The Epidemiology of Rabies in Thailand

A thesis presented in partial fulfilment of the requirement for the degree of
Master of Veterinary Studies

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This thesis is inspired by, and dedicated to, rabies victims.

May there be no more.

Abstract

This study was designed to investigate the epidemiology of rabies in Thailand and to evaluate the rabies control programme. The study involved retrospective analysis of seven years data (1993 to 1999), concerning rabies incidence and control activity. Five datasets from four different organisations responsible for rabies control in Thailand were collected between March and June, 2000.

Control activity data were found to be incomplete due mainly to problems associated with the data collection form and with methods of data storage and retrieval in provincial offices. Recommendations are made in this thesis to modify the data collection form and data storage methods to improve data collection and the usefulness of information collected in the future.

The annual cumulative incidence of rabies in both animals and humans has declined considerably between 1993 to 1999 as a result of the control programme implemented under the Rabies Act B.E. 2535 (1992). Rabies in humans is more common in males than females and is more common in young children (less than 10 years of age) than any other age group. Dogs were the most commonly submitted animal for rabies diagnosis as part of the surveillance programme, accounting for 87% of the total of 40,649 submissions. Cows were more likely to return a positive rabies diagnosis than any other animal (57% of a total of 409 animals submitted) while dogs returned more cases than any other animal species (43% of a total of 35,338 animals submitted). Detailed investigations were confined to dogs. Rabies was more common in non-owned dogs, non-vaccinated dogs, dogs showing signs consistent with furious rabies, and dogs with a history of having attacked or bitten either other animals or both animals and people.

The spatio-temporal pattern of rabies in both dogs and people, showed changes in the distribution of rabies cases during the seven year period of the study. Mixed effect Poisson regression models incorporating spatial and non-spatial random effect terms were used to investigate risk factors associated with rabies. Factors associated with increasing risk of rabies in people at the province level included: increasing dog density, increasing incidence of rabies in dogs, and reduction in human population density. In the 1999 dataset, there was evidence of spatial clustering of rabies risk. In addition a cluster of provinces showed an elevation in rabies risk that was unexplained by the explanatory variables included in the model. The reason for this cluster of elevated risk remains to be elucidated.

Factors associated with an increasing risk of rabies in dogs at the province level included increasing dog population density and increasing proportion of dogs vaccinated against rabies. Relative risk estimates were close to one suggesting the strength of the association for both terms was weak. Increased dog vaccination against rabies is likely to occur in provinces with a higher risk of both animal and human rabies.

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I never expected that without any computer skills and no basic knowledge in epidemiology and statistics, I could become an epidemiologist and create a major piece of work, which will be beneficial to the Rabies Control Programme in Thailand.

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Chapter 1

Introduction

Rabies is a fatal viral disease of all warm-blooded mammals, which has killed substantial numbers of humans and animals for many years. Rabies is still a public health hazard in many parts of the world, particularly Asia. Rabies is an endemic disease in Thailand and dogs are the main reservoirs accounting for more than 96% of rabid animals.

Rabies in Thailand was first recorded in 1912 as the cause of death of the princess due to the lack of rabies post-exposure treatment at that time. The Queen Saovabha Memorial Institute (QSMI) was established after her death and became the place for rabies post-exposure treatment. That initiated rabies control in humans in Thailand.

Rabies control activity in animals was started in 1955 by the Rabies Act B.E. 2498 (1955), under the responsibility of the Ministry of Public Heath. The control strategy concentrated on rabies vaccination and dog destruction. At the same time there were many organisations concerned with rabies control such as the Thai Red Cross Society, the Department of Livestock Development (DLD), the Bangkok Metropolitan Administration (BMA) and the Ministry of Interior (MI). Each organisation had its own authority, policy and methods of rabies control but under the same conditions of limited budget and with little co-operation.

Prior to 1982 more than 300 human deaths (0.78 per 100,000 human population) were reported per year (Yangkratoke et al., 1996). This made Thailand rank third in Asia in numbers of human deaths, lower only than India (first) and the Philippines (second). However, it was believed that the number of human deaths reported were 30 to 50% lower than the real number (Cham-on, 1996). Evaluation of the success of the control programme was based on the number of human deaths and the number of animals rabies positive. Human rabies positive cases were diagnosed by history and symptoms particularly hydrophobia, with only a few cases were confirmed by laboratory testing.

Low coverage of dog vaccination and no enforcement for dog owners to vaccinate their dogs lead to the replacement of the Rabies Act 1955 (B.E.2498) by the Rabies Act 1992 (B.E. 2535). Human rabies control is under responsibility of the Ministry of Public Health (MI) and animal rabies control is under the responsibility of the

Department of Livestock Development (under the Ministry of Agricultural and Co-operative) while local municipalities and the Bangkok Metropolitan Administration under the Ministry of Interior have authorities in rabies control. The two main regulations for rabies control in the Rabies Act B.E. 2535 (1992) are: all dogs over two months of age must be vaccinated and tagged and dogs found in public without any valid vaccination tag will be caught and destroyed after five days unless contact is received from the owner.

Since 1996 closer co-operation among organisations has been implemented and developed. The National Board of Rabies Committee was formed and the National Rabies Control Programme was implemented.

The National Board of Rabies Committee sets the control strategy for local officers at every level and evaluates the feedback of the control programme from the provincial officers. The number of human deaths due to rabies per year has decreased, as has the number of animals dying of rabies. In 1993 Thailand ranked seventh out of ten countries in Asia for human deaths (Yangkratoke et al., 1996).

The author has been involved in rabies control in Thailand since 1977 with rabies control activity in university and the BMA rabies vaccination campaign initially because of the near death of one sister due to encephalomyelitis from human rabies vaccine. Since 1986 the author has worked in a rabies vaccine production section of the Department of Livestock Development. More recently the author has been responsible for rabies control and is currently working as a member of the National Board of Rabies Committee.

The factors hindering rabies control in Thailand included the inability to control stray dog populations due to general lack of knowledge of the people and peoples' attitudes and beliefs. The National Rabies Control Programme has not previously been evaluated by epidemiological analysis of data concerning rabies in animals and humans. In part this was due to the fact that control data were recorded separately by each organisation responsible.

The objective of this study was to analyse rabies status and incidence in Thailand during the period from 1993 to 1999, at the provincial and district levels including analysis of risk factors associated with rabies in animals and humans using epidemiological and statistical methods, an assessment of quality of data, and the reporting and filing systems. Geographic Information System mapping information will be used to illustrate and focus on the critical areas of disease incidence. This analysis is intended to be beneficial to the National Rabies Control Programme in Thailand.

Chapter 2

Rabies

Rabies is derived from the Latin word "*rabere*" which means "*madness*" (West, 1972; Bisseru, 1972). Rabies was present in Egypt before 2300 B.C and also in ancient Greece (Murphy et al., 1999). The association between animal bites and human fatal disease has been recognized in many parts of the world for more than 2000 years. Rabies has never been a major cause of human mortality but of all communicable diseases, human rabies is considered the most severe.

Rabies ranks 12th on the WHO list of major killer diseases (Meslin and Stohr, 1997), is an OIE list B disease and currently remains an ongoing threat to human populations and animals in many parts of the world. About 60,000 human victims die of rabies each year while more than 10 million people require post exposure treatment. Most of the disease occurs in developing countries particularly in Asian countries (Meslin and Stohr, 1997). Rabies represents an economic burden for both developed and developing countries due to the costs of human post exposure treatment, diagnosis, surveillance and immunisation of domestic animals and wildlife. However, the most serious losses are the number of humans suffering and killed by rabies.

The Disease

Aetiology of the disease

The rabies virus is classified as a Rhabdovirus in the Family Rhabdoviridae, genus Lyssavirus which are rod or bullet-shaped ultrastructually (*rhabdos* = rod in Greek), and composed of a single stranded RNA (ribonucleic acid) genome, 11-15 kb in size ((Murphy et al., 1999). There are four serotypes determined by monoclonal antibody typing (Beran and Steele, 1994). These serotypes are:

Serotype 1-Challenge Virus Standard (CVS) representing the majority of field and fixed laboratory strains, and found in all continents except Antarctica and Australia

Serotype 2-Lagos bat, first isolated from bats found in Central and South Africa.

Serotype 3-Mokola, first isolated from shrews found in Central Africa.

Serotype 4-Duvenhage, first identified from bats found in South Africa.

At least two additional serotypes have been recently described, **Australian bat lyssaviruses** and **European bat lyssaviruses 1 and 2** (Murphy et al., 1999).

The virus

Characteristics of virus

Rabies virus particles are approximately 180 nm in length and about 75 nm in diameter. Each particle has a helical core of ribonucleoprotein (RNP) called nucleocapsid surrounded by a membrane–derived envelope. The RNA core contains a single stranded coil of RNA associated with three internal proteins which are transcriptase, nucleoprotein and phosphorylated protein. Another protein located on the inner side of the envelope is called matrix protein.

The external surface of the viral envelope is covered with 10 nm long projections or spikes comprised of glycoprotein (Charlton, 1988). These glycoprotein spikes constitute rabies viral antigen that induce neutralizing antibody production which may confer immunity to the disease (Murphy et al., 1999). Surface glycoprotein may also be involved in other immune mechanism such as interaction with cytotoxic T cells and cytokines (Charlton, 1988). Sites on the surface glycoprotein are also believed to be involved in the attachment of virus to susceptible cells (Murphy et al., 1999).

Rabies virus is synthesized in the cytoplasm of infected neurons. Accumulations of virus nucleocapsid are often associated with large cytoplasmic inclusions called Negri’s bodies which are visible using light microscopy. Virus is released from cells by budding through the cell membranes without destruction of the host cells (Murphy et al., 1999).

Excretion of virus

The excretion of rabies virus and the levels of virus excreted are the most important factors for transmission. Rabies virus can be excreted in saliva of infected animals for many days after the onset of clinical signs of disease. Rabies virus has also been found in dog saliva up to seven days before signs of rabies were observed (Fekadu et al., 1982).

The “carrier state”, a chronic infection with or without a period of clinical signs during which animals can transmit disease by excreting virus in saliva, can be found in dogs. Rabies virus has been isolated from the saliva of clinically normal dogs and dogs with transient paralysis (Charlton, 1988). In 1981, Fekadu *et al* (1981) found that saliva collected on day 42 and 169 from a dog that had recovered from experimental Ethiopian strain rabies inoculation produced fatal rabies in mice inoculated intracerebrally. Fekadu *et al* (1981) also reported that viable virus could be isolated from the palatine tonsil of an experimentally infected dog up to 305 days after its recovery.

Rabies virus can be excreted from the saliva of cats for one to three days and cattle for one to two days prior to onset of signs. The virus may be detectable earlier in wildlife than in dogs, in skunk up to four days prior to clinical disease onset, one to two days in foxes and 12 days in insectivorous bats. Virus can be excreted in urine and this may lead to transmission by aerosol in foxes and bats. Excretion in milk also occurs but is considered to not represent a major hazard because viral particles will be destroyed by enzymes present in the milk (Kaplan et al., 1986; Beran and Steele, 1994).

Survival outside the host

The rabies virus is comparatively fragile and cannot exist free in the environment for a long period. It is consequently dependent on the host species for survival.

Rabies virus remains viable in a carcass for less than 24 hours at 20?C. It survives much longer when the carcass is refrigerated. It remains stable for several days at 0-4?C and survives for about 24 hours in saliva in temperate climates. Rabies virus will survive indefinitely when freeze dried or kept at –70? but freezing samples in a common freezer with subsequent thawing will damage the tissue and destroy the virus. Virus can survive longer in unrefrigerated tissue stored in 50% glycerol at room temperature or in pure glycerol at 4?C. It can be preserved in a 20% suspension of infected tissue or a high protein or amino acid solution (Kaplan et al., 1986).

As an enveloped virus, rabies virus can be easily inactivated by detergent and phenolic or organic halide compounds. It is extremely labile when exposed to ultra violet light, and heat (Kaplan et al., 1986; Greene and Dreesen, 1990). Its infectivity is lost when treated with proteolytic enzymes, with X- irradiation and by exposure to acid and alkaline conditions below pH 4.0 or above 10.0 (Kaplan et al., 1986).

Routes of transmission

The possible routes of transmission of rabies are:

?? **Direct contact**: Exposure to the infectious saliva from a rabid animal by direct bite is the most common route of infection. Rabies virus cannot penetrate through normal skin but licking, scratching or contact with freshly abraded skin or mucous membranes such as conjunctiva, nasal mucosa and the anus may allow transmission of infection.

?? **Ingestion**: Transmission via oral exposure is essentially limited to the most highly susceptible species. This can occur in wildlife among predators and prey.

?? **Airborne**: Inhalation of rabies aerosol into the nose and throat may be an important route of transmission in some species of animals living in high density populations such as foxes and bats (Beran and Steele, 1994) but is extremely rare in humans (Kaplan et al., 1986). Two accidental cases of airborne infection in humans by inhaling aerosol rabies virus in the laboratory were reported. Aerosolised virus from bat urine has been suspected as an exposure pathway for wildlife investigators.

?? **Transplantation**: Corneal transplantation has been reported to result in transmission from human to human (Kaplan et al., 1986).

?? **Transplacental infections** in skunks, bats and cows have been reported (Greene and Dreesen, 1990). No transplacental infection has been reported in humans. (Kaplan et al., 1986)

?? **Milk-borne transmission** has been demonstrated in sheep and neonatal transmission through milk of lactating dams of wild reservoir species may be more frequent. For human consumption, any virus in milk would be quickly inactivated by viricidal enzymes or by pasteurisation.

?? **Environmental transmission** by fomites has occurred occasionally (Beran and Steele, 1994).

The role of predation can be important for spillover hosts since during predation, a wound may occur due either as a defensive bite or as an oral laceration from a bone fragment. Such wounds can potentially allow transmission rabies from prey to the predator.

Pathogenesis

The lyssaviruses have a predilection for neural tissue (neurotrophism) where they migrate to the central nervous system and cause severe signs. Following a bite wound, the virus may remain inactive or replicate in local nervous tissues (and possibly skeletal muscle). The virus then spreads to neuromuscular junctions and neurotendinal spindles after a variable period (days or weeks). By retrograde (centripetal or axoplasmic) flow in peripheral nerves, transport of the virus to the central nervous system (CNS) needs a minimum of 21 days.

After progression in CNS, the virus moves rapidly to the brain. The virus enters the spinal cord or brain stem ipsilateral to the initial inoculated site. The infection then spreads to contralateral neurons and ascends bilaterally in the spinal cord or brain stem to the forebrain. The damaged motor neurons can cause typical flaccid paralysis and ascending paralysis. Viral invasion leads to inflammation and degeneration of nervous tissue.

From the CNS the virus spreads centrifugally to other tissues such as heart, cornea, adrenal glands, etc via peripheral, sensory and motor nerves. Visceral and somatic portions of cranial and spinal cord nerves and the autonomic nervous system are affected. The virus spreads via cranial nerves to salivary glands which indicates that the brain has been already infected. Viremia is not detectable, the virus effects the neural system and results in mental status changes and respiratory failure which is fatal (Greene and Dreesen, 1990).

Host Range

Host range in different environments

All warm-blooded animals are vulnerable to infection by rabies virus, however the degree of species susceptibility varies considerably.

Foxes, coyotes, jackals, wolves, mongooses and certain rodents are among the most susceptible animal groups. Infection in foxes may be transmitted via respiratory or oral exposure.

Wolves are considered to be extremely susceptible to rabies. Wolves with rabies are aggressive and lose all reticence to enter inhabited areas. Wolf bites are extreme exposure hazards causing a very high incidence of rabies in victims not provided with post-exposure prophylaxis and often 15-50% incidence in those provided with vaccine only.

Mongooses are considered highly susceptible to the virus and are a maintenance host for rabies. Rabies was historically enzootic in mongoose in India, Burma, Nigeria and South Africa and spread to Caribbean Islands. Caribbean mongoose rabies type is a unique variant and most closely related to canine types (Beran and Steele, 1994).

Skunks, raccoons, bats, rabbits, cattle and some members of Felidae and Viverridae (mongoose) have a high susceptibility. Racoons are usually confined to their own habitat area, but rabid racoons can be found outside this area, for example in the northern and mid western USA where they have come into contact with skunks. Skunks with rabies can be found outside their natural habitat area again following interaction with rabid racoons. This is most clearly shown in the northern Atlantic states, where the racoon epidemic is at its peak. Reported cases of rabies in skunks can be the result of spillover from foxes while most cases of rabies in red foxes are reported as a result of spillover from racoons (Eng and Fishbein, 1990).

In developing countries, the domestic dog is the major reservoir of rabies while wild animals such as the fox, raccon, wolf, jackal, mongoose and other carnivores are the main reservoirs in America and Europe. Vampire bats are an important reservoir in North, Central and South America.

Dogs, sheep, goats, horses and non-human primates have moderate susceptibility. Cats are considered to be alternate hosts of rabies. All birds and primitive mammals such as the opossum have low susceptibility. Younger animals are usually more susceptible to rabies infection than older ones (Greene and Dreesen, 1990).

Maintenance hosts and spillover hosts in different locations

Rabies appears in cyclical outbreaks (Kaplan et al., 1986). The epidemiology of the disease depends closely upon the ecology of the virus, and factors associated with geographical region including the range and susceptibility of mammalian species in differing regions. The epidemiological and ecological situations are considered in several geographical areas.

?? **Europe**

In the past, dogs, foxes and wolves were the main source of rabies in Europe. Increasingly effective vaccination programmes and application of population control methods over four decades, have resulted in many countries achieving freedom from dog rabies. Bat rabies appeared in north central Europe in 1985 and has been considered enzootic since 1991 (Beran and Steele, 1994). Since 1990 fox rabies has been eliminated from Switzerland and some other countries. However, dog rabies remains a problem in the southernmost areas of the former USSR and foxes are still a major host of rabies (Swanepoel, 1994; Murphy et al., 1999).

