period under study implying that their number in Gozo remained relatively constant.***

- ✓ ***A statistically significant decrease ($r = -0.946$, $p < 0.0005$) was registered in the number of female bovines greater than two years of age on dairy holdings in Malta + Gozo from 2004 to 2012.***

- ✓ ***The average milk production/cow/day for the period 2004 to 2012 was found to be 17.68 litres (SD 1.70). The minimum was 15.93 litres registered in 2004 and the maximum was 20.45 litres registered in 2012. This represents an increase of 28.37%.***

- ✓ ***The average herd size on dairy holdings in Malta from 2004 to 2012 was 102.25 (SD = 6.67).***

- ✓ ***The average herd size on dairy holdings in Gozo from 2004 to 2012 was 131.76 (SD = 5.93).***

- ✓ ***The average herd size on dairy holdings in Malta + Gozo from 2004 to 2012 was 110.89 (SD = 5.17).***

- ✓ ***The average herd size in Malta showed a weak but statistically significant decrease ($r = -0.692$, $p = 0.039$) from 2004 to 2012.***

- ✓ ***The average herd size in Gozo alone showed no statistically significant changes during the study period implying that the average herd size was relatively constant during this period. This result was also obtained when data for Malta and Gozo were taken together.***

- ✓ ***Trend lines show that the average herd size in Malta and Gozo appear to be on the increase as from 2010 and 2011 respectively.***

- ✓ ***A statistically significant difference ($p < 0.0005$) is present between the average herd size on dairy holdings in Malta (102.25 ± 6.67) and in Gozo (131.76 ± 5.93).***

- ✓ ***The trend regarding the average number of female bovines greater than two years of age on dairy holdings in Malta was relatively stable with a mean of 49.49 (SD = 1.51).***

- ✓ ***In Gozo the average number of female bovines greater than two years of age on dairy holdings showed an increase in the first half of the study period but then decreased again in the second half. The average in Gozo was 60.68 (SD = 3.77).***

- ✓ ***No significant correlation is present between the average number of female bovines greater than two years of age on dairy holdings in Malta, Gozo or Malta and Gozo taken together implying that this average remained relatively constant during the study period.***

- ✓ ***A statistically significant difference ($p < 0.0005$) is present between the average number of female bovines greater than two years of age on dairy holdings in Malta (49.49 ± 1.51) and Gozo (60.68 ± 3.77).***

- ✓ ***The mean number of female bovines on the Maltese Islands during the period 2004 to 2012 was 12,567.89 (SD = 1,039.70) whereas the mean number of male bovines was 3,134.44 (SD = 730.22).***

- ✓ ***In Malta alone, the mean number of female bovines was 8,228.32 (SD = 833.66) whereas the mean number of male bovines was 1,878.78 (SD = 478.48).***

- ✓ ***In Gozo alone, the mean number of female bovines was nearly half that present in Malta at 4,339.67 (SD = 269.66) whereas the mean number of male bovines was relatively similar to Malta at 1,255.67 (SD = 258.89).***

- ✓ ***A statistically significant ($p < 0.05$) strong negative correlation is present between the mean number of male and female bovines and the period under study on both islands and also when taken together implying that their numbers decreased on both islands during the study period.***

- ✓ ***A statistically significant ($p < 0.05$) strong positive correlation is present between the ratio of female to male bovines and the year in Malta, Gozo and***

Malta plus Gozo implying that the ratio of female to male bovines on dairy holdings on both islands increased during the study period.

- ✓ ***The mean ratio of female to male bovines on dairy holdings in Malta plus Gozo from 2004 to 2012 was 4.14 (SD = 0.66).***

- ✓ ***A statistically significant difference ($p < 0.05$) is present between the ratio of female to male bovines on dairy holdings in Malta (4.55 ± 0.78) and Gozo (3.56 ± 0.56).***

Chapter 4

A comprehensive benchmark study investigating dairy calf mortality rates up to 180 days of age on dairy holdings on the Maltese islands together with the study of five risk factors influencing calf mortality

4.1 Introduction

The study of calf mortality is of particular relevance from both an economic and also from an animal welfare point of view (Fraser and Broom, 1997). As a result, establishing calf mortality rates is one of the steps towards evaluating the efficiency and the state of animal welfare of the dairy sector on the Maltese Islands. The dairy industry is the predominant industry within the bovine husbandry sector on the islands of Malta and Gozo and establishing a benchmark calf mortality rate is therefore of importance to this industry. It is also important to compare local data on mortality rates with calf mortality rates in other countries since this gives a good indication of the state of animal health and welfare on dairy holdings on the Maltese Islands. Published estimates of calf mortalities vary according to the time periods calves are followed throughout the study and according to whether or not data for abortions and stillbirths are also included. In fact, according to Radostits (2001), calf mortality can be divided into four groups depending on the age at time of death: abortion or prenatal deaths (stillborn calves from 40 to 270 days of gestation), perinatal mortality (stillborn after 270 days of gestation or until 24 hours after birth), neonatal mortality (death between 1 and 28 days of age), and older calf mortality (death between 1 and 6 months of age). This variation in data makes it difficult to make comparisons across countries.

Several authors have reported calf mortality rates in different countries. These include calf mortality rates of 4.6% in live born dairy calves up to one year of age in Norway (Gulliksen et al., 2009), 4.0% in live born dairy calves up to 210 days of age in Sweden (Svensson et al., 2006) and an average of 2.0% to 6.0% on British cattle farms for calves followed up to six months of age (Ortiz-Pelaez et al., 2008). A study carried out

by the Department of Environment, Food and Rural Affairs (DEFRA) of the United Kingdom (UK), estimates that up to 6.0% of calves born in the UK die before reaching 6 months of age (DEFRA, 2003). Azizzadeh et al. (2012) report a mortality rate of 6.5% in live born dairy calves up to 90 days of age in Iranian Holstein dairy herds.