?? **Americas and Canada**

Wildlife have been the major rabies reservoir in North America since 1996. Racoon, skunk, fox and coyote are the main reservoirs of rabies in America. The bat also plays a role in human deaths due to rabies (Pasteur Institute.,).

Red foxes are responsible for the maintenance and spread of rabies in the subarctic and northeastern parts of North America, in subarctic Asia and in central and Eastern Europe. The fecundity of foxes and their foraging behavior enables them to be an important host of rabies (Beran and Steele, 1994).

?? **Latin America**

Vampire bats are the important reservoir transmitting rabies to humans and farm animals, particularly cattle.

?? **Africa**

Dogs remain the major vectors of about 90% of rabies cases. In South Africa, the yellow mongoose is the dominant wildlife host, with 70% of all wildlife cases. The black backed jackal (*Canis mesomelas*) has also been identified as one of three major hosts of rabies in South Africa (Greene and Dreesen, 1990).

?? **Asia**

Dogs are the main vectors of rabies in Asia and are responsible for the majority of human rabies reports. Particularly in India mongoose and jackal rabies is found (Murphy et al., 1999; Pasteur Institute., 2001).

?? **Australia, New Zealand and Oceania**

Rabies has never been reported in Australia and New Zealand. However in 1996 a related virus (Australian bat lyssavirus) was discovered in flying foxes in Queensland. This virus is closely related to rabies virus, and caused fatal infections in two people infected by flying fox (pteropid bat) and a yellow-bellied sheath-tail bat (*Saccolaimus flaviventris*) (Field et al., 1999; Field, 2001).

Course of the disease

The incubation period of rabies is unique compared with other infectious diseases. The proportion of animals that develop rabies and the duration after exposure depends on the site of the bite, severity of the bite, species of animals involved, age of bitten individual, strain and amount of virus and post-exposure treatment. This influences the route of virus entry into and spread to the CNS (Greene and Dreesen, 1990; Murphy et al., 1999). In naturally occurring cases, incubation periods have been reported from 3 weeks to 6 months (average three to eight weeks) in dogs, two to six weeks in cats and two weeks up to 12 months in human (average three to six weeks). Well-documented incubation periods may vary from ten days to six years. More typically, first symptoms are noted between 30 and 90 days after exposure.

Clinical signs

Rabies has classically been divided into three major stages, prodomal, furious and paralytic or dumb. All clinical signs are referable to neural involvement and include initially paraesthesia and pain at the wound site. Later fever, headache malaise and apprehension are noted. Progression of disease results in changes in mental status. Physical changes are also referable to nervous involvement and include difficulty swallowing, hypersalivation, priapism, muscle spasms and ultimately paralysis. Death may occur rapidly as a week from onset of signs, and is due to respiratory failure. Only four human cases have been reported that have survived following development of clinical signs.

Human

Prodomal symptoms

When the virus reaches the CNS the first signs reported by humans include feeling generally unwell, loss of appetite, headache, fever, irritability, restlessness and anxiety. This may progress to muscle pains, salivation and vomiting and is then followed by one of two clinical types *furious* and *dumb* rabies or both.

Furious rabies

Within a few days or a week after initial signs, the patient may show a stage of excitement with painful muscle spasm followed by hydrophobia**,** aerophobia and periods of extreme excitement. Hydrophobia means fear of water which is a restricted sign of rabies and sometimes used as a synonym for rabies (Kaplan et al., 1986).

Dumb rabies

This form occurs in less than one fifth of human cases but it is a common clinical pattern in animals. The patient may become literally dumb due to paralysis of laryngeal muscles. This is due to pathological changes in the lowest part of brain stem (medulla oblongata), the spinal cord and the nerves arising from it.

Animals

?? **Dogs and cats**

In dogs and cats, as in man, the first symptoms usually reflect abnormal sensation e.g. licking, scratching, rubbing or chewing at the wound site even if it has been completely healed (Kaplan et al., 1986). The prodomal signs of nervousness, solitude, fever and behavioural changes are also noted. Pupillary dilation with or without sluggish palpebral or corneal reflexes becomes apparent. Friendly animals become irritable and may snap while the fractious animals become more docile and affectionate.

Animals then become restless, hypersensitive to auditory and visual stimuli, excitable, photophobic and hyperaesthetic and bark and snap at imaginary objects. The dogs usually roam and eat unusual objects, and may avoid contact with people or prefer hiding in dark or quiet places. They may try to bite or attack when caged or confined and develop muscular inco-ordination, disorientation and seizure. This may progress to a short paralytic state and even death during seizure episode.

The period from the prodomal stage to death is seldom longer than ten days. Rabid cats are often more savage and dangerous than rabid dogs (Kaplan et al., 1986). Cats develop the furious phase more consistently showing erratic and unusual behaviours. They may bite or scratch moving objects. Muscular tremors and weakness or inco-ordination may be found while some may run continuously until dying of exhaustion (Greene and Dreesen, 1990).

?? **Cattle**

Symptoms are similar to other animals but the furious phase is uncommon. Twitching of muscles and a copious flow of saliva are very apparent. Sexual excitement is not frequently found. The animal bellows in a changed, hoarse–sounding voice and paws the ground with its forefeet. Rumination ceases which results in constipation followed by liquid faeces and rectal prolapse. The animal becomes paralysed and collapses. The clinical course of disease is about four to seven days.

?? **Horse**

The clinical symptoms are similar to other animals with signs of pain and discomfort in the infected site. Horses tend to develop more furious symptoms than cattle with violent kicking and biting reported. The animal dies within two to six days after the symptoms appear.

?? **Pig, sheep and goat**

These animals show similar clinical pictures as cattle.

?? **Wild animals**

Foxes

Foxes are considered to be extremely susceptible to rabies and highly susceptible to respiratory and oral route exposures (Beran and Steele, 1994). The clinical period is short. The outstanding feature is loss of fear of people, dogs or other animals and hyperactivity (Kaplan et al., 1986). In the excitement stage foxes may snarl, attack or charge passing people, animals or passing vehicles. In the late stage the animals become incoordinated and die in convulsion.

Skunks and raccoons

In the excitement stage the animals appear in open places in daylight, losing their fear of people and may enter livestock pens and attack other animals or people. Affected animals become incoordinated, progressively unable to walk, prostrate and die.

Insectivorous and Frugivorous Bats

Infected bats may have a very long incubation. Clinical rabies is usually manifested as erratic flying or flopping on the ground during daytime and affected bats may attack people during this disoriented phase.

Vampire bats

Hematophagous bats feeding on cattle are principal vectors of cattle rabies in Central and South America. Clinical signs in vampire bats are not well elucidated and vary from inapparent to fatal paralysis. They may have muscular tremors and deranged behavior and may attack people or other animals. In the paralytic phase, paralysis of one or both wings might be found, followed by paralysis of the legs, neck and lower jaw.

Diagnosis

In many parts of the world rabies in humans and animals is still diagnosed based on clinical signs and symptoms (WHO, 1992).

In general, a diagnostic laboratory should determine the diagnostic result and inform the responsible medical personnel for urgent treatment if a positive diagnosis is made. In addition, a negative laboratory result will save unnecessary cost of treatment and psychological stress associated with the possibility of having rabies.

In addition, laboratory identification is beneficial for disease surveillance in defining the current epidemiological patterns of rabies and monitoring control programmes in that country.

Laboratory tests for rabies

For timely administration of post-exposure prophylaxis, rapid and accurate laboratory diagnosis in both humans and animals is essential.

Human

Virus isolation

Rabies virus can be isolated from saliva, tears and respiratory tract secretions of patients but is rarely found in cerebro-spinal fluid and urine during the first five to seven days of the illness. It takes at least five to seven days for virus isolation in mice or tissue culture. Specific antibody against rabies in cerebro-spinal fluid is believed to indicate local production of the antibody in the brain resulting from rabies encephalitis rather than rabies vaccine immune response, and does not usually appear until about five days after the first symptom (Kaplan et al., 1986). Specific cytopathic effect (CPE) is not found in tissue culture (Charlton, 1988).

?? **Corneal impression smears and skin biopsies**

Application of a glass slide to the surface of the eye and skin biopsies taken under local anaesthesia are less invasive methods for rabies diagnosis. Taking corneal epithelial cells is insensitive and uncomfortable for the patients. The skin biopsy technique has produced positive results in all cases of rabies encephalitis from whom adequate biopsies were obtained on admission to hospital in Thailand (Kaplan et al., 1986).

?? **Direct Fluorescent Antibody (dFA or FAT)**

The standard test for post mortem diagnosis of rabies in humans is the direct FAT which was thoroughly evaluated by Goldwasser and Kissling in 1958 (Bowen-Davies and Lowings, 2000). It is recognised as the most rapid and reliable routine test. Unlike many other virus tests, the dFA test for rabies is based on the principle that rabies virus is present in nervous tissue and in particular the brain. The key areas of the brain for examination are the cerebrum, cerebellem, hippocampus, medulla, thalamus and brain stem.

Fluorescently-labelled anti-rabies antibody is added to rabies suspected brain tissue and binds to nucleoprotein of rabies virus (antigen). Unbound antibodies will be washed away. When viewed with a fluorescence microscope the antigen-antibody bound areas will appear as a bright fluorescent apple green color while no staining is evident if the virus is absent.

?? **Routine histopathology**

General histopathology is a non-specific and less sensitive method for rabies diagnosis. However, histologic examination of biopsy or autopsy tissue is occasionally useful in unsuspected cases that have not been tested by specific methods. Infected brain tissue stained with histologic stain i.e. hematoxylin and eosin, may be recognized as encephalomyelitis, characterised by mononuclear infiltration, perivascular cuffing of lymphocytes or polymorphonuclear cells, lymphcytic foci, and nodules of glial cells or Negri's bodies. The histologic stains are non-specific and false positive results may be obtained. Only the well-trained and experienced technician can distinguish non-specific from specific inclusions.

?? **Immunohistochemistry (IHC) methods**

These methods are more sensitive and specific than other histologic staining methods such as hematoxylin and eosin (H&E) and Sellers stains, and are commonly used on formalin fixed tissue. The procedure is similar to dFA but uses enzyme-labelling systems to increase sensitivity. Moreover rabies virus variants may be detected by using monoclonal antibody.

?? **Electron microscopy**

Rabies virus ultrastructure can be examined by using an electron microscope. The structural components of the virus and details of viral inclusions such as glycoprotein spikes can be observed by this method.

?? **Amplification methods**

These methods are used when samples contain small amount of rabies virus, difficult to detect by routine methods. Two methods are used for confirming the dFA test results and performing infectivity studies.

Viral culture, using mouse neuroblastoma (MNA) or Baby Hamster Kidney (BHK) can be used to increase virus concentration, and therefore the sensitivity of detection.

Amplifying rabies DNA from RNA using enzyme reverse transcriptase (RT), polymerase chain reaction (PCR) technique can produce up to 10^{12} times the original amount of nucleic acid in the sample. This technique is used to confirm dFA results from samples that contain minute amounts of rabies virus such as saliva, skin biopsy or rotten brain specimens.

?? **Serology**

Serology tests are used to confirm the isolation of rabies virus and assess immune responses in vaccinated persons or animals as evidence of nonfatal infection and in experiments involving pathogenesis. Two types of serological tests are used.

Serum neutralisation test (SN)

SN was the first serologic test developed and remains the standard of comparison for other testing procedures. The test measures IgG antibodies using serial dilutions of heated–inactivated sera mixed with a standardised level of infective virus. The mixtures are inoculated intracerebrally into weanling mice or cell culture. Antibody titres are calculated by the number of surviving mice or amount of plaque formation.

Antigen binding tests

Using enzyme-linked immunosorbent essay (ELISA) to detect either IgM or IgG antibodies is highly sensitive with good specificity. Antigen is adsorbed on test plate and then overlayered with single or serial dilutions of test sera. The result can be read visually or with automated spectrophotometric readers with compatible printers (Beran and Steele, 1994).

Animal

?? **Seller's test by light microscopy**

Seller's test is a combination of clinical case history and and histology, used for many decades to diagnosed rabies. Staining brain tissues by "*Seller's stain*" (1 percent solution of basic fuchsin and methylene blue in absolute methanol), "Negri bodies" can be found.

Negri bodies are round to oval specific cytoplasmic inclusion bodies. Their size varies from 0.25 to 27 ?m and they appear magenta in color by Seller's stain. They are found most frequently in the pyramidal cells of Ammon's horn, cerbellum, in the cells of medulla and ganglia and are sometimes in the nuerons of the salivary glands, tongue or other organs. Negri bodies are not always distinguished from other inclusion bodies and are often absent from rabies positive cases. Misclassification of distemper virus inclusion bodies as Negri bodies has resulted in false diagnosis of rabies in the past. However when correctly identified Negri bodies are considered pathognomonic for rabies (National Center for Infectious Disease, CDC,).

This method is also rapid (within two hours), inexpensive and no special equipment is required. As a result it remains the standard diagnostic technique in some developing countries. However, the results of this test should never be relied upon without confirmation with dFA.

?? **The direct fluorescent antibody test (dFA)**

The most frequently used for rabies diagnosis in animals.

?? **Mouse inoculation test (MIT)**

Mouse inoculation test was formerly the "gold standard" for rabies diagnosis. It is used as a primary test in some countries but usually used as a confirmatory test to confirm negative dFA results particularly in the case of humans bitten or scratched. A suspension of the suspected tissue (brain or salivary gland) is injected intracranially and the mouse monitored for 28 days. A positive result is detected by death of animal within 4 to 28 days after injection. The positive animal brain must be confirmed by positive dFA or another post-inoculation test (Bowen-Davies and Lowings, 2000).

?? **Rapid rabies enzyme immunodiagnostic (RREID)**

Suspected tissues are homogenized and examined for rabies nucleocapsid antigen using purified hyperimmune globulin followed by a peroxidase conjugated immune globulin and chromagen substrate. A yellow-orange color change is used to detect positive samples (Beran and Steele, 1994). RREID is a rapid test but has poorer sensitivity than dFA.

Prognosis

Human

Rabies is generally regarded as an inevitably fatal disease both in human and animals. According to Kaplan et al., (1986), humans might survive rabies if their vital functions could be sustained. In general most of the patients died about five days after the first signs of illness (Kaplan et al., 1986).

Animal

There are many reports of dogs surviving after rabies infection. Dogs may recover from clinical rabies and may then intermittently excrete virus in their saliva (Fekadu, 1993).

Treatment

Human

Rabies is a fatal and incurable disease and therefore prevention of establishment of infection before or after exposure is the main treatment approach.

Post exposure treatment (PET)

The first step of post exposure treatment is immediate and thorough wound cleansing and flushing with soap and water.

Human rabies immunoglobulin and vaccine are needed after exposure to rabid or rabies suspected animals. The criteria are as follows:

A person exposed or attacked from wildlife or bats should receive post exposure treatment. The animal involved in the attack should be killed, and tested as soon as possible, regardless of whether it is considered to be a suspect rabies case.

A person exposed or attacked by any non-wild animal (privately owned, unvaccinated pet or stray dog for example) should have PET initiated immediately. The animal should be confined and observed for at least 7-10 days. This may require caging if repeat observation will be difficult. If the animal shows no evidence of rabies during the seven to ten day period of observation or is proved rabies negative, human PET is then discontinued.

If a person is attacked by an animal of unknown status and the animal then disappears, a full course of PET should be applied.

The World Health Organization (WHO) and Centres for Disease Control (CDC) have guidelines for post exposure treatment and assessment of each category of exposure and level of risk.

Two kinds of rabies immunoglobulins, human rabies immunoglobulin (HRIG) and equine rabies immunoglobulin (ERIG), are currently effective forms of passive immunization used in serious or high risk exposure cases except for the exposed person who has been vaccinated previously. HRIG is given at 20 IU/kg and ERIG at 40 IU/kg by infiltrating one half around the wound and one half intramuscularly followed by five doses of cell culture vaccine one each on day 0, 3 7, 14 and 28 (Greene and Dreesen, 1990).

In 1991 the WHO Expert Committee endorsed and promoted post exposure treatment by an intradermal route as an economical alternative for rabies treatment particularly in developing countries with a vaccine shortage (Meslin and Stohr, 1997). There are two types of intradermal regimen, two-site and eight-site regimens. The 2-2-2-0-1-1 intradermal (ID) regimen by giving 0.1 ml injection at each of two sites in the deltoid region on day 0, 3, 7, and one dose of 0.1 ml at one site on day 28 and 90. The eight-site regimen is 8-0-4-0-1-1 by giving 0.1 ml vaccine 8 sites on day 0, four sites on day 7 and one site on day 28 and 90 (Wasi et al., 1996; Wasi et al., 1997). (Warrell, 2001) reported that the two-site intradermal regimen stimulates a rapid immune response and the eight-site regimen is preferred when RIG is not available. However intradermal injection needs to be done by well-trained staff.

The regimen may be slightly different in each country. Effective PET can reduce both mortality rate and psychological sickness.

Animal

In previously immunised animals exposed to a rabid animal, one booster dose of vaccine should be administrated and the animal observed for 3 months. Treatment of non-vaccinated animals exposed to a rabid animal is not recommended.

Prevention

Human

Taking all reasonable precautions to avoid exposure to rabid animals is the best way to prevent rabies. In Thailand vaccination of dogs and cats is an important protective measure against human exposure. Dog population reduction and control is an indirect way to reduce rabies exposure. In areas where other wildlife act as reservoirs, oral vaccination is an effective way to reduce incidence of rabies.

Pre-exposure immunisation has been found to be highly protective for people with a high risk of occupational exposure to rabies such as veterinarians or rabies lab personnel. Three doses of cell cultured vaccination are given followed by a one or three yearly booster or booster whenever the antibody titres below 0.5 IU/ml (Greene and Dreesen, 1990).

Animal

Vaccination

Rabies can be effectively eliminated in the dog population when 70 to 80 percent of animals have been successfully immunised (Kaplan et al., 1986).

Control

Control of rabies depends on the reservoir host and level of infection in that area. Ecological study of the rabies reservoir in a particular area is an important factor influencing the success of a rabies control programme. The maintenance of rabies in animal populations requires the availability of a susceptible host and contact between vector animals. Control of rabies may be achieved by breaking these cycles (Beran and Steele, 1994).

Domestic animals

Dogs are a major source of human rabies responsible for maintaining the disease. Cats are an alternate host and a secondary source of human exposure.

Parenteral vaccination of dogs and cats is the most effective way to control rabies in domestic animals. Dogs over three months should be vaccinated, followed by a booster inoculation six months or one year after. Between 70 to 80 percent of dog population in each community should be vaccinated followed by regular booster inoculations. In endemic areas, revaccination is recommended to maintain a high immunity level with timing dependent on the effective immune period and vaccination coverage.

Oral immunisation is recommended for areas where parenteral vaccination is difficult to achieve at 70 to 80 percent vaccination coverage.

Dog population management is another key factor for rabies control in dogs. Three practical methods of dog population management are reproduction control, habitat control and movement control (World Health Organization, 1992).

Livestock

Cattle are the most frequent livestock species infected with rabies. To control rabies in cattle in endemic areas, dog rabies in these areas should be eliminated. In endemic areas of wildlife rabies, animals at risk should be vaccinated (Greene and Dreesen, 1990).

Wildlife

Currently oral vaccination is widely used for wildlife rabies control in various kinds of wild animals particularly in foxes. The principle is to create and maintain sufficient population immunity to break the transmission cycle.
Reduction in numbers of wildlife is not generally effective as a means of rabies control and is not recommended on a large scale.

Rabies Control and Eradication

Successful Rabies Eradication in

Switzerland

Switzerland is the first country which successfully eradicated rabies in foxes by using a bait vaccine. The systemic vaccination campaign in foxes started in October 1978 by using chicken–head baits containing 10^7 infectious units of modified live rabies vaccine (SAD-Bern strain) (World Health Organization, 1992) and a vaccinia-rabies recombinant vaccine. The vaccine was stabilized by 10% egg yolk (Steck et al., 1982) and used tetracycline as a biomarker. In field vaccination trials, baits applied at the rate of 10-20 per square kilometre where fox populations ranged from 1.0-2.4 per square kilometre halted the rabies epizootic spread (Boyle, 1994). From 1986 no fox rabies has been detected and in 1990 Switzerland was declared a rabies free country (Murphy et al., 1999).
In September 1992 the first case of bat rabies was found in Switzerland, from *Myotis daubentoni* bat. The virus strain was identified as European bat lyssaviruses (Kappeler, 1992).

Kihm (1995) reported that in 1994, 167 foxes were found infected by rabies in Switzerland. The response has been to increase control measures by extending vaccination zones and increasing the density of vaccine baits from 15 to 25/km^2 and by introducing a summer campaign aimed specifically at fox cubs, in addition to the spring and autumn vaccination campaigns.

Successes and Failures of Rabies Eradication in Asia

In Asia canine rabies is endemic and a serious problem marked by the high number of animal and human mortalities reported. There are eight countries which are rabies free, Bahrain, Hong Kong, Japan, Malaysia, Qatar, Singapore, Taiwan and the United Arab Emirates (Beran and Steele, 1994). Japan and Malaysia have been free of rabies since 1950 and 1967, respectively (Rahman and Joseph, 1985); (Shimada, 1971); (Bisseru, 1972). It is thought that strict enforcement and policies of dog registration, vaccination and stray dog destruction have made rabies control and eradication effective in these countries.

From 1979 to 1983 there were only ten cases of rabies (nine dogs and one goat) reported in Malaysia, and all cases occurred in the immune belt area at the border with Thailand. In the immune belt annual vaccination campaigns are conducted, only vaccinated dogs are licensed and unlicensed dogs are destroyed (Rahman and Joseph, 1985).

On the contrary, in Korea where no cases of rabies were reported from 1985-1992 due to the combination of vaccination and stray dog removal programme there was an outbreak of rabies in native cattle and dairy cows in 1994. The virus was spread via raccoons. This resulted in an epidemiological survey and a wildlife rabies control programme (Lyoo, 1997).

In India rabies is endemic and has not so far been controlled for various reasons. Dogs are the main source of infection. There are about of 20 million dogs in India with 80 percent of these strays (Rahman, 1997). Sehgal (Sehgal, 1997) reported that approximately 30,000 people die of rabies annually, 500,000 undergo vaccination and the hospital admission rate for rabies cases is 1:1,000.

One of the reasons that India still has not succeeded in rabies control is that India has wildlife reservoirs (jackals, foxes, mongooses and bats), which play important roles in rabies transmission (Ajuha et al., 1985).

Principles and Designs of a National Rabies Control Programme in Dogs

The basic principles for control programmes in dogs and other domestic animals are epidemiological surveillance, immunisation, dog population management and international cooperation. The relative priority of each depends on social, cultural and economic factors in that region or country (World Health Organization, 1992).

Epidemiological surveillance

Surveillance of rabies is the basis of any programme for rabies control. Epidemiological data should be collected, evaluated, processed and mapped. The information is also required for planning, organising and implementing control programmes.

Mass immunisation

Mass vaccination campaigns have been the most important measure applied for controlling rabies. At least 75% of the dog population in each community should be vaccinated within a short time period, e.g. one month. In areas where the dog population turnover is rapid, it may be necessary to carry out a mass vaccination campaign each year. For this activity the use of inactivated rabies vaccine is recommended.

All dogs and cats presented should be vaccinated regardless of their age, weight or state of health. Puppies less than 3 months old at first vaccine should be given a vaccine booster at 6 months of age. Colour tags or plastic collars can be used to identify vaccinated animals and colours changed yearly.

Oral immunisation of dogs could be an alternative method used to achieve a 75% coverage of dogs in unrestrained populations or areas where parenteral vaccination may be difficult.

Dog population management

Collection of dog population data and study of dog ecology is a key component for dog population management and control. Knowledge of dog abundance is a prerequisite for planning of animal control and vaccination campaigns. Dog population surveys should be completed before any programme is initiated. Data such as dog ownership, relationship to human society, population density, age, dominant sex, habitat and relationship to other species should be collected. Dog population size, distribution and accessibility are also essential data for programme planning, as well as attitude of people and society toward dogs.

Two terms of dog status, “owned dog and stray dog” are commonly used and defined by WHO as follows:

Owned dog: dog(s) owned by at least one household or restricted family and can be measured on records such as dog licensed, movement restrictions and/or vaccinations records.

Stray dog: dog(s) found straying, free roaming, abandoned or lost, and which are not in rabies control regulation.

Three practical methods of dog population management are habitat control, reproduction control and movement restriction.

(i) Habitat control

Habitat control is an indirect way to control dog population number. The size of a dog population is regulated by feed sources and habourage. The food availability areas for dogs such as residential areas, market, industrial areas, warehouses etc should be managed to be clean and reduce available feed. Community education is needed for effective habitat control.

(ii) Reproduction control

Prevention of mating in dogs by confinement or sterilisation is the simplest way to control dog population. Safe, effective, oral administered chemical substances for permanent sterility are needed. Surgical methods are considered to be costly, time consuming and not practical.

Stray dog destruction is believed to be one of the most effective ways to eliminate a source of reservoirs and cut the transmission cycle. Approximately 50-80% of a stray dog population has to be eliminated each year for this to be a successful control strategy (Kuwert et al., 1985). However, this method is not successful in many countries and is no longer considered an effective direct control measure except for unvaccinated dogs as the vaccinated strays can then prevent ecological filling by immigrating dogs.

(iii) Movement restriction

Registration is an effective way of dog population management and control which may aid in successful rabies control in rabies free countries. Dogs should be confined in the premise and leashed or muzzled in public. This includes dog transportation regulations. However this is a difficult task to achieve particularly developing countries.

Control of other reservoir animals

This programme should be done at the same time or whenever feasible. Cats are closely associated with dogs in both urban and rural ecosystems and often infected by rabid dogs. Cats may play a significant role in the transmission of rabies from its reservoir in dogs or other animals to humans. When rabies control in dogs is effective, it will also reduce or break the transmission cycle from dogs to other animals.

Health education

This programme is one of the most important strategies to control rabies in both humans and animals. Programmes should include advice on reducing dog numbers and reproduction rates in unsupervised dogs and reducing the habitat carrying capacity by giving up littering. Much of the problem has been to understand the relationship of dogs to society.

Community control programme

Rabies control programmes should be planned and endorsed at government level and done both in urban and local areas (district level). Cost–benefit and cost-effectiveness analyses should be performed prior to development of rabies control programmes to study their feasibility and to select the best strategy.

Rabies control programmes will be successful if they are in the interests of the local community. Intersectoral and intercommunity co-operation may lead to effective control activities and reductions in cost.

The control programmes in most countries in Asia are based on the principles described above. The actual methods used in each country vary due to many factors including policy, incidence of disease, geography, religion, attitude of people in the country, etc. Some countries such as Malaysia and Japan have succeeded in rabies control and eradication while some are still face the problems of controlling rabies such as India, Indonesia and Thailand.

International Co-operations

International co-operation in development and transfer of technology such as diagnostic techniques, vaccines and rabies research can assist in the establishment of effective control of rabies. Government or national co-operation with international services such as World Health Organization, Food and Agricultural Organisation (FAO) or the International Office of Epizootics (OIE) and the co-ordination of control programmes between neighbouring countries are also important factors influencing the success of a control programme.

Rabies Control in Thailand

Development of Rabies Control in Thailand

The first record of human rabies in Thailand

Human death from rabies in Thailand was first recorded in the diary written by Prince Dumrongrachanuparp (Julanarm, 1986); (Thongcharoen et al., 1980) who lost his daughter, Princess Bunlusirisarn known as Princess Pao, due to rabies in 1912. She was bitten by a rabid dog while she was playing with her friends. At that time there was no post-exposure treatment, no rabies vaccine and no serum in Thailand. There was only the Pasteur Institute in Saigon, Viet Nam and she missed the ship to Saigon. She was treated by local treatment and a Western doctor. The vaccination was ignored after the wound was healed. Three months after that she showed signs of rabies and died.

Her death resulted in the establishment of the Pasteur Institute in Thailand that was called “Paturasapha” on April 26, 1913 by the contribution of Thai people who loved her. The name of the institute was changed to “Queen Sauvabha Memorial Institute” (QSMI) by King Monkutklao in 1917. Paturasapha started producing dry rabbit spinal cord rabies vaccine in 1912 and changed to Semple vaccine in 1958. Semple vaccine is used in both humans and animals. These two vaccines were no longer used from 1943 and 1989 respectively (Thongcharoen et al., 1980).

Initially the impurity of the vaccine caused lots of side effects, and as a result the use of vaccine was considered only for treatment of patients bitten by rabid animals. So the first rabies diagnostic laboratory was established at QSMI in 1950. The diagnostic technique used at that time was Seller’s stain (Yangkratoke et al., 1996).

Despite post-exposure treatment of rabies contact patients, the number of human deaths was still increasing every year. This resulted from a lack of animal rabies control. To complete the control strategy and break the disease cycle, the Rabies Act 1955 (B.E. 2498) was launched under the responsibility of Ministry of Public Health. The Department of Livestock Development (DLD), the organisation which is responsible for animal disease control, started producing animal rabies vaccine from primary cell, LEP Flury Virus Modified Live Virus - Chick Embyro Origin (LEP Flury-MLVCEO) in 1961 under the responsibility of the Rabies Section of the Division of Veterinary Biologics. Immunity from the vaccine lasted for 1 year, which was longer than the Semple vaccine. The technique of vaccine production was subsequently changed to live attenuated vaccine from Primary Pig Kidney Cell.

In 1962 an inactivated vaccine from secondary cell culture was introduced. This kind of vaccine was produced by a stationary monolayer cell culture (BHK-21, Baby Hamster Kidney Cell clone 13), with the virus seed being a Pasteur Virus Strain from the World Health Organization (WHO), inactivated by 2- bromo ethylamine (BEA). Due to limitations of budget and equipment, only a small number of vaccine doses (300,000 doses) were produced per year and these were used by the DLD veterinary officers only (Srisongmuang, 1992).

The control activity by vaccination of dogs started in the confined area at American Camp in Udon Thani and Nakhon Ratchasima province. The American Camp donated animal rabies vaccines used at that time. While the control of rabies in animals was developing, in addition the diagnostic technique changed from Seller's stain to Fluorescent Antibody technique in 1967.

In 1975 the rabies control strategy was implemented in municipalities in rural areas and expanded to urban areas. These activities included dog destruction by poisoning and anaesthetic guns. Moreover, a dog population survey was done for control planning.

A human vaccine, (suckling mice brain vaccine or SMBV), was developed and produced in 1977 by the government. Two years later a Human Diploid Cell Vaccine (HDCV) was introduced and it is now widely used despite the high cost.

The rabies control strategy up to 1980 was not quite effective. Small numbers of dogs were vaccinated, as the Rabies Act of 1955 could not enforce dog owners to get their dogs vaccinated. Insufficient budget to provide free vaccine for owners who were unable or unwilling to pay for it, has hindered the success of the control programme. The low coverage of vaccination lead to the revision of the Rabies Act (Yangkratoke et al., 1996).

The Rabies Act B.E 2535 (1992) was launched on February 12, 1992 under the responsibility of the Ministry of Agricultural and Cooperatives, by the Department of Livestock Development, covering the provision of sufficient veterinary officers and facilities to control rabies in animals for the whole country (Thai Government, 1992)

Current rabies situation

Rabies is endemic in all regions of Thailand with relatively high incidence rates in both humans and dogs. Numbers of human rabies cases have been steady decreasing from 370 deaths, Cumulative Incidence per 100,000 population (CI=0.78), in 1980 to 74 deaths (CI=0.11) in 1995, up to in 69 in 1999 and falling to 48 in 2000. Deaths were reported all year round with a slight increase from November to March. Results from an epidemiological PET survey in 1993 showed that 133,946 patients were treated and 51% of PET were administrated to children under 12 year olds. From 1994 more than 160,000 PET were reported per year (Kingnate et al., 1997).

Dogs are the main reservoir species for rabies, responsible for about 96% of human deaths. Cats are responsible for about three to four percent of human deaths. The proportion of rabies positive animals in relation to total submissions has been decreasing from 47% in 1990 to 34% in 1997 (Kingnate et al., 1997). Among the positive cases 95-96% were dogs, three to four percent were cats and one percent was other animals and wildlife.

Current Rabies control strategies

Human rabies control

In humans, under Department of Communicable Disease (DCD) responsibility, all cases exposed to rabies both due to direct or indirect contact must be given immunoglobulin and / or vaccination against rabies until or unless the contact animal is proven negative.

Human rabies control is under the responsibility of the DCD, Ministry of Public Health (MOH) The control programme has been integrated with the Primary Health Care (PHC) Programme. Community Fund establishment from community participation is encouraged.

Four types of imported cell culture vaccines have been used for post-exposure treatment since 1978. Purified Vero Cell rabies vaccine (PCRV) and purified chick embryo cell vaccine (PCEC) are used in government service are distributed and available in local hospitals all over the country. The demand for PET has been increasing by 10-15% every year. About 10% of the PET vaccinees had equine rabies immunoglobulin (ERIG) injected. Human rabies immunoglobulin (HRIG) is usually available in private sectors. Currently the Thai Red Cross Society produces an adequate amount of HRIG.

Stocks of vaccine equivalent to 1 month's requirement, are stored at Provincial Health Offices and district hospitals. One or two ampoules of ERIG are reserved for emergencies involving severely exposed patients.

Health education by the physician in charge, teachers and village health volunteers are also important components of the control programme in humans.
Publicity campaigns are delivered through audio, visual and printed media although under a limited budget.

The human rabies control programme co-operates with local dog rabies control by Department of Livestock Development and municipality.

Animal rabies control

The DLD has been fully responsible for rabies control in animals since 1992 after the Rabies Act B.E 2535 (1992) was promulgated. As rabies is a disease threatening to both human and animal life, co-operation between the organisations involved is necessary.

In collaboration with DCD and other agencies of concern, such as the Ministry of Interior (MI), the Bangkok Metropolitan Administration (BMA), the Thai Red Cross Society (TRC), universities, a National Board of Rabies and Other Zoonoses has been designated by the cabinet in order to facilitate the control activities. The National Rabies Control and Eradication Programme was set up in 1995 with the main objective to produce "zero human deaths from rabies by the year 2000".

The first phase of the programme was implemented in the southern part of Thailand to reach the objective in 1996, as there was a high probability of success. The factors, which underpinned the control activity, were the lowest incidence of rabies in the southern area due to religion (Moslem) and low dog population. The border adjacent to Malaysia made the control programme and dog movement controls more effective. The second phase aimed at the central and the eastern regions in 1998 and the northern and the north-eastern regions during the third phase in the year 2000.

The three main control strategies are immunisation, dog population control and Public Relations. The control activities are as followings:

?? **Dog population survey**

Done by local (district) officers and village volunteers yearly. These data are used for project planning and evaluation.