The objectives of this study were to determine for the first time, the overall live born calf mortality rates up to 180 days of age in dairy herds on the Maltese Islands and to study five risk factors which included:

- the island on which the calves were born;
- the sex of the calves;
- the average herd size of the holding on which the calves were born and reared;
- the year of birth of the calves;
- the season of birth of the calves.

Some of these risk factors have been investigated in other countries by a number of authors including Jenny et al. (1981), Waltner-Toews et al. (1986a, b), Wells et al. (1996), Svensson et al. (2006) and Gulliksen et al. (2009).

To the best of our knowledge no studies on calf mortality rates on the Maltese Islands have been published to date. In an unpublished doctoral thesis entitled 'Assessment of the impact of EU accession on the livestock industries in Malta' M. Vella de Brincat (2002) reports an estimated average calf mortality rate of 12% during 2002 whereas in another unpublished doctoral thesis entitled 'Improvement of quality and quantity of dairy milk in the Maltese Islands' J. Azzopardi (2006) reports an estimated 10% to 15% mortality rate in calves within the first month of age during 2005. In both these works, the mortality rate is an estimate and no indication is given on how these results were calculated.

4.2 Materials and methods

4.2.1 Collection of data

This part of the study was carried out using data pertaining to all the dairy herds present on the islands of Malta and Gozo. On both islands all dairy herds are registered in the Maltese National Livestock Database. The NLD was introduced in 2002 and recognised as being fully operational by the European Union in 2004 (European Commission, 2004a).

All bovine herds on the Maltese Islands have to be registered with the Veterinary and Phytosanitary Regulation Department (VPRD) which currently forms part of the Ministry for Sustainable Development, the Environment and Climate Change (Government of Malta, 2005a; Government of Malta, 2005b). Furthermore, it is mandatory to tag all calves within 20 days of birth (Government of Malta, 2005a). As a result all tagged bovines on the Islands of Malta and Gozo can be traced through the centralised NLD.

In the NLD, exits of bovines from dairy holdings are coded as individual events. This means that a record exists for each registered movement of every bovine on these holdings. These events include bovines which are slaughtered, sold or those dying on the holding. The date of death has to be reported by the owner within seven days of the event occurring (Government of Malta, 2005a).

4.2.2 Study design

A retrospective longitudinal study was conducted on all the dairy herds present on the islands of Malta and Gozo and registered in the NLD. The study period was from 1st January 2004 till 30th June 2012. A total of 162 dairy holdings were active during all or part of the study period. One hundred thirteen of these dairy holdings were located in Malta and 49 in Gozo. All calves born alive on dairy holdings from the 1st January 2004 till the 31st of December 2011 were followed for 180 days from their date of birth.

Calves included in the study were all ear tagged and could be traced up to the date of notification of death or, if still alive, up to 180 days from the date of birth. For the purposes of this study, the death of a calf was registered as an event when it was born alive and notified as having died by any cause before 180 days of age on the same holding of birth. Calves that were slaughtered or sold before 180 days of age, or those that were still alive at the end of the follow up period of 180 days were censored on the date of slaughtering, sale or at 180 days of age respectively.

Mortality rate is defined by Dohoo et al. (2009) as the number of animals that die from all causes in a defined time period. It is calculated as the number of animals that die in a population per unit of animal-time during a given time period. In this study the calf mortality rate was determined by calculating the number of deaths per total number of calf-time at risk (in days).

A total of 44,078 calves were included in the study, of which 28,848 were born in Malta and 15,230 in Gozo. In total 2,821 calves were registered as having died on the same holding where they were born before reaching 180 days of age. For these calves the date of death was considered as the failure time. For the surviving calves day 180 was considered as the failure time.

Only dairy herds were included in the study since 85.43% and 98.91% of bovines in Malta and Gozo respectively were present on dairy holdings during the study period. The majority of non-dairy holdings are small holdings, mostly managed on a part-time basis, and buy in young calves from the dairy holdings to fatten and slaughter.

4.2.3 Statistical methods

The data collected was transferred from the NDL to Microsoft Excel files where data verification and validation was performed. The data was then transferred to two statistical packages namely SPSS version 21 and STATA 12 where survival analysis was performed.

The five risk factors studied were: the island on which the calves were born, the sex of the calves, the average herd size of the holding on which the calves were born and reared, the season of birth and the year of birth of the calves. The season of birth variable was coded as a categorical variable of four levels according to the date of birth of each calf in the following manner:

- Calves born from the beginning of March to the end of May were registered as being born in spring;
- Calves born from the beginning of June to the end of August were registered as being born in summer;
- Calves born from the beginning of September to the end of November were registered as being born in autumn;
- Calves born from the beginning of December to the end of February were registered as being born in winter.

The holdings where the calves were born and reared were divided into six groups according to the average herd size of the holding during the study period:

- Group 1: ≤ 25 bovines;
- Group 2: 26-50 bovines;
- Group 3: 51-100 bovines;
- Group 4: 101-200 bovines;
- Group 5: 201-300 bovines;
- Group 6: > 300 bovines.

To calculate the average herd size, the database was used to locate all the animals that were present on each holding at any time during the study period. The number of days during which each animal was present during the period (animal-days) was then calculated. The total number of animal-days divided by the number of days in the period gives the average herd size on any particular holding.

Survival analysis, including Life tables, Kaplan-Meier curves and Cox regression analysis, was used to account for any calves censored during the study due to sale or slaughter before 180 days and due to right censoring at the end of the study period.

A Cox proportional hazard model was used to evaluate the association between the five risk factors and the survival of calves up to 180 days of age. The assumption for proportional hazards was met. A backward stepwise approach was used to select the risk factors that best explained calf survival. Those risk factors that were not statistically significant at $P<0.05$ were removed from the model one at a time until only the statistically significant variables were left.