?? **Immunisation**

By the Rabies Act B.E 2535 (1992) all dogs must be vaccinated firstly at 3 month and tagged, followed by yearly revaccination or as recommended by the veterinarian or rabies control officer involved.

Under DLD responsibility, a goal of 80% dog vaccination is targeted. Free parenteral vaccination has been provided with emphasis on public areas (temple, school and tourist areas), remote areas and poor animal owners. About 1-2 million doses are administered per year. The vaccination campaign has been performed yearly during March and April and routine free and charged vaccinations are available all year round. This activity also involves other organisations and private veterinary practitioners.

?? **Dog population control**

As the dog has close habitat and relationship with humans, reduction in the dog population to a manageable level can assist in reducing the risk of rabies exposure. Stray dogs are a rabies high-risk group, which need to be controlled and limited. Three methods are used for dog population control:

(i) Temporary birth control

Hormonal injection by medroxyprogesteone acetate subcutaneously in female dogs is a fast and convenient method for mass birth control. However, re-injection at 6-12 months intervals is needed.

(ii) Permanent birth control

Sterilisation by castration and ovariohysterectomy (spey) is an effective way for dog birth control but only small numbers of animals can be treated in this way. The disadvantages are mainly low numbers of surgeries with insufficient personnel and time.

In addition these methods are limited to owned dogs or dogs that can be restrained which are not the main problem of rabies transmission.

(iii) Other methods

Destruction of stray dogs by strychnine seems to be an effective way to reduce mass dog population. This method has been opposed in particular by religious groups such as Buddhists.

Under the Rabies Act B.E 2535 (1992), non-owned or stray dogs found not tagged in the public areas must be captured and caged for 5 days. If there is no contact from the owner during that time, the dog is then destroyed.

Recently two alternative techniques have been developed to control stray dogs and dogs which cannot be restrained and seem to be acceptable by public. One is anaesthetising stray dogs by using a blowpipe applicator and anaesthetic dart to restrain the animal for sterilisation or vaccination. This method is limited to experienced blowers and takes time. The other research developed by (Samitasiri, 1993) is feeding dogs with an oestrogen like powder extracted from a local herb which can prolong the oestrus cycle or inhibit mating behaviour in dogs. This method needs further research to identify the effective dose, time and duration to use.

?? **Epidemiological surveillance**

Passive surveillance involves facilitating and encouraging people to submit suspected or exposed animals for rabies confirmation.

Active surveillance is being conducted by sampling strays and animals not suspected of having rabies, including wildlife, for a rabies survey. Samplings are performed from all over the country. This activity is one of the policies launched to every province with the target of 1 animal per ten villages but in practice the number has never met the target as so many factors influence specimen submission and transportation.

?? **Diagnostic laboratory services and extensions**

Currently 38 rabies diagnostic laboratories located in 27 provinces across Thailand, covering all regions, to serve the people and fulfil epidemiological surveillance activity. Twenty-four laboratories are the responsibility of the DLD up from four laboratories in 1993 after the promulgation of the Rabies Act B.E 2535 (1992). Thirteen laboratories belong to the Ministry of Public Health (MPH). The remaining laboratory belongs to the Queen Souvapha Memorial Institute (QSMI). Two provinces have three laboratories (Bangkok and Chaingmai) and seven provinces have two laboratories.

?? **Public Relations**

The main objective is to educate people about potential risks of rabies as well as preventive measures and first aid in cases of rabid animal exposure. Public awareness will also facilitate cooperation on public control campaigns.

?? **Village trained volunteers**

As a result of insufficient veterinary personnel and heavy workloads, village-trained volunteers are seen as a solution for labour demands. The one or two-day training course is performed yearly with a vaccination kit and handbook. These volunteers become local veterinary assistants for many activities during the campaign, including Public Relations and dog population surveys. Currently about 70,000 village volunteers are trained, one per one village.

?? **International collaboration**

The Malaysia-Thai Joint Technical Working Group Meeting on livestock development between the Department of Veterinary Service of Malaysia and the Department of Livestock Development is conducted annually and focuses on active rabies surveillance and animal movement control. The Queen Saovabha Memorial Institute is a WHO rabies collaborating lab for rabies research. Trainees from many Asian countries sponsored by WHO visit and exchange experiences in rabies control. The co-operation includes OIE and other organisations working with rabies.

Organisations responsible

As mentioned above, the Department of Livestock Development (DLD) under the authority of the Ministry of Agriculture and Co-operative and the Department of Communicable Disease (DCD) under the authority of the Ministry of Public Health are the main organisations responsible for rabies control. There are three organisations which have authority for local areas and rabies research: Ministry of Interior (MI), Bangkok Metropolitan Administrative (BMA) and the Thai Red Cross Society (TRC).

The Ministry of Interior through the Department of Local Administration (DOLA) is responsible for rabies control in local areas together with DLD. DOLA local veterinary officers and local DLD officers have full authority in rabies control, vaccination and dog destruction.

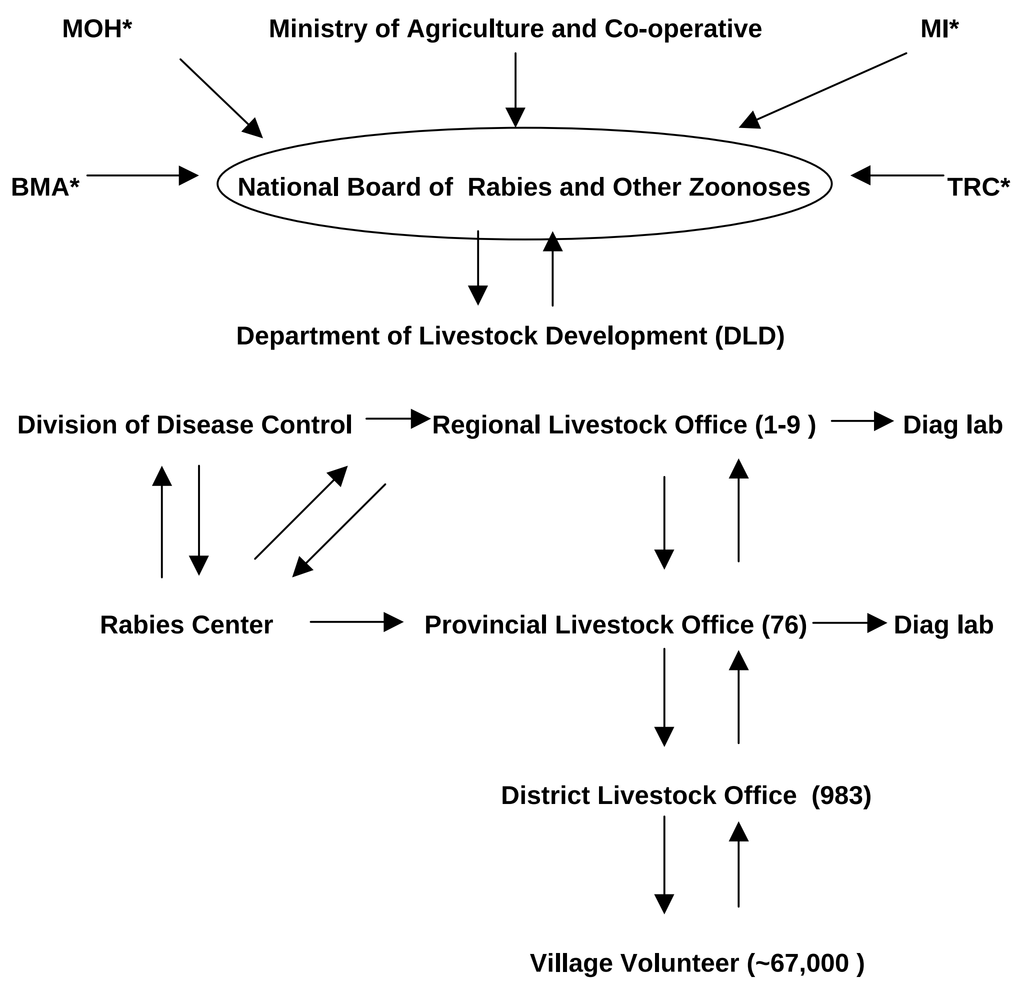
The Bangkok Metropolitan Administration (BMA) through the Department of Veterinary Public Heath maintains the Rabies Control Unit which is responsible for rabies control in Bangkok. The control activities consist of dog and cat immunisation campaigns, routine mobile dog and cat vaccination and sterilisation services in every District Health Service Centre subsidised by BMA.

The Thai Red Cross Society (TRC) is a WHO collaborating laboratory which is the biggest rabies diagnostic lab and human rabies post-exposure treatment centre in Thailand, located in Bangkok. TRC has developed new rabies diagnosis techniques and research, which are useful for rabies control.

Co-operation among these organisations has resulted in progressive and effective rabies control in Thailand.

Rabies Control and Eradication Co-ordinating Systems are shown in Figure 2-1.

Rabies Control and Eradication Coordinating System



***Co-operative organisations**

MOH = Ministry of Public Health
MI = Ministry of Interior
BMA = Bangkok Metropolitan Administrative
TRC = Thai Red Cross Society (WHO Collaborating Lab)

Figure 2-1 Rabies control and eradication co-ordinating system

DCD is the co-ordinating centre for the National Board of Rabies and Other Zoonoses and DLD is the main body for animal rabies control. The local DLD officers follow the policy of The National Rabies Control and Eradication Programme. The DLD working system consists of nine regions, each of which are responsible for and co-ordinate with up to seven to ten Provincial offices (76 in total). Each provincial office is responsible for district offices in that province and the district officer is responsible for subdistricts and villages. The working policy is top down and the reporting system is bottom up.

The Rabies Centre, Division of Disease Control, is the co-ordinating centre responsible for rabies control by implementation of the National Rabies Control Programme policy and data reporting within DLD local offices and between other organisations concerned.

Local officers at every level participate in the local rabies control committee which consists of local organisations similar to the National Board of Rabies Committee. The committee sets the suitable control strategy for that area based on the National Programme.

Problems and constraints in control strategies

?? **Inadequate co-operation** between organisations in both central and local office in some regions, provinces and districts results in work overlap or failure to achieve targets.

?? **Religion** is one factor which can make success of the control programme more difficult. In Thailand most people are Buddhist and dog destruction, one of the most effective ways to control rabies, is seriously opposed. This maintains the stray dog population and facilitates rabies transmission.

?? **Insufficient budget** effects success of rabies control as an effective rabies control programme needs a substantial amount of money over a long period of time which cannot be afforded by government. Other sources of funding such as Non Government Organisations (NGOs), private sector or community funds are needed.

?? **Geographical differences** result in difficulties with vaccination and reservoir control and human post-exposure treatment. In remote areas fewer facilities are provided due to isolation and difficulties in transportation. This makes human rabies control incomplete and maintains rabies reservoirs. Moreover, irregular electricity supply to remote areas can cause inconsistent refrigeration of stored vaccine rendering it ineffective.

Criteria for declaration of Rabies Free Area

According to WHO (World Health Organization, 1992): Criteria for declaration of Rabies Free Area is

"A rabies-free area may be defined as one in which an effective import policy is implemented and, in the presence of adequate disease surveillance, no case of indigenously acquired rabies infection has been confirmed in humans or any animal species at any time during the previous 2 years."

"Conversely an area can be considered to be rabies-infected if an indigenously acquired rabies infection has been confirmed in humans or any animal at any time during the previous 2 years."

To evaluate and improve the control programme, good data recording and reporting systems, and epidemiological analyses should be conducted to monitor disease status and the flaws or loopholes of the current programme. New technologies such as Geographic Information System (GIS) might clearly illustrate the distribution of the disease and relationships between disease patterns and other factors, which will be beneficial for disease control planning.

Geographic Information System (GIS)

What is GIS?

A GIS (Geographic Information System) is a specialised computer database integrated for management of geographically-linked data which handles two types of information, *geographical information* (locations of features e.g. boundaries, districts etc) and *attribute data* (the attributes of the location e.g. number of animals, population, prevalence of disease etc.). The system consists of data collection, input, storage, manipulation and analysis and output (Sharma and Cameron, 1999b).

Why is GIS used?

GIS has applications in the study and control of environment and habitat-dependent diseases and related conditions. GIS can perform spatial analysis from information stored including relationship among diseases. This makes GIS different from a standard database (Jones, 1991; Sharma and Cameron, 1999b).

One of the advantages of GIS is to provide information which allows a better understanding of the epidemiology of disease. A key component of epidemiological studies is the distribution and correlation of the disease to number of factors such as species, age, sex and time. GIS also allows analysis of the spatial distribution and analysis of the disease. GIS is also beneficial in the development and improvement of animal health data systems.

Disadvantages include cost, complexity and demand in requirements which makes implementation in some countries difficult (Sharma and Cameron, 1999b).

How is GIS used?

GIS is widely used for many purposes particularly in an epidemiological study of disease or for management of disease epidemics or animal health programmes. In the mid 1970s the US Department of Agriculture had completed the eradication of screwworm fly by using remote sensing to drop sterile males ((Barnes, 1991). Marsh et al. (1991) used GIS in an epidemiological study of pseudorabies (Aujeszky's disease) in Minnesota swineherds. Sanson et al. (1991) developed a programme for managing a foot and mouth disease epidemic which allows the rapid integration of important information specific to the geographical setting where the emergency is occurring.

In Thailand Sharma and Cameron (1999a) set up a case study using GIS as part of an animal health system and reported the successes and failures of the application. The report showed that a successful system needs strong and sustained top management involvement and support management and a well-documented system to overcome data incompatibility and data conversion problems.

GIS and rabies surveillance and control

Epidemiological studies of rabies should address several questions, for instance, what kinds of animal are the major carriers of the disease, how many people get rabies, how and why they get disease, which areas of the country have high incidence, how to prevent people from getting rabies and how to control or eliminate this disease. Presentation of epidemiological information on maps using Geographic Information Systems (GIS) provides an extra dimension of information useful in rabies control strategy planning.

In order to achieve effective control of rabies, well designed surveys, data collecting system and surveillance are needed. Target animal population, prevalence and disease outbreak information should be sourced. Clustering of disease events may provide clues of the disease process and assist in formulating and evaluating disease control programmes (Ward and Carpenter, 2000).

Objectives of the study

The objectives of this study are:

1. To study the quality of data and data reporting and filing systems of the Rabies Control Programme and comment on the recording form design as a means of collecting data suitable for analysis.
2. To evaluate the effectiveness of the Rabies Control Programme from 1993 to 1999, after the promulgation of the Rabies Act 2535 B.E (1992), which would be beneficial for rabies control and surveillance in Thailand for the 21^{st} century.
3. To analyse risk factors associated with rabies in animals and humans.
4. To investigate spatio-temporal patterns of rabies in dogs and people using GIS.

This project will form the basis of a formal report to each of the organisations involved in rabies surveillance and control in Thailand as well as other interested organisations which might assist in rabies control planning.

Chapter 3

Materials and Methods

Data quality

Sources and types of data

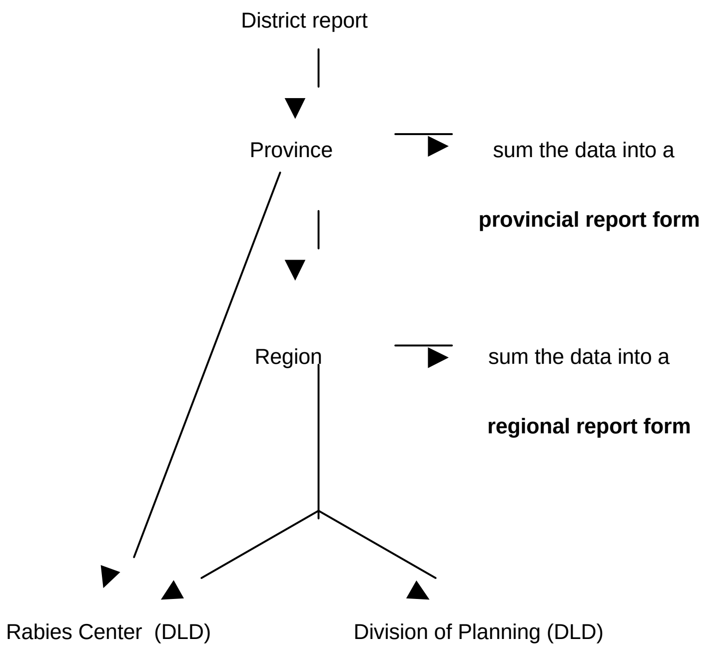
Sources of data for this study were from four organisations responsible for rabies control in Thailand. Two types of data were collected, paper-based (collected as paper sheets) and entered into a computer database and electronic data which were obtained as electronic files in spreadsheet or EpiInfo or ASCII text file format. Five sets of data were collected, two in paper-based data and three in electronic format representing animal surveillance, human deaths attributed to rabies and human population data. Sources and types of data used in this study are shown in Table 3.1

Table 3-1. Sources and types of data used in this study

Data	Detail of data	Year	Source of data	Process of data
Paper-based data				
1.Provincial activity data*	Rabies control activity report at provincial level for 76 provinces	1993-1999	The Rabies Centre, Division of Planning, Regional office (DLD)	Collected from the Rabies Centre and entered by 1 person
2. District activity data*	Rabies control activity report at district level for 26 provinces in the central area	1993-1999	25 Provincial offices (DLD) and the Rabies Control Section (BMA)	Collected from data submitted from the BMA and DLD Provincial offices, entered by 3 persons
Electronic sheet data				
1. Surveillance data	Passive and active surveillance of animal rabies data from rabies diagnostic laboratories all over the country	1993-1999	The Rabies Centre (DLD) and the Division of Epidemiology (MPH)	Annual routine report (DLD, MPH)
2. Human death attributed to rabies	Human death attributed to rabies in detail	1993-1999	The Division of Epidemiology (MPH)	Annual routine report (MPH)
3. Human population data	Human population	1993-1999	The Registration Processing Centre (MI)	Annual routine report (MI) and http:// www.dola.go.th

DLD = Department of Livestock Development
MPH = Ministry of Public Health
BMA = Bangkok Metropolitan Administration
MI = Ministry of Interior
* Paper-based data collected and entered during March to May 2000
** Electronic sheet data obtained in electronic file

The two sets of paper-based data represented measures of control activities, at either the district or province level. The flow of control activity data is shown in



1.