The hazard function plot gave a humped profile and the two appropriate distributions for the parametric model are the Log-normal and Log-logistic distributions. Both the Akaike information criterion (AIC) and the Bayesian information criterion (BIC) indicate that the Log-normal Accelerated failure time (AFT) parametric model provides the best fit. This model was further used to evaluate the outcome of the variables in the study using STATA 12 and no significant differences were encountered from the results obtained by the proportional hazards models.

4.3 Results

A summary of the results obtained in this study is shown in Table 18.

Table 18: Risk factors, number of live births, deaths and mortality rates of calves up to 180 days of age included in the study together with significance values and Exp (B) values for the various risk factors

Risk factor		Live births (n)	Deaths (n)	Mortality rate (%)	*P* value	Exp(B)	95% CI for Exp(B)
Island of birth					<0.001		
	Malta	28,848	1,519	6.05		0.675	0.626-0.729
	Gozo	15,230	1,302	8.80			
Sex of calf					<0.001		
	Male	21,136	1,482	8.50		1.413	1.312-1.522
	Female	22,942	1,339	6.00			
Average herd size					0.010		
	≤25	1,000	51	5.85	0.868	1.025	0.764-1.376
	26-50	2,097	116	6.73	0.309	1.114	0.905-1.372
	51-100	10,439	617	6.63	0.167	1.094	0.963-1.244
	101-200	14,066	934	7.39	0.003	1.199	1.065-1.350
	201-300	10,581	697	7.30	0.001	1.239	1.092-1.406
	>300	5,895	406	7.04			
Year of birth					<0.001		
	2004	6,436	371	6.42	0.131	1.130	0.964-1.323
	2005	6,287	460	8.28	0.000	1.455	1.251-1.694
	2006	5,921	425	8.15	0.000	1.423	1.220-1.660
	2007	5,790	347	6.43	0.259	1.097	0.934-1.288
	2008	4,948	377	8.17	0.000	1.413	1.207-1.654
	2009	4,808	294	6.78	0.056	1.176	0.996-1.389
	2010	4,799	284	6.44	0.160	1.128	0.954-1.334
	2011	5,089	263	5.77			
Season of birth					NS		
	Spring	9,848	629	7.04			
	Summer	11,660	731	7.00			
	Autumn	11,250	730	7.16			
	Winter	11,320	731	7.12			
NS = not significant							

The overall mortality rate up to 180 days of age of live born calves on dairy holdings on the Maltese Islands was found to be 7.08% (Fig. 23).

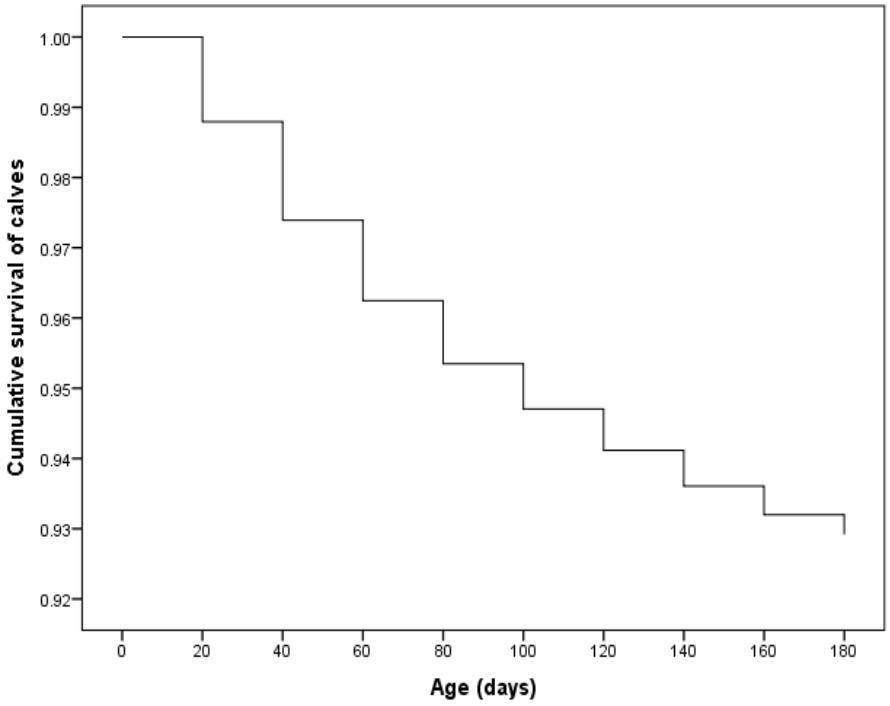


Figure 23: Cumulative survival curve for calves on dairy holdings on the Maltese Islands starting from day of birth to 180 days of age

The mortality rates on the 162 holdings in the study varied significantly from a minimum of 0.00% to a maximum of 24.80%. The number of reported deaths reaches its peak during the first 30 days of age of the calves and then it decreases progressively till 180 days of age (Fig. 24).

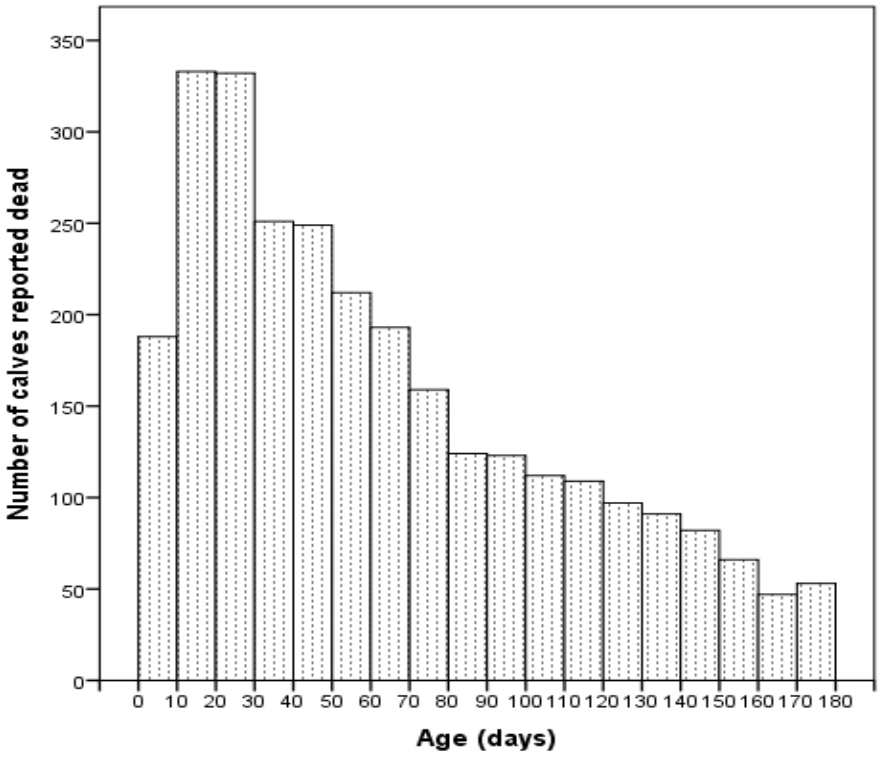


Figure 24: Histogram showing the distribution of reported deaths in calves by age in days from the day of birth up to 180 days

The median age at death was 52 days and the mean was 63.43 days (SD = 45.96). Twenty five per cent of the calves were reported dead by 25 days of age and 75% died before reaching 96 days.

The daily hazard rate increased from day 1 to reach a peak of 0.0010 at 15 days of age. It then decreases to peak again at 0.0010 on day 44. The daily hazard rate then decreases gradually till 180 days of age (Fig. 25).

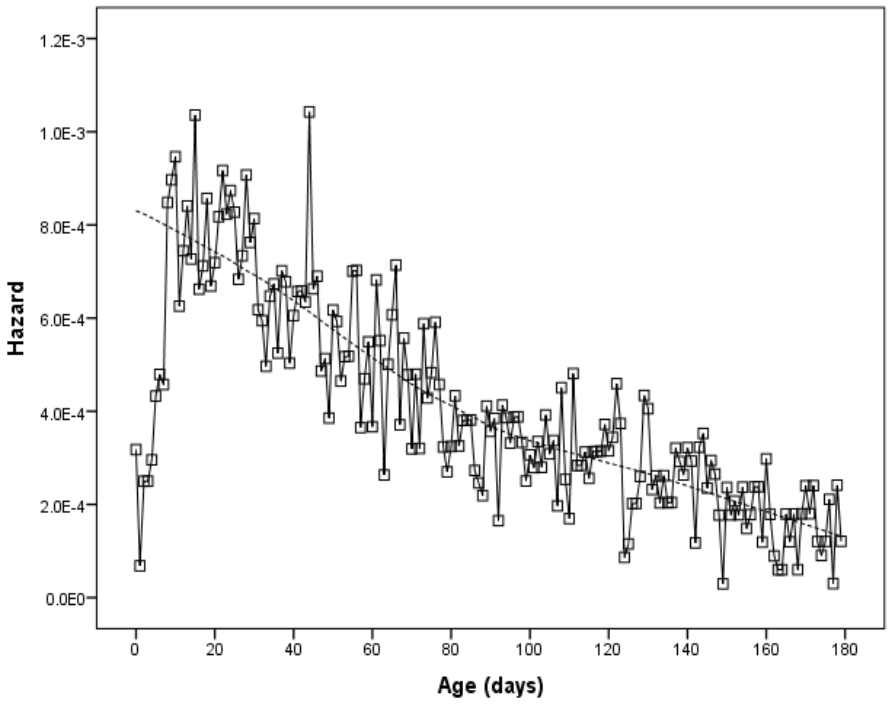


Figure 25: Line diagram showing the daily hazard of death in calves from birth to 180 days of age. The dotted line is a lowess smoothed curve generated from the data

The results obtained when the five risk factors were analysed are summarised by the Kaplan-Meier curves shown in Figures 26 to 30.

4.3.1 The island on which the calves were born

When the mortality rates on the islands of Malta and Gozo are analysed separately, a value of 6.05% was obtained for calves on holdings in Malta and 8.80% for those in Gozo (Fig. 26).