Figure 3.1. Control activity reporting system

Two separate report forms are used by District Officers to report control activities each month. One is for free of charge control services and the other is used to report control activities which attract a charge. Report forms from each district within a single province are submitted to the Provincial Office and aggregated to produce a Province level report. Province reports are submitted both to Regional Offices where they are aggregated further and also to the Rabies Centre where a national aggregated report is produced. In 1996, a computer-based system was implemented for reporting at the province level. Form design at different levels in the system has changed as often as every year.

The Division of Planning handles data from all projects, together with activity reports from every Division in the Department of Livestock Development at Regional and Provincial level. The Regional Offices handle the monthly and yearly reports of every province under their responsibility. To collect data at district level, it was necessary to trace back to the Provincial Office for the processed data as the original data submitted from the district may have been discarded or may not have existed at all.

Letters seeking permission to collect data were submitted to the following bodies:

?? The Department of Epidemiology, Ministry of Public Health for data regarding deaths in humans attributed to rabies.

??

?? The Registration and Evaluation Centre, Department of Local Administration, Ministry of Interior for human population (census) data.

?? The Rabies Control Section, Department of Public Health, Bangkok Metropolitan Administration for rabies control activity data and Bangkok dog population data.

?? The Director General of the Department of Livestock Development, Regional and Provincial Veterinary Offices for surveillance data and control activity data at the province level.

Data pertaining to human deaths attributed to rabies, were obtained in two datasets. A detailed dataset contained specific information on a number of variables relating to the deceased including district/province in which exposure occurred, district/province in which death occurred, date of death, age of person, gender of person, history of exposure, type of animal involved in the exposure incident, age of animal, and rabies vaccination status of animal. A second dataset contained a simple summary of human deaths per year attributed to rabies and represented the basis of an annual report submitted to the World Health Organisation each year. Only the data from the detailed dataset were used in this study because of the interest in the additional information contained in that dataset.

Two datasets relating to human census information were obtained from the Ministry of Interior. The first dataset contained data relating to year, district and province and identifying human population by gender. This data contained population values for each year from 1993 to 1999. A second dataset was then obtained directly from the Ministry web site (http://www.dola.go.th), which contained population data categorised by age (in one year increments from the first year of life to greater than 100 years of age), gender, year, district and province. Data were downloaded only for 1996 due to size of the datasets and time taken for downloading and re-organising the data into age group categories. 1996 was chosen as a representative year for population data because it was in the middle of the study period.

Data Collection

The author travelled to Thailand to personally supervise collection of data due to the need to visit different offices and obtain data from multiple sources.

Electronic file data were obtained as a series of files either on floppy disks or via the internet (email and world wide web download). These included surveillance data, human census data and human rabies case data.

Control activity data were obtained as paper sheets, including both typewritten and handwritten records representing district level data and province level data. A database for entering and storing district level control activity data was developed by the author in Epi Info 6 (Version 6.04b, October 1997; CDC and WHO Statistic Programme) before to travelling to Thailand. Epi Info 6 was chosen because it was already familiar to the data entry personnel and it is a simple, effective program for entering and storing data. The design of the database and the data entry screen were based on a recent version of an activity report form obtained by the author. The database comprised of 72 variables. Copies of the blank database were then loaded onto floppy disks to provide to data entry personnel for facilitation of data entry in Thailand.

The author and three other individuals were responsible for data entry. The author briefed the data entry personnel on the use of the Epi Info 6 database for data entry and explained the objectives of the study. Paper sheets containing control activity data were distributed to each person along with one blank copy of the Epi Info 6 database, for data entry. EpiInfo files from each data entry person were then merged into a single control activity database file. Photocopies of all paper sheets were also made as a back up and to facilitate subsequent data checking.

Data quality assessment

On return to New Zealand, all data were imported into a custom designed database for data manipulation and data quality checking.

The following types of data errors were assessed:

Data entry error: A total of 3272 records from 26 provinces were entered in the District control activity data set and 529 records from 76 provinces were entered in the

Provincial control activity data set. Each record contained data values for multiple variables, for example 1 record from the Provincial data set contained all the data summarising control activities in that province, for one particular year. A random sample of 5% of records from each data entry person was selected by generating random numbers. Each selected record was then assessed by comparing the value stored in the Access database to the value on the photocopy of the original paper sheet obtained from Thailand. Results were summarised for each entry person.

Implausible data: Data in the entire database were sorted in ascending and descending order, each time using a different variable as the sorting variable. The first few values were then compared to overall summary statistics for that variable, to screen the data for obvious errors in either data recording or data entry which might result in an individual cell value being order(s) of magnitude larger or smaller than the remainder of the data values stored in that variable. Unusual values were then compared against values in the relevant paper copy and corrected if required. If the data value in the original paper copy was identical to the value in the database, then it was left unchanged.

Missing data: Variables in the database were screened for blank entries to determine the proportion of missing data in each variable. It became apparent that data entry personnel had left cells blank whenever the paper sheets contained any of the following values: 0, “blank”, or “-”.

Symbolic codes used in FAO, WHO and OIE reports indicate that a hyphen (-), is interpreted as “not reported” and a blank cell ( ), is interpreted as “no information available” or missing value. A decision was made to recode blank cells in the database in the following manner:

?? Blank cell = missing value

Where the relevant cell in the paper records was also blank.

This was interpreted as meaning that data were deemed to have existed and therefore should have been collected, but were not recorded on the paper reporting form. These cells represented data which should have been collected and which was not collected.

?? 0 = no activity

0 or “-” in the relevant cell in the paper records.

This was interpreted as meaning that a value of zero (0), was a valid estimate of the measure of activity, which occurred in that district or province, for that month or year.

?? -99 = Variable did not exist at the time the report form was completed.

No cell existed on the paper record for that variable.

Changes in paper form design during the study period meant that there were many paper report copies which did not contain listings for specific variables.

Data cells within each variable could then be classified as valid data, missing data and data did not exist. Summary reports were then prepared to assess proportions of data in each of these categories for each variable.

Data within files which were obtained electronically could not be subjected to the same level of scrutiny as no paper records were available to compare cell values. No corrections were made to these file types.

Assessment of data completeness

All data files were then subjected to a general assessment of completeness i.e. proportion of data cells in each variable which contained valid cell values. Missing values and data that did not exist were combined into a category called invalid data. The remaining data values (including zero values and other numerical values greater than zero), were deemed to be valid data.

Descriptive analysis

Six sets of data were used for analysis:

?? An animal surveillance data consisted of two sets of data, passive and active surveillance.

?? Human rabies case data

?? Human population data (human census)

?? Control activity data consisted of two sets of data, provincial and district control activity data

Surveillance data

There were two sets of surveillance data, **passive and active** surveillance.

Passive surveillance data were recorded from rabies suspected animals submitted to diagnostic labs for rabies confirmation. From a total of 40,659 records, seven records in 1993 had errors in the result code which invalidated the analysis of the result. These seven records in 1993 were deleted, leaving 40,652 records available for analysis. Summary statistics were calculated for numbers and proportions of rabies positive cases, organised in categories based on other variables in the dataset.

Active surveillance data were convenience samples collected from animals with no clinical signs of rabies and which were not suspected of rabies. Prior to 1998, Active Surveillance records were included with Passive Surveillance data without any distinction between the two. A total of 1,520 active surveillance records were available for analysis.

Separate active surveillance data recording was initiated in 1998 and a total of 1520 records were available for analysis. There were no rabies positive cases in this dataset (one animal returned an inconclusive result). No further analyses were performed on this data set due to the low number of records and absence of rabies positive cases.

Human rabies case data

Data were available on 433 human deaths attributed to rabies with associated information collected on an additional 10 variables covering demographics and exposure history. Summary statistics were calculated for numbers and proportions of human deaths organised in categories based on other variables in the dataset.

Human census data

Human census data were available for each gender and in one year age groups from 0 to >100 years. Analysis of the annual total population for Thailand showed that population increased each year between 1993 and 1999 by 0.3%. This represents a small increment in a total population of around 60 million. A decision was made to use detailed census data for 1996 as denominator data for all analyses. Data from the 1996 census were aggregated to provide province level population data, categorised by gender and by seven ranges of age (0 to 10, 11 to 20, 21to 30, 31 to 40, 41 to 50, 51to 60 and >60 years).

Control activity data

Control activity data were recorded each month during the period from 1993 to 1999, in 10 provinces. Six provinces had monthly records for every district. Four provinces had missing data from some districts in any one month. All data were aggregated to the province level and an average per district value computed for each variable. This was done by dividing the total monthly value for each variable at the province level, by the number of districts which contributed data in that month. This allowed comparisons to be made between provinces. Summary statistics were calculated for control activities aggregated by month and organised in categories based on other variables.

In addition, where variables contained data in several subcategories, information was aggregated to produce a total for that variable. For example dog population data could be recorded under one of seven different categories: owned male, owned female, total owned, non owned male, non owned female, total non owned, total. In fact it was common for data to be present only in the total column or alternatively only in the total non-owned and total owned columns, in the records obtained from Thailand. The same finding appeared in all control activities (vaccination, hormone injection, castration, spey and euthanasia). All analyses were performed using a single total value for each variable.

Finally very little control activity data were available for species other than dogs. Only data for dogs were used in analyses.

Comparative analysis

Univariate and bivariate analysis

Selected comparisons were performed using variables, which contained more complete data (fewer missing values or blanks), and which appeared to have an association of interest based on review of the descriptive analysis results.

A series of chi-squared tests of association were performed using 2x2 tables and in some cases Mantel–Haenszel tests where stratification of data was deemed appropriate. Associations between exposures and outcomes were expressed as relative risk measures with 95% confidence intervals. Where the 95% confidence interval included 1, there was no significant association between the exposures (or level of the risk factor), and the outcome of interest (using ? =0.05 as the threshold for significance). If the 95% confidence interval for the relative risk did not include 1, then the risk factor (or level of the risk factor) either significantly increased the risk of the outcome occurring (RR>1), or significantly decreased the risk of the outcome occurring (RR<1).

Selected bivariate comparisons of continuous variables were performed using scatter plots and linear regression equations were applied to provide an indication of the relationship between variables.

Disease measurement

Cumulative incidence (CI) estimates per 100,000 population were made for each province for both dog rabies cases and human rabies cases. The numerator for dog rabies cases was the number of positive cases reported for each year or month, in each province. The denominator was the province specific, annual estimate of the total dog population. This estimate is likely to under estimate the actual annual CI of rabies in dogs in Thailand as the number of dogs submitted for diagnosis has been decreasing and not all human deaths were reported in detail.

For human cases, the numerator was the monthly or yearly reported number of investigated deaths attributed to rabies in each province and the denominator was the gender and age group specific census data recorded for each province in the 1996 census. Given the relatively small and constant increase in census derived population estimates each year, it was felt that using data derived from the 1996 census could be considered representative of the human population in each year.

For the overall annual cumulative incidence of human deaths over the seven years from 1993 to 1999, the total number of human deaths from 1993 to 1999 was used as numerator and the total number of human population from 1993 to 1999 used as a denominator. The overall cumulative annual incidence of dogs rabies over the seven years from 1993 to 1999 used the total number of dog rabies positive cases from 1993 to 1999 as a numerator and the total number of dog population from 1993 to 1999 as the denominator. Cumulative Incidence was reported as the point estimate and 95% confidence interval (Gardner and Altman, 1989).

GIS and Spatial analysis

Spatial analysis

Human rabies

Human population estimates for each of the 76 provinces of Thailand were obtained for each of the seven twelve-month periods from January 1993 to December 1999. Counts of the number of deaths in each province attributable to rabies were obtained for the same time periods.

The analyses presented here are for two selected annual data sets (1994 and 1999) in an attempt to assess changes in rabies incidence throughout the study period. The 1994 data set was selected in preference to the 1993 data set because changes in administrative boundaries meant that three provinces did not exist in 1993 and as a result the 1994 dataset was more directly comparable to the 1999 dataset.

Internally standardised (Carlin and Louise, 1996) expected human rabies counts in each province for each year were calculated as:

$$E_{it} ? n_{it} \bar{y}_t$$

where n_{it} was the estimated population in the *i*th province for the *t*th year, and $\bar{y}_t$ was the proportion of the human population diagnosed with rabies in the *t*th year, calculated across all provinces. For each year chloropleth maps of the standardised mortality ratio (that is, the ratio of observed rabies cases to the number expected, SMR_t) were plotted using the Geographic Information System package ArcView for Windows Version 3.1 (Environmental Systems Research Institute, Redlands, California, USA).

To assess the nature of spatial autocorrelation that may have been present in the distribution of SMR_t a spatial correlogram (Bailey and Gartrell, 1995) was constructed using first, second, third and fourth order spatial weight matrix specifications appropriate for the 76 provinces of Thailand.

Because rabies is a relatively rare disease the observed number of cases was assumed to follow an independent Poisson distribution with the mean number of cases recorded in each province in each year given by $?_{it}$. The mean number of cases for each province and year was assumed to be equal to the product of the relative risk of disease $?_{it}$ and the expected number of cases for each province and year, E_{it}:

$$?_{it} ? E_{it} ?_{it}$$

Bayesian ecological models were constructed to quantify the influence of hypothesised risk factors on province-level rabies relative risk. Province-level explanatory variables thought to influence the relative risk of human rabies were: (1) the proportion of dogs vaccinated against rabies, (2) human population density, (3) dog population density, and (4) the standardised mortality ratio for canine rabies.

To achieve normality the vector defining the proportion of dogs vaccinated against rabies was subject to a Freeman-Tukey transformation (Freeman and Tukey, 1950) and the vectors of human and dog population density were subject to a square root transformation.

A three-stage process was adopted to quantify model parameters. In the first stage the relationship between province-level estimates of each hypothesised risk factor and province-level standardised mortality ratios for rabies was assessed using pairwise scatterplots. In the second stage explanatory variables showing a relationship with rabies risk were included in a fixed-effect model using a Markov Chain Monte Carlo algorithm (Gilks et al., 1996) implemented in WinBUGS version 1.3 (Spiegelhalter et al., 1998). Global Moran’s I statistics (Moran, 1950) were calculated using the residual terms from the fixed-effect model to identify the presence of not-accounted for spatial autocorrelation in the data. Where spatial autocorrelation in the residual terms from the fixed-effect model existed, the third stage was to include spatial and non-spatial heterogeneity terms in a mixed-effect model (Besag et al., 1991)

Posterior estimates of the structured heterogeneity terms from the mixed-effect model were plotted as chloropleth maps. This identified provinces where there was an excess of human rabies incidence that was not explained by the proportion of dogs vaccinated against rabies, human population density, dog population density and the standardised mortality ratio for canine rabies.

Canine rabies

Canine population estimates for each of the 76 provinces of Thailand were obtained for each of the seven twelve-month periods from January 1993 to December 1999. Counts of the number of deaths in each province attributable to rabies were obtained for the same time periods.

The analyses presented here are for two selected annual data sets (1994 and 1999) in an attempt to assess changes in rabies incidence throughout the study period.

As for the human rabies analyses, internally standardised expected canine rabies counts were determined and the ratio of observed canine rabies counts to those expected where plotted as chloropleth maps. Spatial correlograms for the ratio of observed to expected rabies counts were constructed using first, second, third and fourth order spatial weight matrix specifications appropriate for the 76 provinces of Thailand.

Bayesian ecological models were constructed to quantify the influence of hypothesised risk factors on province-level rabies relative risk. Province-level explanatory variables thought to influence the relative risk of human rabies were: (1) the proportion of dogs vaccinated against rabies, and (2) dog population density.

Pairwise scatterplots were constructed to determine the relationship between province-level estimates of each hypothesised risk factor and province-level standardised mortality ratios. Those variables showing a relationship with canine rabies risk were included in a fixed-effect model using a Markov Chain Monte Carlo algorithm (Gilks et al., 1996) implemented in WinBUGS version 1.3 (Spiegelhalter et al., 1998) . Global Moran’s I statistics (Moran, 1950) were calculated using the residual terms from the fixed-effect model to identify the presence of not-accounted for spatial autocorrelation in the data.

Chapter 4

Results

Data quality

Data entry error

Error rates found from each data entry personnel are shown in Table 4-1.

Table 4-1. Error rates for each data entry person

Data entry person	Total records entered	No. of records randomly selected	No. of data cells checked	No. of errors	Percent errors	Total entry cells
1*	264	13	174	1	0.57	3111
2*	1669	84	1272	16	1.26	25272
3*	1096	64	1491	21	1.48	23967
4**	532	27	685	17	2.48	14523
Total	3561	188	3622	47	1.55	66873

* Entered District activity data
** Entered Province activity data

Errors identified in the randomly selected records appeared to be due to the entry of incorrect numbers, either as a result of misreading of the value from the paper copy or striking the incorrect key on the keyboard.

All data entry personnel had less than 2.5% errors in the cells that were checked, and three of the four personnel returned less than 1.5% errors. An error rate of less than 1.5 per 100 cells was deemed unlikely to adversely influence the results of any analyses, particularly since extreme values were being screened for all variables. Data processor number 4 returned the highest error rate. Every cell value for all data entered by this person was then checked against the paper copies of the data and corrections made where necessary.