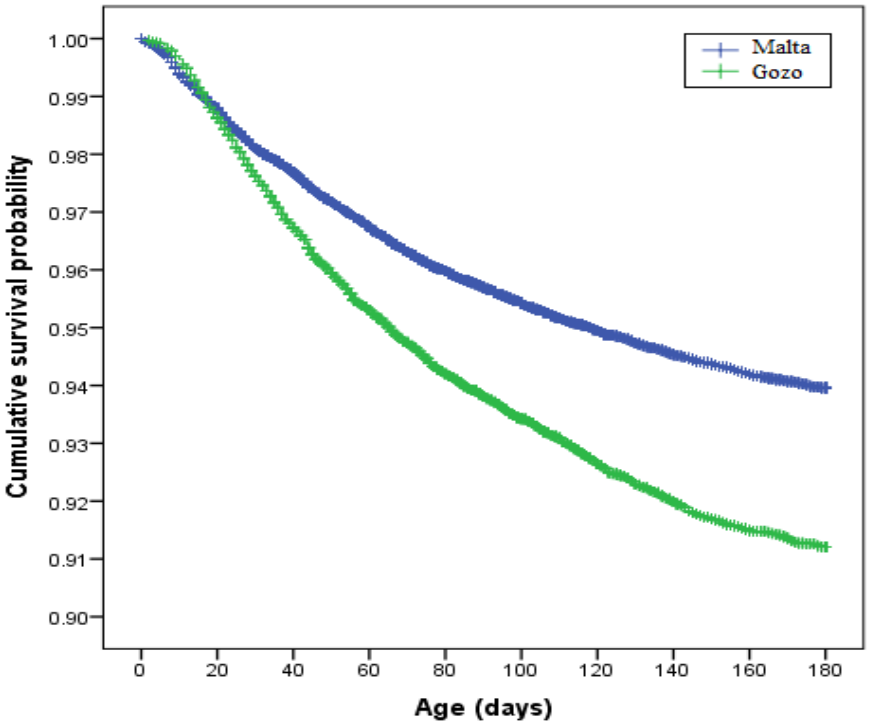


Figure 26: Kaplan-Meier curves showing the cumulative survival probability of calves from day of birth to 180 days of age on dairy holdings on the Maltese Islands stratified by the island of birth of the calves

Cox Regression analysis demonstrated that the cumulative survival probability of calves in Malta was significantly different from that in Gozo ($P<0.001$; exponentiation of the B coefficient [Exp (B)], 0.675; 95% CI for Exp (B), 0.626-0.729). The risk of a calf dying before reaching 180 days of age is reduced by an estimated 32.50% on holdings in Malta compared to Gozo.

4.3.2 The sex of the calves

Of the 44,078 calves entered in the study, 21,136 were male and 22,942 female. The number of calves reported dead before reaching 180 days of age was 1,482 males and 1,339 females. The cumulative proportion of calves surviving up to 180 days of age is 0.915 (8.50% mortality rate) for males and 0.940 (6.00% mortality rate) for females. The Kaplan-Meier curves indicate a difference in the survival probability of male and female calves (Fig. 27).

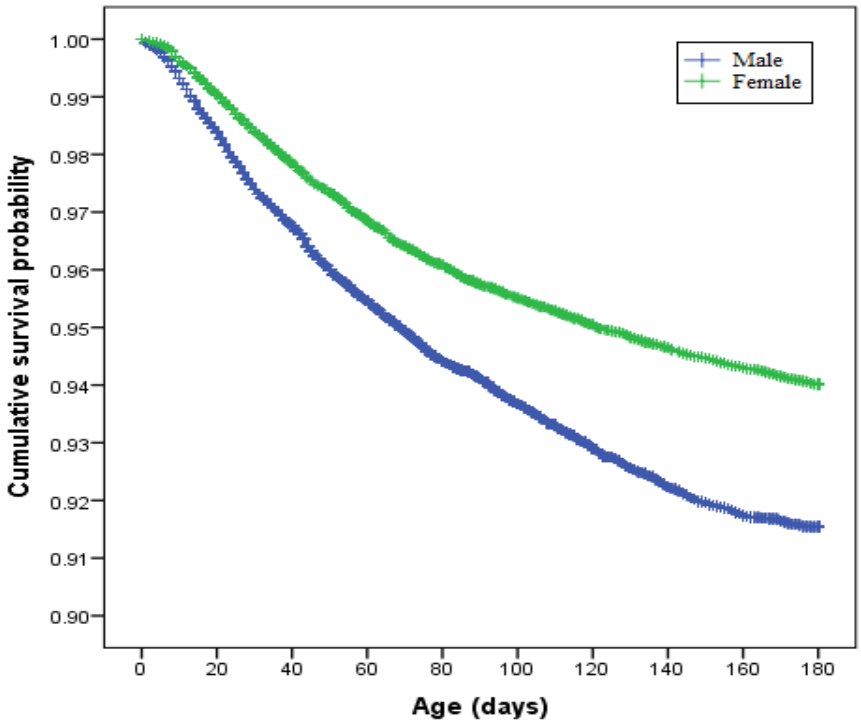


Figure 27: Kaplan-Meier curves showing the cumulative survival probability of calves from day of birth to 180 days of age on dairy holdings on the Maltese Islands stratified by sex of the calf

Cox Regression analysis demonstrated that these values were significantly different (P<0.001; Exp (B), 1.413; 95% CI for Exp (B) 1.312-1.522). A male calf on the Maltese Islands is estimated to have a 41.30% higher risk of death before reaching 180 days of age than a female calf.

The higher mortality rate for male calves was registered in both the islands of Malta and Gozo. The mortality rate of male calves up to 180 days of age in Malta was found

to be 7.00% whereas for those in Gozo it was 10.00%. Female calves in Malta had a mortality rate up to 180 days of age of 5% whereas for those in Gozo it was 8%.

4.3.3 The average herd size of the holding on which calves are born and reared

When the effect of the average herd size of the holding on calf mortality was analysed by Cox Regression analysis, a significance of $P = 0.01$ (Table 18) was obtained. The mortality rates were significantly higher in Groups 4, 5 and 6 having an average herd size of 101 – 200 bovines, 201 – 300 and greater than 300 bovines respectively. The Kaplan-Meier curves indicated that from 60 days of age onwards, the mortality rate for calves on holdings having an average herd size of ≤ 25 is lower than all the other groups of dairy holdings (Fig. 28).

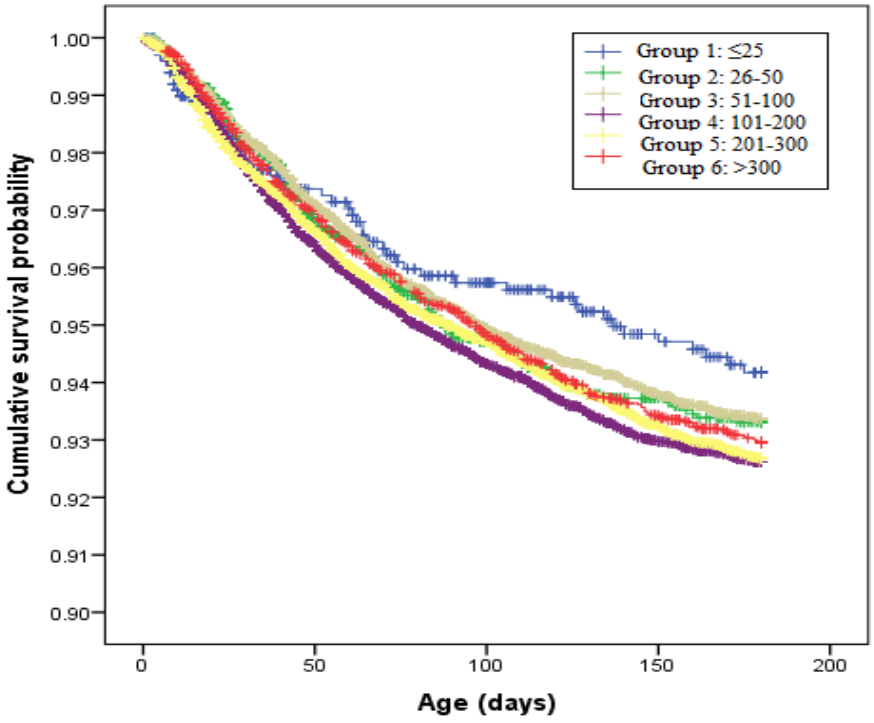


Figure 28: Kaplan-Meier curves showing the cumulative survival probability of calves on the Maltese Islands stratified by average herd size

4.3.4 The year of birth of the calves

The Kaplan-Meier curves also demonstrated that there was a significant difference between the mortality rates registered in 2005, 2006 and 2008 and the rest of the study period (Fig. 29) and Cox Regression analysis gave a *P* value of <0.001.

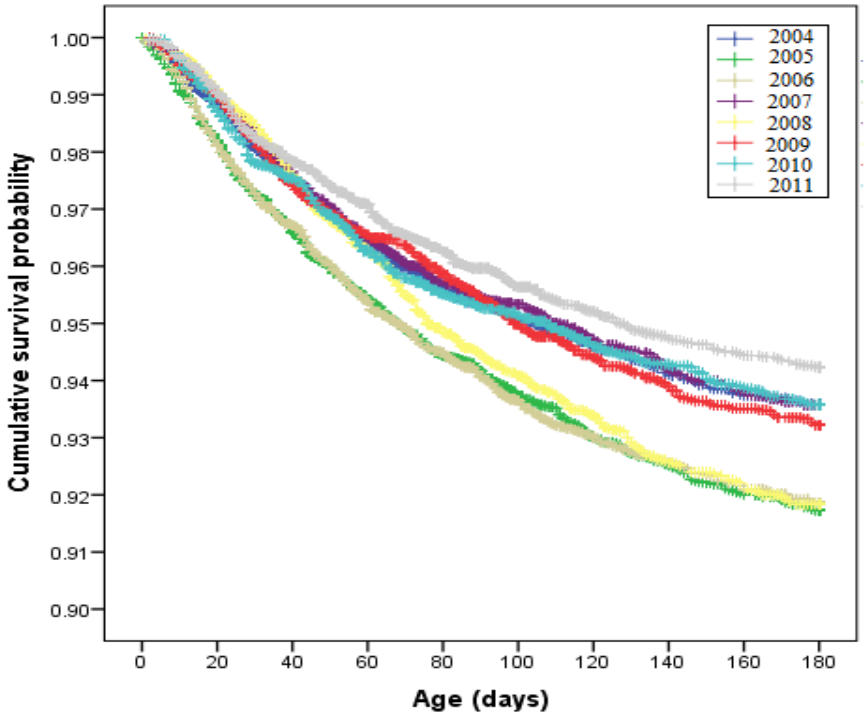


Figure 29: Kaplan-Meier curves showing the cumulative survival probability of calves from day of birth to 180 days of age on dairy holdings on the Maltese Islands stratified for the year of birth

The highest mortality rates were registered in 2005, 2006 and 2008 with values of 8.28%, 8.15% and 8.17% respectively. The general trend showed a decrease in the mortality rate along the years with the lowest mortality rates of 6.78%, 6.44% and 5.77% being registered in 2009, 2010 and 2011 respectively. When the analysis was adjusted for island of birth and sex of the calves, the resulting trends were similar.

4.3.5 The season during which calves were born

Mortality rates were not affected by season (P = 0.962) indicating that there is no significant difference in the mortality rates of calves born during the different seasons. The difference is also not significant when adjusted for the islands of Malta and Gozo. Kaplan-Meier curves suggest that for calves born during spring, the mortality rate is slightly lower for the first 60 days of age (Fig. 30). However, mortality rates for calves over 60 days of age are very similar whichever season they were born in.