Examination of the files which were obtained in electronic form, revealed a small number of errors due to duplicate records. A total of 55 of the 40,714 passive surveillance records were found to be duplicated and were deleted, leaving 40,659 records. Two records from the total of 1,522 active surveillance records were found to be duplicated and were also deleted, leaving 1,520 records for analysis.

Implausible data

A total of 10 cell values were corrected as a result of this assessment. Of these 7 values had an extra digit inserted in the database cell value compared to the paper copy value, and 3 values were numerically different but did not have extra digits.

Missing data

The percentages of missing data in the Provincial and District Control activity datasets are shown in Figure 4-.and Figure 4-4-2. respectively.

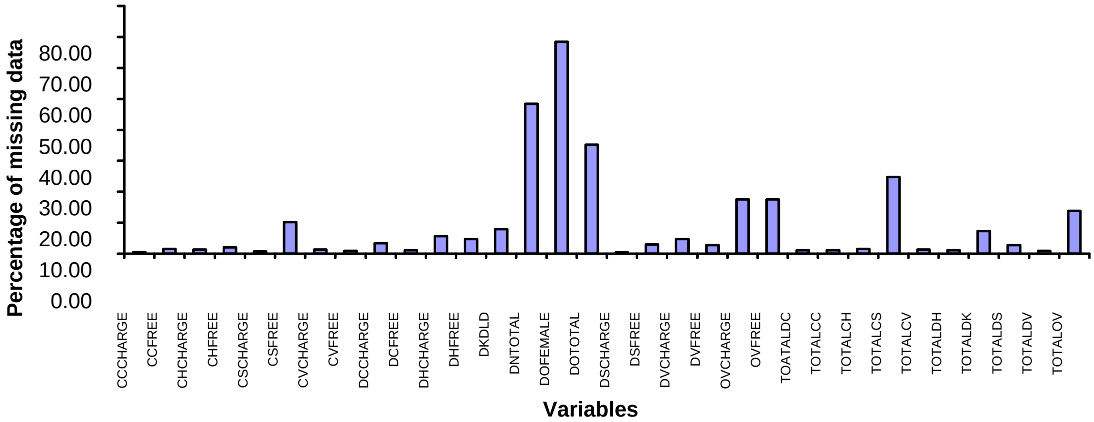


Figure 4-1. Percentage of missing data in Province control activity data

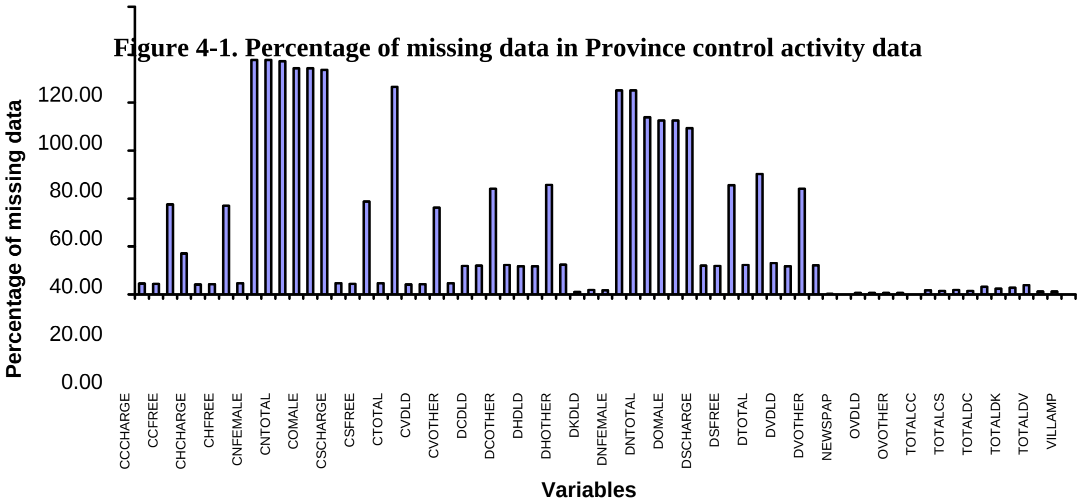


Figure 4-2. Percentage of missing data in District control activity data

Missing Province Activity data accounted for 7% of cells from 42 variables after correcting.
Missing District activity data occurred in 26% of cells from 67 variables after correcting.

Assessment of data completeness

Provincial control activity dataset

Number of variables from the Provincial control activity dataset categorised according to the percentage of valid data values, are shown in Table 4-4-2

Table 4-2. Number of variables from the Provincial control activity dataset categorised according to the percentage of valid data values.

Percentage of valid data	Number of variables	Variables		
>0-20	16	TRAINVIL	VILLAMP	TV
		EXHIBIT	RADIO	NEWSPAP
		OTHERPR	DCCHARGE	OVFREE
		CSCHARGE	TRAINVOL	OVCHARGE
		DSCHARGE	CCCHARGE	TOTALOV
		DKOTHER		
>20-40	13	CSFREE	TOTALCS	DOFEMALE
		CVFREE	TOTALCC	TOTALCV
		CCFREE	TOTALCH	CHFREE
		CHCHARGE	CVCHARGE	TOTALDK
		DKDLD		
>40-60	1	DNTOTAL		
>60-80	2	DOTOTAL	DHCHARGE	
>80	10	TOTALDV	DCFREE	TOATALDC
		TOTALDH	DVFREE	DHFREE
		DTOTAL	TOTALDS	DSFREE
		DVCHARGE		
Total	42			

The Provincial control activity dataset had 12 of 42 variables (29%) with greater than 40% valid data values. Explanations of the variable names are listed in Appendix II.

District control activity dataset

Number of variables from the District control activity dataset categorised according to the percentage of valid data values, are shown in Table 4-34-3.

Table 4-3. Number of variables from the District control activity dataset categorised according to the percentage of valid data value

Percentage of valid data	Number of variables	Variables		
>0-20	9	CTOTAL	DNMALE	DNFEMALE
		COTOTAL	COMALE	COFEMALE
		CNTOTAL	CNMALE	CNFEMALE
>20-40	19	CSFREE	CVFREE	CHFREE
		CCFREE	TRAINVIL	DKOTHER
		TV	NEWSPAP	DOTOTAL
		VILLAMP	RADIO	EXHIBIT
		OTHERPR	DOMALE	DOFEMALE
		DNTOTAL	OVDLD	OVOTHER
		OVCHARGE		
>40-60	8	TOTALOV	DSFREE	DCFREE
		DHFREE	OVFREE	DTOTAL
		CCOTHER	DVFREE	
>60-80	19	TOTALCV	DSOTHER	TOTALCS
		CVDLD	CSDLD	CVCHARGE
		CCDLD	CVOTHER	CSCHARGE
		CSOTHER	CHDLD	CHOTHER
		CHCHARGE	DKDLD	TRAINVOL
		TOTALDK	CCCHARGE	TOTALCH
		TOTALCC		
>80	17	TOTALDH	TOTALDC	TOTALDV
		DISTCODE	TOTALDS	DVDLD
		DHDLD	DCOTHER	DCDLD
		DHOTHER	DHCHARGE	DVCHARGE
		DVOTHER	DCCHARGE	MONTH
		DSCHARGE		
Total	72			

Fourty-four of the total of 72 variables (61%) contained more than 40% valid data values. Explanations of the variable names can be found in Appendix II.

None of the variables from the control activity datasets contained 100% valid data values. Some provinces reported more detailed information e.g. records identified individual districts and contained information for each month of each year. Other provinces only reported annual summary information at the province level with no data relating to either monthly activity or districts within the province. A decision was made to proceed with further analyses only using data aggregated to the province level because of the sparsity of data at the district level.

Surveillance dataset

Percentages of missing data values in the passive surveillance dataset are shown in Figure 4-3.

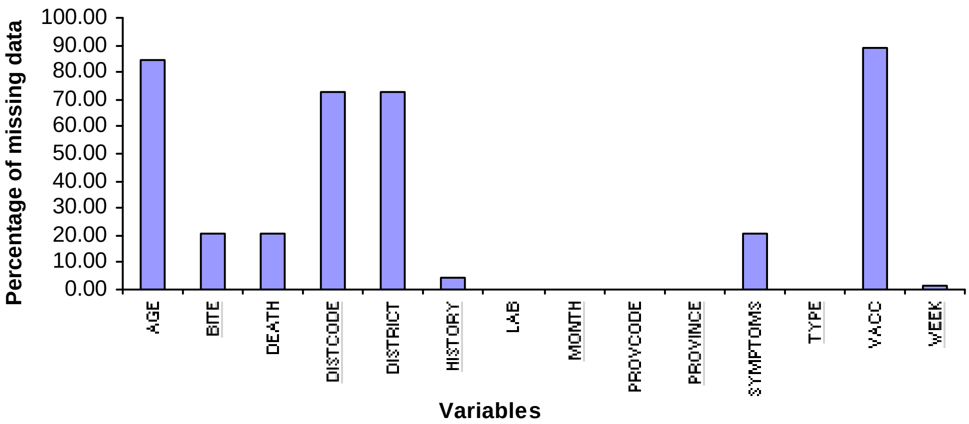


Figure 4-3. Percentage of missing data values in the passive surveillance dataset

A total of 33% of data values were missing from the 40,659 records. The variable with the highest percentage of missing data (history of animal, with 93% missing values), was only added to the reporting form in 1999.

Human deaths attributed to rabies

In detailed reports of human deaths attributed to rabies, percentages of missing data in each variable from the human death dataset are shown in Figure4-4.

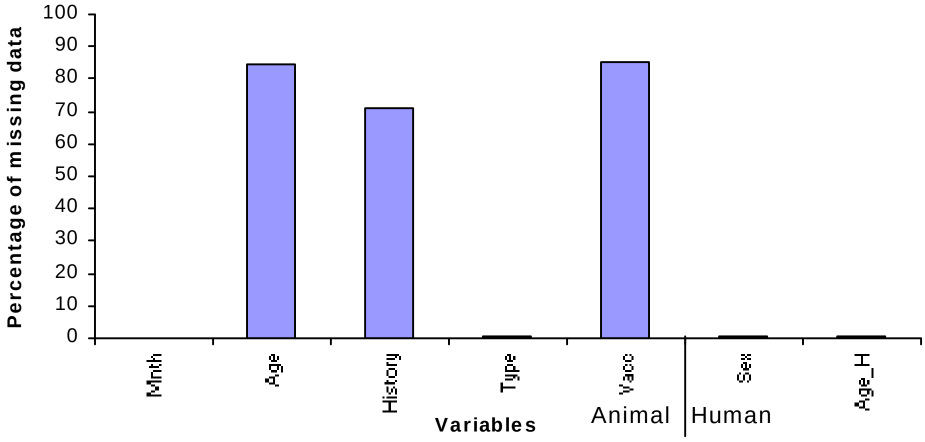


Figure. 4-4 Percentages of missing data in each variable from the human death dataset

Relatively high percentages of missing data occurred in the variables pertaining to the animals associated with exposure.

Data available for analysis

At the conclusion of the data quality assessment process, five sets of data were ready for data extraction and analysis. Details of the datasets are presented in Table4-4.

Table4-4. Number of records available for analysis in each dataset

Data	Original records	Records used	Remarks
District activity	3,272	3,272	
Province activity	532	529	3 provinces did not exist in 1993
Surveillance	42,236	42,179	Deleted duplicates
Human death	434	433	One case from Laos

A total of 10 provinces contained sufficient control activity data at the monthly level to warrant analyses aimed at assessing the patterns of change in various variables over the months of the year. The data for these 10 provinces were derived from the District control activity dataset by aggregating data where necessary to the province level.

The Provincial control activity dataset contained sufficient valid data for further analyses aimed at assessing the patterns of change in various variables over the seven years of the study period.

Descriptive analysis

Passive surveillance data

The 40,652 records of passive surveillance data from 1993 to 1999 consisted of 12 key variables which were year (YEAR), province code (PROVCODE), district code

(DISCODE), type of animal (TYPE), history of animal (HISTORY), age of animal (AGE), animal vaccination history (VACC), symptoms or clinical signs of animal submitted for diagnosis (SYMPTOMS), suspected animal contact (BITE), how animal died (DEATH) and result of diagnosis (RESULT). Number and percentage of total variables, valid and missing data are shown in Table4-5.

Table4-5. Number and percentage of total variables, valid and missing data

Variables	Total records	Valid	Percent valid	Missing	Percent missing
YEAR	40,652	40,652	100	0	0
MONTH	40,652	40,651	100	1	0
PROVCODE	40,652	40,650	100	2	0
DISTCODE	40,652	11,168	27.47	29,484	73
TYPE	40,652	40,649	99.99	3	0
HISTORY	40,652	2,750	6.76	37,902	93
AGE	40,652	6,144	15.11	34,508	85
VACC	40,652	4,490	11.04	36,162	89
SYMPTOMS	40,652	32,152	79.09	8,500	21
BITE	40,652	32,155	79.1	8,497	21
DEATH	40,652	32,154	79.1	8,498	21
RESULT	40,652	40,652	100	0	0

Five variables, YEAR, RESULT, TYPE, MONTH, PROVCODE had 100% valid data. SYMPTOMS, BITE and DEATH had 79% of valid data while DISCODE, HISTORY and VACC had less than 30%valid data (27%, 15% and 7%) respectively.

Positive rabies cases by year

The percentage of positive cases from suspected cases submitted for rabies diagnosis in each year, are shown in Figure 4-5.

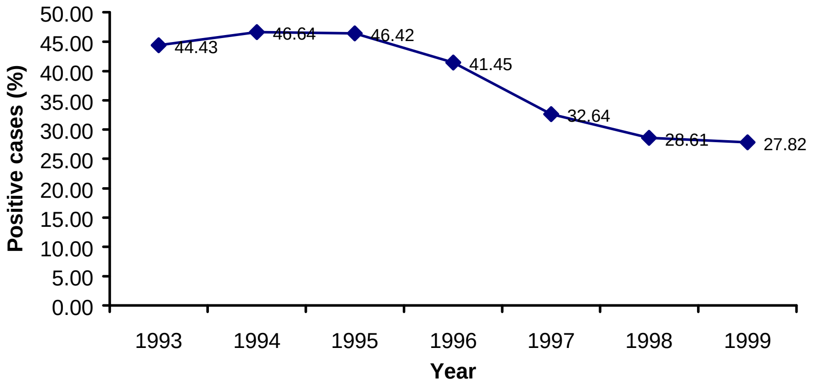


Figure 4-5. Rabies positive cases as a percentage of total yearly submissions from 1993-1999

The percent of positive rabies cases has been decreasing from about 47% in 1994 and 1995 to 28% in 1999. The overall average percentage was 40%.

Positive rabies cases per month

The number of positive rabies diagnoses expressed as a percentage of suspected cases submitted for rabies diagnosis in each month over the seven year period from 1993 to 1999 are shown in Figure 4-5.

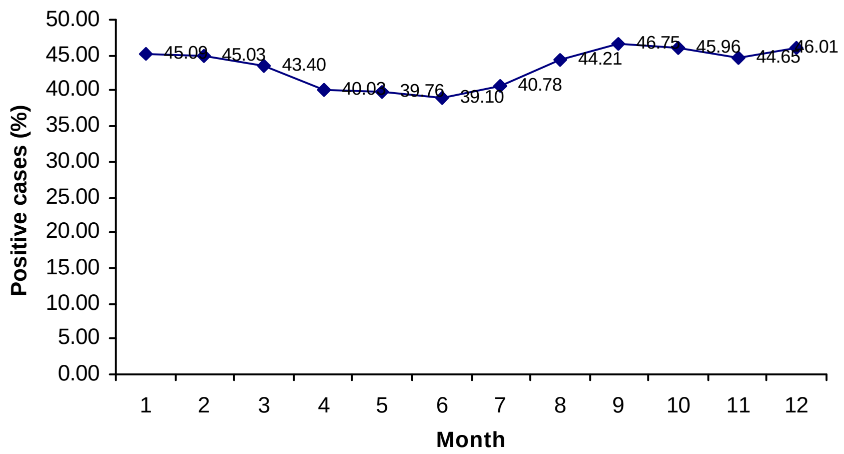


Figure 4-5. Percentage of rabies positive per month from 1993 to 1999

Percentage of positive rabies cases was highest in January and February (about 43%) and lowest in May and June (36%).

Positive rabies cases by province

The number of districts in each of several categories of the number of rabies positive cases expressed as a percent of the total number of suspect cases submitted are shown in Table 4-6

Table 4-6. Number of districts in each category of percentage positive cases

Percent positive	Number of province
>40	43
20-40	26
<20	7
Total	76

Percent of rabies positive compared to cases submitted per province showed that 43 provinces had more than 40% positive cases, 26 provinces had between 20 to 40% positive and 7 provinces had less than 20%. Provinces 75 and 32 had the highest percentage of positive cases, which was 65% and 61.59% respectively. Province 15 had the lowest percentage of positive cases (13%).

Positive rabies cases by district

The number of districts in each of several categories of the number of rabies positive cases expressed as a percent of the total number of suspect cases submitted are shown in Table 4-7.

Table 4-7. Number of districts in each category of percentage positive cases

Percent positive	Number of district
100	50
>=80<100	12
>=60<80	45
>=40<60	111
>=20<40	203
<20	79
0	195
Total	695

There were 50 districts that had 100% positive cases from cases submitted but the number of cases submitted per district was very low (from 1 to 5). Submitted cases from 195 districts were all negative.

Positive rabies cases by types of animal

The number and percentage of positive cases in each animal type is shown in Table 4-8.

Table 4-8. Number and percentage of positive cases in each type of animal.