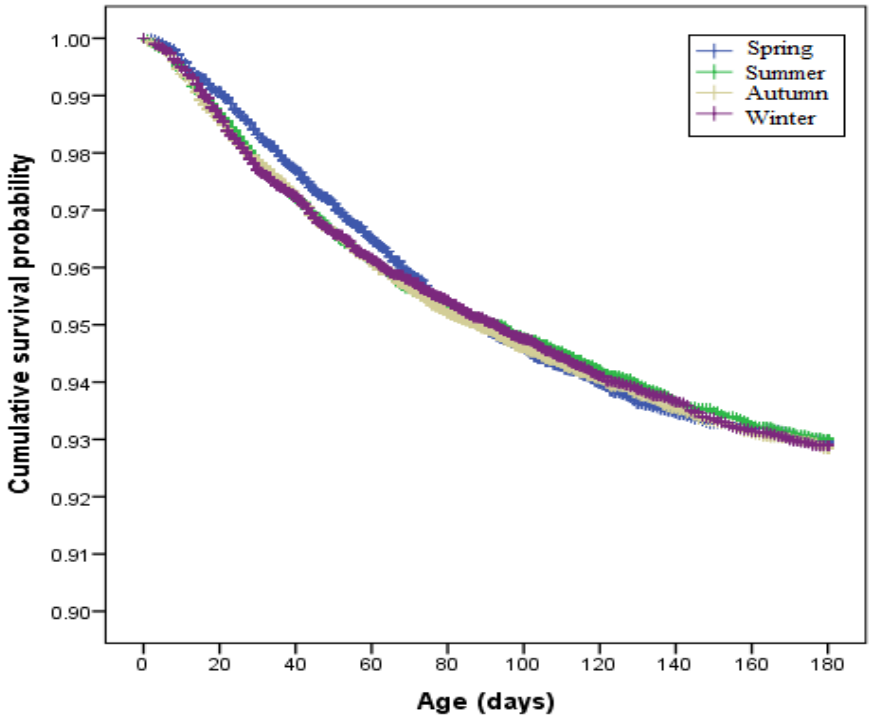


Figure 30: Kaplan-Meier curves showing the cumulative survival probability of calves from day of birth to 180 days of age on dairy holdings on the Maltese Islands stratified for the season of birth

4.4 Discussion

Reported calf mortality rates vary widely depending on many factors, some of which may be specific to the particular population being studied. The aim of this part of the research project was to determine a benchmark for the mortality rates up to 180 days of age of live born calves on dairy holdings on the Maltese Islands and to study five risk

factors which can be associated with calf mortality. It is based on a study of the whole dairy bovine population on the two islands and not on just a small sample of holdings, thus giving a realistic result on the mortality rates of calves on the islands. All the dairy bovine holdings in the study were managed as intensive production systems during the study period and 89.14% of the calves belonged to the Holstein Friesian breed.

The calf mortality rates on dairy farms reported in this study are similar to those reported by some authors in other countries (Agerholm et al., 1993; Svensson et al., 2006; Brickell et al., 2009; Azizzadeh et al., 2012). In this study the overall mortality rate up to 180 days of age of live born calves on dairy holdings was found to be 7.08%. This value is very similar to the 7.00% reported by Agerholm et al. (1993) in Denmark, which however also included stillbirths. Furthermore, the median age at death reported in this study (52 days) is very similar to the 50-day median age at death reported by Svensson et al. (2006) in Swedish dairy calves. Mortality rates on the island of Malta were found to be significantly lower (6.05%, $P<0.001$) than those in Gozo (8.80%). Further study is needed to identify if this is due to management, herd or environmental factors.

In some studies on calf mortality rates stillbirths were also included in the study leading to a higher mortality rate being reported (Agerholm et al., 1993). This was not possible in this study since stillbirths would not be ear tagged and as a result their details are not inserted in the NLD. This can lead to an underestimation of calf mortality rates. Under current Maltese legislation, births of calves have to be notified within seven days of age and they have to be ear tagged within 20 days of age (Government of Malta, 2005a). As a result, calves that died on the holding in the first few days after being born and not ear tagged may have not been reported and would not be registered on the NLD. Hence calf mortality rates for the first 20 days of age reported in this study may be under-estimated. The degree of under-estimation is difficult to determine since no other source of notification and registration is present. This has also been reported by Brickell et al. (2009) in a study carried out in England.

The daily hazard rate with peaks at 15 and 44 days of age found in this study is slightly different from what has been described by Azizzadeh et al. (2012). In their study the highest daily probability of death in Iranian Holstein dairy herds was greatest from the

day of birth to 20 days of age, after which it decreased markedly. The second peak at 44 days in our study may be due to the fact that some of the calves dying a few days after birth on the Maltese Islands may not have been tagged yet and as a result would not show up on the NLD.

The highest monthly mortality rate of 2.00% was recorded for the first 30 days. The monthly mortality rates then decrease progressively with age reaching a low of 0.46% at 5-6 months. The relatively high mortality rate within the first month of age seen in this study has also been reported in studies carried out in the USA (Jenny et al., 1981), Denmark (Agerholm et al., 1993) and Sweden (Svensson et al., 2006).

Differences in mortality rates in male and female calves have already been reported by a number of authors, with male calves having a higher mortality rate than females. Chore et al. (1998) reported 14.40% mortality in male calves and 11.14% mortality in female calves in India. Bleul (2011) reported that the mortality rate up to 120 days of age for the Holstein breed in Switzerland was 6.70% and 4.70% for male and female calves respectively. The mortality rate of 6.00% for female calves on the Maltese Islands is very similar to that found in another study in the UK were a mortality rate of 6.80% was reported in female Holstein Friesian calves born alive during the first 6 months of age (Brickell et al., 2009).

Lower mortality rates on smaller holdings have been reported by Hartman et al. (1974) in New York dairy farms and by Gulliksen et al. (2009) in Norwegian dairy herds. On the other hand, Jenny et al. (1981) reported a decrease in calf mortality with increasing herd size in dairy herds in South Carolina whereas James et al. (1984) found no correlation in dairy herds in Virginia. The fact that the lowest overall mortality rate on the Maltese Islands was registered on dairy holdings with the smallest average herd size (≤ 25) might be due to the fact that since these holdings tend to be owned and managed by family members, calves may be looked after with greater care resulting in a lower calf mortality rate. In fact, Jenny et al. (1981) have reported that when the owner or his immediate family were responsible for the rearing of calves, the mortality rate was lower. Larger farms may also have more calves within the age associated risk period leading to higher mortality rates.

Calf mortalities were also analysed according to the year of birth of the calves to verify if there were any changes in mortality rates during the eight year study period. Following EU accession in 2004, direct financial support was given to the dairy sector resulting in the restructuring and upgrading of a number of dairy holdings (MSDEC, 2013). The modernisation of the holdings on both islands, together with better management, may have led to the gradual decrease in calf mortality rates especially during the last three years of the study.

A number of studies have taken into consideration the effect of the season of birth on calf mortality. Martin et al. (1975) have reported that calves born during periods of extreme temperatures in USA had a higher risk of death than calves born during temperate days. Gulliksen et al. (2009) reported that calves born in winter in Norway were more likely to die compared to calves born in summer. On the other hand Azizzadeh et al. (2012) reported a higher risk of calf mortality in Iranian Holstein dairy herds in summer and that this is most likely due to differences in ambient average temperatures. To verify if similar trends are present on the Maltese Islands, stratification by season of birth was carried out. No significant differences ($P = 0.962$) were found between the different seasons in this study. This may be due to the relatively mild climate present on the Maltese Islands. During the period under study the air temperature varied from an average minimum of 12.7 °C in February to an average maximum of 26.9 °C in August (National Statistics Office, Malta, 2012).

It was not possible to include certain possible confounding factors such as the presence of dystocia, twin births, failure of passive transfer, different levels of management on holdings etc. since no data was available regarding such factors. This could be a limitation of this part of the study since these factors may influence mortality rates especially during the first few weeks of life of the calves.

4.5 Conclusions

The use of the NLD to estimate calf mortality rates on the Maltese Islands shows how information present in this database can be used for research and not only for data collection. The results presented in this study can be used as a benchmark and to lead

further research towards identifying some of the reasons for the differences reported here and to investigate possible confounding factors mentioned in the discussion. This can lead to the further lowering of calf mortality rates thus ensuring a more efficient and profitable dairy sector on the islands of Malta and Gozo.

Key Findings of Chapter 4

- ✓ ***The overall mortality rate of live born calves up to 180 days of age on dairy holdings on the Maltese Islands was found to be 7.08%.***

- ✓ ***The mortality rates on the 162 holdings in the study varied significantly from a minimum of 0.00% to a maximum of 24.80%.***

- ✓ ***The median age at death was 52 days whilst the mean was 63.43 (SD = 45.96).***

- ✓ ***Twenty five per cent of the calves were reported dead by 25 days of age whilst 75% died before reaching 96 days of age.***

- ✓ ***The daily hazard rate increased from day 1 to reach peaks at 14 and 44 days of age of 0.0010.***

- ✓ ***The highest monthly mortality rate of 2.00% was recorded for the first 30 days of life of the calves. The lowest was of 0.46% in the 5 to 6 month age period.***

- ✓ ***The overall calf mortality rate on the island of Malta was 6.05% and 8.80% in Gozo (P<0.001, Exp (B) = 0.675, 95% CI for Exp (B) = 0.626-0.729).***

- ✓ ***The risk of a calf dying before reaching 180 days of age is reduced by an estimated 32.50% on holdings in Malta compared to Gozo.***

- ✓ ***The overall male calf mortality rate was 8.50% and that for females was 6.00% (P<0.001, Exp (B) 1.413, 95% CI for Exp (B) = 1.312-1.522).***

- ✓ ***A male calf on the Maltese Islands is estimated to have a 41.30% higher risk of death before reaching 180 days of age than a female calf.***

- ✓ ***Mortality rates on larger holdings were on average higher than those on smaller holdings especially for calves of more than 60 days of age (P = 0.01).***

- ✓ ***The general trend shows a marked decrease (P < 0.001) in the mortality rate along the years with the highest mortality of 8.28% being registered for 2005 and the lowest of 5.77% for 2011.***

- ✓ ***No significant difference (P = 0.962) was present in the mortality rates of calves born during the different seasons in both Malta and Gozo.***

- ✓ ***Kaplan-Meier curves suggest that for calves born during spring, the mortality rate is slightly lower during the first 60 days of age.***

Chapter 5

General Conclusions

This main aim of this research project was to bring to light valuable data regarding the bovine dairy sector, which has been collected over the last ten years in the Maltese National Livestock Database, and via data mining techniques compile a number of data sets. These data sets were then validated and analysed statistically. The majority of the results reproduced in the three research sections of this thesis are being reported for the first time.

The appraisal of the NLD has been carried out so that any weak points or drawbacks of the system could be pointed out. This section of the thesis can also be used as a guideline by other countries wanting to implement a computerised identification and registration system for bovines.

The statistical analyses regarding the number of bovine dairy holdings together with the detailed analyses of the trends in the number of bovines is mainly of national interest and can be used in drawing up future policies regarding on-farm planning, stocking densities, animal waste programmes and the future of the milk producing industry, which is the most important sector within the bovine husbandry sector on the Maltese Islands.

Finally the intention of analysing in detail the calf mortality rates on the Islands of Malta and Gozo was to establish a benchmark drawn from the whole dairy bovine population and to compare this benchmark with mortality rates in other countries where the bovine husbandry industry is well established. Hopefully these results will lead to further research in the area since a number of questions arising from this study still need to be answered. For example, it would be interesting to see what is causing the difference in mortality rates between the two islands, if the differences between male and female calves are due to the reasons already reported by authors in other countries,

if the calf mortality rates continue in the present trend i.e. decreasing from year to year. The effects of the size of the average herd on the holding on which the calves are born and reared need to be studied in detail since these may yield results which can then be implemented on bigger farms to reduce their calf mortality rates. The lowering of calf mortality rates should be one of the main aims of the Maltese bovine husbandry sector since this reflects better animal health and welfare standards and ultimately leads to an improvement in the economic outcome of the dairy holdings.

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