Animal type	Total	Positive	% positive	Negative	Inconclusive	Unknown
Dog	35,338	15,295	43	19555	458	30
Cat	3,819	626	16	3142	48	3
Cow	409	234	57	174	1	0
Buffalo	47	13	28	32	0	2
Pig	66	16	24	50	0	0
Goat	15	4	27	11	0	0
Sheep	45	4	9	41	0	0
Horse	67	3	4	64	0	0
Monkey	122	18	15	104	0	0
Gibbon	349	8	2	334	7	0
Langur	40	15	38	24	1	0
Rat	108	8	7	93	6	1
Squirrel	83	10	12	72	0	1
Rabbit	41	0	0	41	0	0
Hare	4	1	25	3	0	0
Chipmunk	33	5	15	28	0	0
Other	33	4	12	29	0	0
Unknown	30	10	33.33	17	3	0
Total	40,649	16,274	40	23,814	524	37

From 18 types of animal submitted for rabies diagnosis, cows had the highest percentage positive (57%) as a proportion of the total number of cases submitted, while none of the rabbits submitted had a positive result. Dogs had 43% positives.

Among the positive cases, dogs contributed the highest proportion of rabies positives (94%) while cats, cows and other types of animal contributed 4%, 1% and 0.73% respectively.

Positive rabies cases by animal history

From 2750 animal history records in 1999, the number and percentage of positive cases in each category of animal history is shown in Table 4-9.

Table 4-9. Number and percentage of positive cases in each category of animal history from number of submitted cases in dogs

History	Total	Positive	% positive	Negative	Inconclusive	Unknown
Owned	2,060	477	23	1,561	22	0
Non-owned	361	161	45	191	9	0
Unknown	329	139	42	190	0	0
Total	2,750	777	28	1,942	31	0

Overall, 28% of submissions were rabies positive and non-owned and unknown status dogs were more likely to be positive than owned dogs.

Positive rabies cases by range of animal age

Approximate animal age of submitted cases has been recorded since 1998. From five ranges of age in 6,144 canine records, the number and percentage of positive cases is shown in Table 4-10.

Table 4-10. Number and percentage of positive cases from dogs submitted in each range of age

Age	Total submitted	Result Positive	% positive	Negative	Inconclusive	Unknown
< 3 months	914	220	24	682	11	1
3-6 months	1,133	342	30	782	8	1
>6-12 months	733	227	31	495	11	
>12 months	1,596	431	27	1,144	20	1
Unknown	1,768	529	30	1,205	34	
Total	6,144	1,749	28	4,308	84	3

Overall, 28% of submissions were rabies positive and there was not much variability among age groups.

Positive rabies cases by vaccination history

From 4,490 records of animal rabies vaccination history, the number and percentage of positive cases submitted in each category of vaccination history is shown in Table4-11.

Table 4-11. Number and percentage of positive cases in dogs submitted in each category of vaccination history

Vaccination history	Total submitted	Result Positive	% positive	Negative	Inconclusive	Unknown
None	2,286	662	29	1,594	27	3
< 1month	281	78	28	202	1	0
1-6 months	374	46	12	322	4	2
< 6 month - 1yr.	275	32	12	242	1	0
> 1 years	239	56	23	179	4	0
Unknown	1,035	375	36	647	12	1
Total	4,490	1,249	28	3,186	49	6

Overall, 28% of submissions were rabies positive and non-vaccinated and unknown status dogs were more likely to be positive than vaccinated dogs.

Positive rabies cases by symptoms

From 32,152 records of symptoms shown before death, the number and percentage of positive cases is shown in Table 2-12.

Table 2-12. Number and percentage of positive cases in dogs submitted in each group of symptoms

Symptoms	Total submitted	Result				
		Positive	% positive	Negative	Inconclusive	Unknown
Furious	13,167	8,658	66	4,317	183	9
Dumb	10,511	2,142	20	8,239	118	12
Normal	4,598	675	15	3,830	83	10
Furious and dumb	86	61	71	24	1	0
Other	597	115	19	480	1	1
Unknown	3,193	721	23	2,426	41	5
Total	32,152	12,372	38	19,316	427	37

Animals which showed furious and dumb symptoms prior to submission had the highest risk of a positive diagnosis, with 71% rabies positive.

Positive rabies cases and other animal contact

There were 32,155 records of other animal or human contact prior to submission of suspected cases for diagnostic work. The number and percentage of positive cases in each category of contact are shown in Table 4-13.

Table. Number and percentage of positive dogs by history of contact

Other animal contact	Total submitted	Result				
		Positive	% positive	Negative	Inconclusive	Unknown
Other animal	13,082	6,911	53	5,961	197	13
Human	5,046	1,992	39	2,952	96	6
None	10,192	1,756	17	8,339	91	6
Both	1,303	1,179	90	104	14	6
Contact saliva	546	75	14	467	3	1
Unknown	1,985	461	23	1,493	26	5
Total	32,155	12,375	38	19,316	427	37

Thirty eight percent or 12,375 cases were rabies positive. Animals, that both attacked humans and other animals prior to submission had the highest percentage of positives (90%).

Positive rabies cases by method of death

There were 32,154 records of how animals died before being submitted for diagnosis. The number and percentage of positive cases by each type of animal death is shown in Table 4.14.

Table 4-14. Number and percentage of positive cases in each type of animal death

Animal death	Total submitted	Result				
		Positive	% positive	Negative	Inconclusive	Unknown
Natural death	16,308	4,453	27	11,634	209	12
Euthanasia	13,384	7,050	53	6,144	175	15
Unknown	2,446	860	35	1,533	43	10
Total	32,154	12,372	38	19,318	427	37

From 32,154 records, 38% or 12,372 records had positive results. Animals that were killed and submitted for diagnosis had 53% positive.

Human rabies deaths

Variables

From 1993 to 1999 there were 433 cases of human deaths with associated data on 10 variables. The number of records, number and percentage of valid and missing data in each variable are shown in Table 4-15.

Table 4-15. Number of records, number and percentage of valid and missing data in each variable

Variables	Total records	Valid N	Percent	Missing (n)	Missing (%)
Year	433	433	100	0	0
Province	433	433	100	0	0
District	433	433	100	0	0
Month	433	432	100	1	0.23
Human age	433	431	100	2	0.46
Human sex	433	431	100	2	0.46
Types of animal	433	429	99	4	0.92
History of animal	433	125	29	308	71
Animal vaccination history	433	63	15	370	85
Age of animal	433	68	16	365	84

There were 3 variables, Year, Province and District, which had 100% valid data (433 records). Four variables, Month, Human age, Human sex, and Types of animal had 99% valid data. The other three variables, History of animal, Animal vaccination history and Age of animal had higher percentages of missing data, which were 71%, 85% and 84% respectively.

Year (YEAR) and month (MONTH)

The number of human deaths per month in each year from 1993 to 1999 was recorded for 432 cases. The number of human deaths per year and per month from 1993 to 1999 is shown in Figure4-7 and Figure4-8.

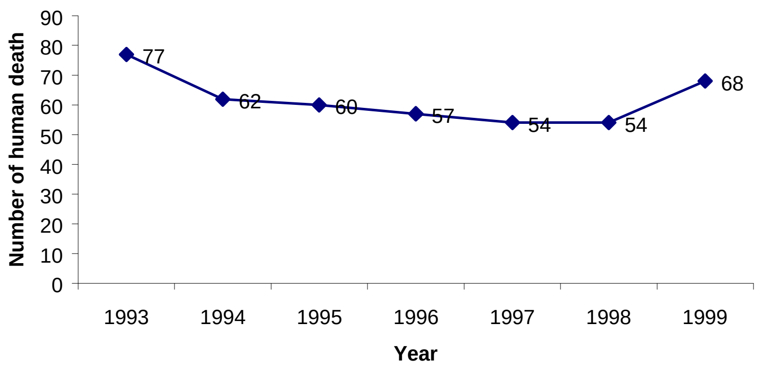


Figure 4-7. Number of human deaths from rabies in Thailand (1993 to 1999)

Numbers of human deaths per year decreased steadily between 1993 and 1998, and then increased to 68 in 1999. Data collected in 2000 (and not included in this analysis) showed human deaths falling to 48.

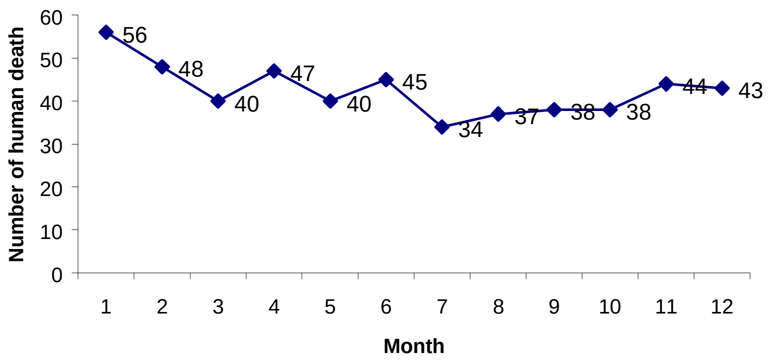


Figure 4-8. Number of human deaths from rabies in Thailand per month (1993 to 1999)

Total numbers of human deaths in each month from 1993 to 1999 showed that the number of human deaths was highest in January (56) and lowest in July (34).

Province (PROVCODE)

From 76 provinces, there were 62 provinces which had human deaths from rabies during 1993 to 1999. Number of human deaths per year per province is shown in Table 4-16.

Table 4-16. Number of human death from rabies in each province from 1993-1999

Number of deaths	Number of provinces	Province code
36	1	30
29	1	20
23	1	31
19	2	10, 60
18	2	34, 71
14	2	13, 32
10	5	64, 90, 33, 70, 4
9	4	62, 67 11, 77
8	3	41, 19, 36
6	7	24, 72, 43, 50, 48, 61, 73
5	4	45, 65, 85, 21
4	8	39, 37, 42,12, 86, 84, 27, 47
3	5	18, 74, 40, 44, 92, 76
2	5	26, 80, 16, 46, 75
1	11	93, 82, 15, 22, 35, 23, 56, 53, 49, 94, 66

Province 30 had the highest number of human deaths (36) between 1993 to 1999. Provinces 20 and 31 had more than 20 human deaths while 6 provinces more than 10. Five provinces had 10 human deaths and 32 provinces had between 2 to 9 deaths. There were 11 provinces that had one human death during 1993 to 1999.

Human age at death (HAGE)

From 433 records, there were 431 records with valid human age data. Eight categories of human age were used in this report. The number and percentage in each category are shown in Table 4-17

Table 4-17. Number and percentage of human deaths in each range of age

Range of human age (Year)	Number of deaths	Percent
0-10	144	33
>10- 20	61	14
>20-30	43	10
>30-40	50	12
>40-50	48	11
>50-60	41	9
>60	44	10
Unknown	2	0.46
Total	433	100

Age groups 1 to 10 and 10 to 20 accounted for most of the human deaths (33% and 14% respectively). All other age groups had a similar proportion of deaths (9 to 11%).

Human gender in deaths attributed to rabies (SEX)

From 433 records, there were 431 records which recorded the sex of humans diagnosed with rabies. Number and percentage of sex of male and female are shown in Table 4-18.

Table 4-18. Number of human deaths from rabies in Thailand by gender (1993 to1999)

Year	Total Human deaths	Gender		
		Male	Female	Unknown
1993	78	49	27	2
1994	62	42	20	0
1995	60	39	21	0
1996	57	37	20	0
1997	54	34	20	0
1998	54	36	18	0
1999	68	43	25	0
Total	433	280	151	2

From 1993 to 1997 average percentages of men dying of rabies (65%) was about twice as high as women (35%).

Types of animal associated with human rabies cases (TYPE)

There were 6 types of animal associated with human deaths in each year. Number and percentage of animal types are shown in Table 4-19.

Table 4-19. Numbers of animals of different species associated with human deaths per year

Year	Total human deaths	Types of animal					
		Dog	Cat	Cow	Monkey	Squirrel	Unknown
1993	77	73	1	0	0	0	3
1994	62	55	0	0	0	0	7
1995	60	53	2	1	0	0	4
1996	56	51	1	0	0	1	3
1997	53	45	1	0	0	0	7
1998	53	45	1	0	1	0	6
1999	68	61	3	0	0	0	4
Total	429	383	9	1	1	1	34

Percentages were estimated using a denominator of 395, which represents the total number of animals of cases with known exposure to specific animal species. Dogs were likely to be most associated with human rabies deaths (97%) and cats were the second most common types of animal (2%). Monkeys and squirrels had similar percentage of association (about 0.25%).

History of animal ownership for animals associated with human deaths (HISTORY)

From 433 records, only 125 records of history of animal ownership were available for analysis. The number and percentage of history of ownership animals associated with human deaths in each year is shown in Table 4-20.

Table 4-20. Number of animals by ownership category for animals associated with human deaths in each year

Year	Total	History of animals		
		Owned	Non-owned	Unknown
1993	2	2	0	0
1994	1	0	1	0
1995	5	1	0	4
1996	5	0	5	0
1997	21	8	13	0
1998	23	10	13	0
1999	68	37	25	6
Total	125	58	57	10

Percentages were estimated using a denominator of 115, which represent the total number of animals of known ownership associated with human cases. Both owned and non-owned animals were equally associated with human rabies deaths (50%).

Animal vaccination history for animals associated with human deaths (VACC)

Rabies vaccination history of animals associated with human death, has been recorded from 1999. The number and percentage of animals in each category of vaccination history (data from 1999 only) are shown in Table 4-21.

Table 4-21. Number of animals by category of vaccination history for animals associated with human deaths in 1999

Animal vaccination history	Total records	Percent
None	47	75
>1year	2	3
Unknown	14	22
Total	63	100

From 63 records of vaccination history in 1999, the data showed that about 75% of animals associated with human death were not vaccinated, 22.22% had unknown vaccination history and 3.17% were vaccinated more than one year prior to submission.

Age of animal for animals associated with human deaths (AGE)

Age of animals associated with human death was only recorded in 1999 are shown in Table 4-22.

Table 4-22. Number of animals by age category for animals associated with human deaths in 1999

Age of animal	Total records	Percent
<3 months	6	9
3-6 months	7	10
>6-12 months	6	9
>12 month	9	13
Unknown	40	59
Total	68	100

From 68 records of five categories of age of animals associated with human deaths in 1999 (almost all the records were dogs), the data showed that animals over 12 months were associated with more human deaths than other age group, though this is not an indicator of risk due to the absence of population information.

Human population

Total human population

There are 76 provinces and 998 districts in Thailand. Human population data for the entire country from 1993 to 1999 are shown in Table 4-23 and Figure .

Table 4-23. Number of human population in total and by gender in Thailand from 1993 to 1999

Year	Male	Female	Total
1993	29,205,086	29,130,986	58,336,072
1994	29,552,978	29,542,441	59,095,419
1995	29,678,600	29,781,782	59,460,382
1996	29,973,059	30,143,123	60,116,182
1997	30,295,797	30,520,430	60,816,227
1998	30,591,602	30,874,576	61,466,178
1999	30,650,172	31,011,529	61,661,701

The population in Thailand has been increasing by 0.3% every year. There were about 58 million people in 1993 and 61 million people in 1999.

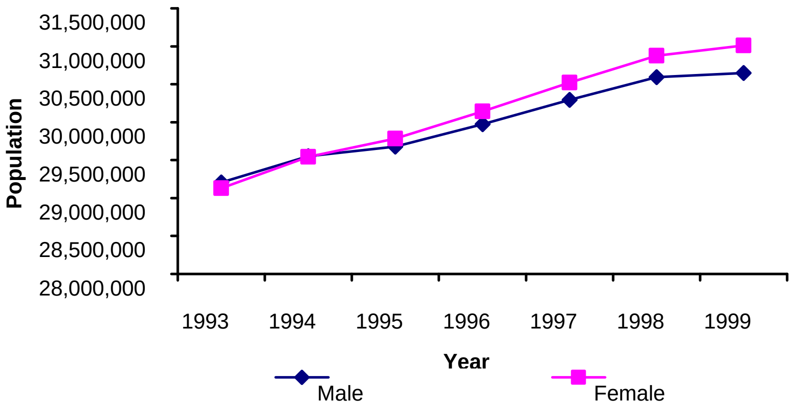


Figure 4-9. Male and female population in Thailand

Numbers of males and females were similar in 1993 but numbers of females became higher than males every year since then. In 1999 the number of females was about one million higher than males.

Population data are recorded for each province in Thailand. Number of provinces in each range of human population is shown in Table 4-24.

Table 4-24. Number of provinces in each range of human population from 1993 to 1999

Population	Number of province
<500000	28
>=500000-1000000	30
>= 1000000	8

There were eight provinces that had populations of more than one million people, 30 provinces had between 500,000 to 1,000,000 and 28 provinces had less than 500,000. Province 10 had the highest population with over five million people while province 85 had the lowest number of population with 158,185 people.

Population by age

Numbers of population in 7 age categories by gender from 1996 data are shown in Table 4-25.

Table 4-25. Numbers of people in seven age categories from 1996 census data

Category	Age range	Male	Percent	Female	Percent	Total	Percent
1	<1-10	5,160,734	51	4,888,595	49	10,049,329	18
2	>10-20	5,331,120	51	5,133,168	49	10,464,288	18
3	>20-30	5,748,783	50	5,702,437	50	11,451,220	20
4	>30-40	4,942,752	50	5,030,058	50	9,972,810	18
5	>40-50	3,157,512	49	3,294,823	51	6,452,335	11
6	>50-60	1,956,550	49	2,071,826	51	4,028,376	7
7	>60	1,953,751	45	2,363,458	55	4,317,209	8
Total		28,251,202	50	28,484,365	50	56,735,567	100

People aged between 20 to 30 years had the highest number (11,451,220) and percentage (20.24%) while people aged between 50 to 60 had the lowest number (4,028,376) and lowest percentage (7.12%).

There were slightly more men than women in age groups up to 30 years. Females become more numerous than males amongst those age categories exceeding 30 years.

Control activity data in 26 provinces

Descriptive statistics were produced for control activity per district per month in 10 provinces from 1993-1999. Details of variables in the data set are shown in Table 4-26.

Table 4-26. Variables in the data set of rabies control activity

Variable	Ctegory	Type of category	Animal
Population	7	Owned male, owned female, total owned, non owned male non owned female, non owned total, total	Dog, cat
Activity			
Vaccination	5	Free, Charged, done by DLD, done by other organistions, Total	Dog, cat, other animals
Hormone injection	5	Free, Charged, done by DLD, done by other organistions, Total	Dog, cat
Castration	5	Free, Charged, done by DLD, done by other organistions, Total	Dog, cat
Spay	5	Free, Charged, done by DLD, done by other organistions, Total	Dog, cat
Euthanasia	3	Kill by DLD, by other organisations, total	Dog
Public Relations	8	Village Amplifier, Exhibition, Newspaper, Radio broadcast, TV broardcast, Other PR(published media, Villager training and Village volunteer training	

There were two groups of data in the control activity dataset, animal population and control activity. Two kinds of animal population, dog and cat, were each recorded in seven categories. For control activity four variables, were recorded in five categories, one in three categories and one in eight categories.

Descriptive analysis of dog population is shown in Table 4-27.

Table 4-27. Descriptive statistics of dog population in 10 provinces (reported as a weighted per district average)

Variable	Total Dog population (DTOTAL)						
	Overall descriptive by year						
	1993	1994	1995	1996	1997	1998	1999
Valid records (n)	23	36	63	73	107	91	73
Missing records (n)	0	0	0	0	0	0	0
Mean	8600.7	7626	9319	8467	9276	9323	9186
Median	7941	7003	8801	9239	8868	8868	9246
Min	7941	6506	6688	4516	4500	5351	4846
Max	9320	9371	11592	12082	14940	14530	14711
SD	704.2	1267.8	1870.0	2561.8	3226.4	3146.7	2919.6
Skewness	0.1	0.7	0.0	-0.2	0.2	0.3	0.3
Mode	7941	6506	11592	11089	14940	12702	10217
Mode count	12	12	12	12	12	12	9

Dog population was assessed once each year and therefore is not presented on a monthly level. Highest median of dog population during 1993 to 1999 was 9,246 per district in 1999.

Vaccination

Descriptive analysis of dog vaccination per district by month is shown in Table 4-28 and Figure 4-10.

Table 4-28. Descriptive analysis of Total Dog Vaccinated (TOTALDV) per district per month in 10 provinces from 1993-1999

Summary statistics	Total Dog Vaccinated (TOTALDV)											
	Overall Descriptive Analysis by Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Valid records (n)	42	40	41	39	40	40	39	39	38	36	37	36
Missing records (n)	0	0	0	0	0	0	0	0	0	0	0	0
Mean	340.3	484	1535	904	614	290	196	328	235	148	174	180
Median	210	425	1155	659	360	179	175	153	147	86	135	150
Min	46	81	53	141	34	40	27	23	25	7	12	30
Max	3667	1518	5208	2682	1816	1163	784	1760	1470	690	908	513
SD	582.0	368.2	1349.3	725.9	535.7	272.1	179.2	409.3	270.8	153.5	179.7	136.6
Skewness	4.9	1.0	1.3	1.1	0.9	1.6	1.8	2.0	3.1	1.9	2.5	1.0
Mode	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	142	#N/A
Mode count	0	0	0	0	0	0	0	0	0	0	2	0

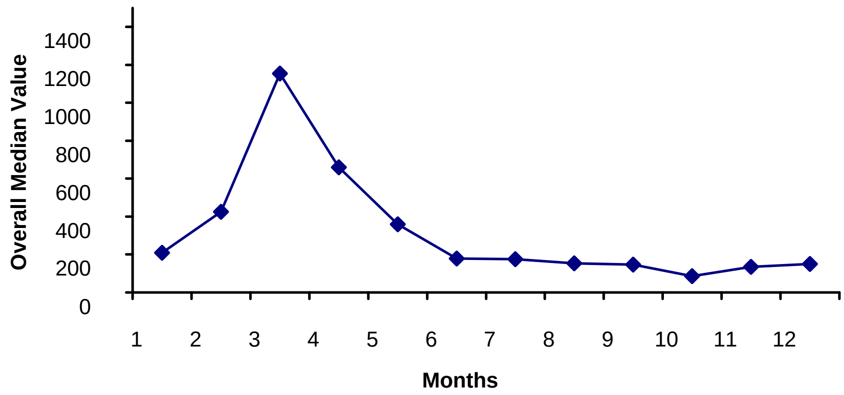


Figure 4-10. Median of overall dog vaccinated per district per month in 10 provinces from 1993 to 1999

Data are skewed and therefore the median is used as the summary measure. The highest median number of dogs vaccinated was in March (1155) with the values in March and April being higher than other months. November had the lowest number of dogs vaccinated (86).

Hormonal injection

Descriptive statistics of the counts of Total Dog Hormone injected (TOTALDH**)** per district by month is shown in Table 4-34 and Figure 4-11.

Table 4-39. Descriptive analysis of Total Dog Hormone injected (TOTALDH) per district per month in 10 provinces from 1993-1999

Summary statistics	Total Dog Hormone injected (TOTALDH)											
	Overall Descriptive Analysis by Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Valid records (n)	42	40	41	39	40	40	39	39	38	36	37	36
Missing records (n)	1	0	0	0	0	0	0	0	0	1	0	1
Mean	101.0	75	229	143	105	68	54	64	58	32	35	43
Median	36	58	138	93	73	42	30	32	36	23	29	32
Min	0	1	4	2	2	2	2	2	2	0	2	0
Max	1305	233	713	898	438	293	301	435	396	146	150	184
SD	230.7	63.8	199.3	166.5	110.2	75.0	64.9	88.0	71.9	35.9	35.1	42.1
Skewness	4.4	0.9	0.8	2.7	1.5	1.6	2.0	2.7	3.2	1.8	1.8	1.8
Mode	#N/A	#N/A	#N/A	204	30	#N/A	#N/A	2	#N/A	123	33	#N/A
Mode count	0	0	0	2	2	0	0	2	0	2	2	0

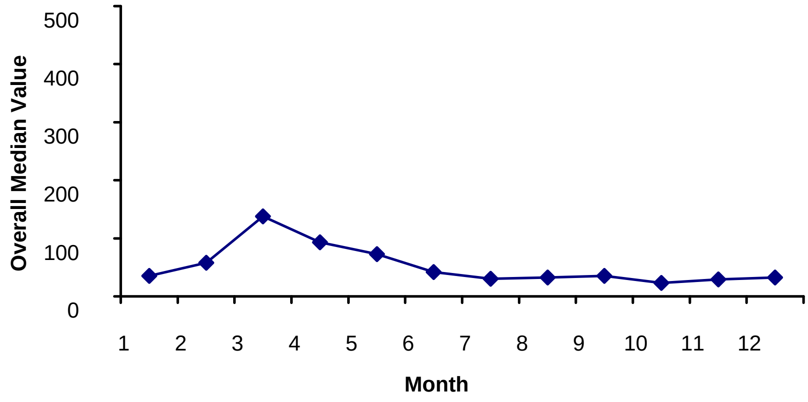


Figure 4-11. Median of overall total dog hormone injected per month in 10 provinces

The highest median number of dogs injected with contraceptive hormones was in March (138) and April (93), with values from these months being higher than other months. October had the lowest number dogs of injected by hormone (23) each year.

Castration

Descriptive statistics of the counts of Total Dog Castrated (TOTALDC) per district by month are shown in Table4-30 and Figure4-12.

Table 4-30. Descriptive analysis of Total Dog Castrated (TOTALDC) per district by month in 10 provinces from 1993-1999

Summary statistics	Total Dog Castrated (TOTALDC) Overall Descriptive Analysis by Month											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Valid records (n)	42	40	41	39	40	40	39	39	38	36	37	36
Missing records (n)	0	0	0	0	0	2	0	2	1	1	0	1
Mean	13.5	16	26	19	17	14	13	26	17	15	13	22
Median	10	13	21	14	16	13	11	13	10	8	10	13
Min	0	0	0	0	0	0	1	0	0	0	0	0
Max	89	49	94	59	55	55	47	330	99	62	64	261
SD	15.1	12.2	21.5	15.6	14.2	13.1	10.8	52.6	19.2	16.4	13.5	43.7
Skewness	3.3	0.7	1.0	1.0	0.9	1.2	1.3	5.4	2.4	1.2	1.8	5.0
Mode	#N/A	1	29	0	#N/A	15	#N/A	#N/A	#N/A	2	#N/A	6
Mode count	0	2	2	2	0	2	0	0	0	2	0	2

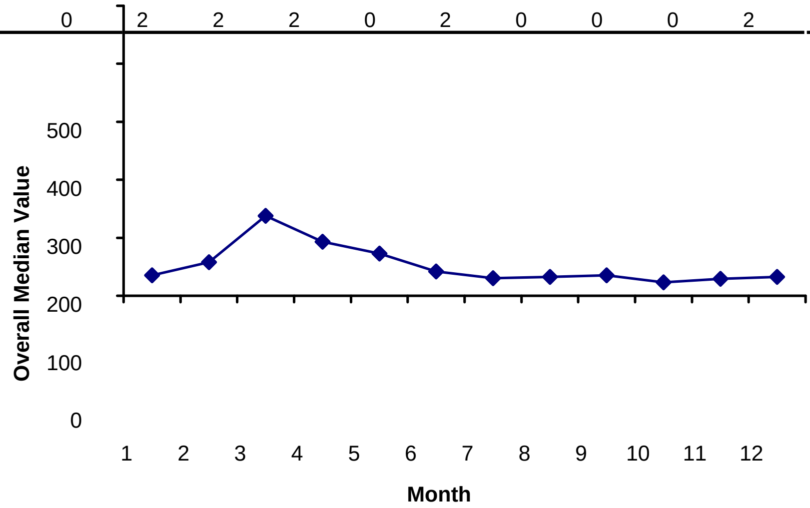


Figure 4-12. Median number of dogs castrated per month in 10 provinces

The maximum number of dogs castrated was in August (330).

Spey

Descriptive statistics of the counts of Total Dog Speyed (TOTALDS) per district by month is shown in
Table 4-31 and Figure 4-13.

Table 4-31. Descriptive analysis of Total Dog Speyed (TOTALDS) per district per month in 10 provinces from 1993-1999

Summary statistics	Total Dog Spayed (TOTALDS) Overall Descriptive Analysis by Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Valid records (n)	42	40	41	39	40	40	39	39	38	36	37	36
Missing records (n)	4	3	5	4	2	3	3	20	2	2	2	3
Mean	5.5	7	10	8	6	6	7	8	9	6	6	8
Median	4	4	9	5	4	4	5	5	6	4	4	4
Min	0	0	0	0	0	0	0	0	0	0	0	0
Max	22	30	37	41	31	40	34	57	57	41	27	58
SD	5.2	6.6	9.9	8.8	6.7	7.3	6.7	11.2	11.3	7.7	6.2	10.9
Skewness	1.4	1.5	1.0	1.8	1.9	2.9	2.1	3.2	2.9	3.0	2.1	3.4
Mode	0	0	0	0	0	0	0	0	0	2	4	0
Mode count	4	3	5	4	2	3	3	3	2	2	2	3

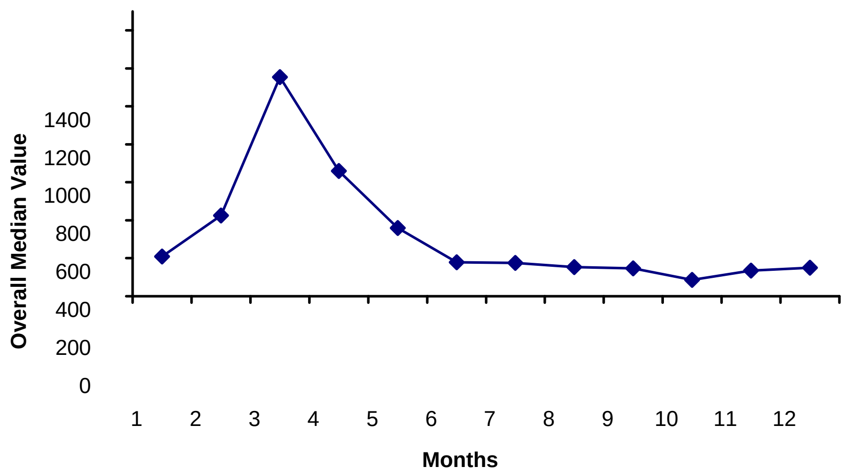


Figure 4-13. Median number of dog speyed per month in 10 provinces

The highest median number of dogs speyed was in March (9) and the maximum number of dogs speyed was 58 in December.

Dogs killed or euthanased

Descriptive statistics of the counts of Total Dog Killed or Euthanased (TOTALDK) per district per month in 10 provinces is shown in Table 4-32.

Table 4-32. Descriptive analysis of Total Dog Killed (TOTALDK) per district per month in 10 **provinces from 1993-1999**

Summary statistics	Total Dog Killed (TOTALDK) Overall Descriptive Analysis by Month											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Valid records (n)	31	31	30	29	29	31	31	31	30	26	27	26
Missing records (n)	19	19	20	20	18	20	18	113	16	15	15	13
Mean	10.9	12	11	6	8	10	10	11	15	13	16	11
Median	0	0	0	0	0	0	0	0	0	0	0	0
Min	0	0	0	0	0	0	0	0	0	0	0	0
Max	62	91	67	41	55	81	72	56	80	58	75	52
SD	20.0	22.5	19.3	12.2	15.4	21.2	19.0	19.4	23.7	21.1	23.6	17.6
Skewness	1.7	2.1	1.7	1.8	2.0	2.3	1.9	1.6	1.3	1.2	1.3	1.3
Mode	0	0	0	0	0	0	0	0	0	0	0	0
Mode count	19	19	20	20	18	20	18	17	16	15	15	13

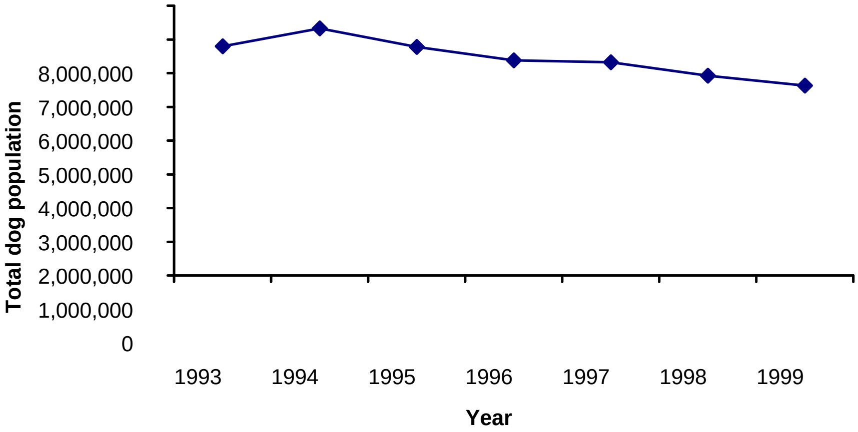
The mean number of dogs euthanased per month was about 10 dogs per month and the maximum number of dogs killed in one month was 91 in February.

Control activity in 76 provinces

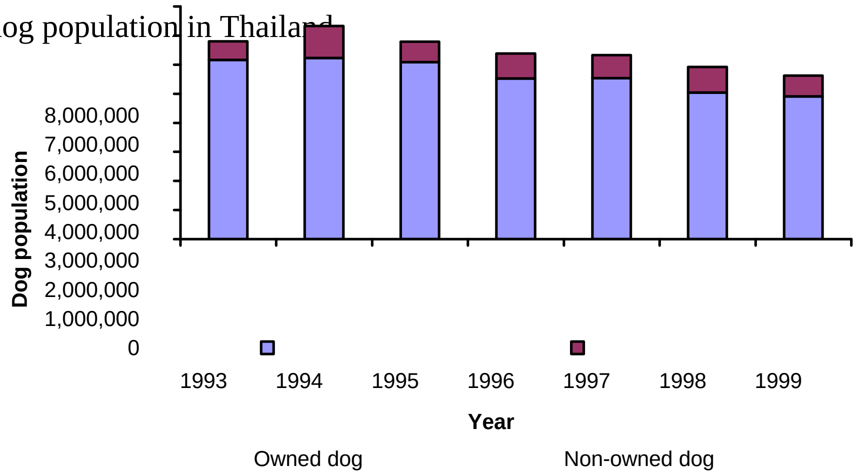
There were 529 records of yearly control activity in 76 provinces from 1993 to 1999. Three provinces did not exist in 1993. Median number of dog population and five activities for each province were as follows:

Total dog population

The records of owned male and female dogs and non-owned male and female dogs were not completely recorded. Total dog population per year and number of owned and non-owned dogs during 1993 to 1999 are shown in Figure 4-14.



A) Total dog population in Thailand



B) Number of owned and non-owned dogs

Figure 4-14. Total dog population per year and number of owned and non-owned dogs during 1993 to 1999

Total dog population has been decreasing yearly from 7,330,660 in 1994 to 5,626,912 in 1999.

Total dog population in each province varied from year to year. A frequency histogram of the median province total dog population over the seven year study period is shown in Figure 4-15.

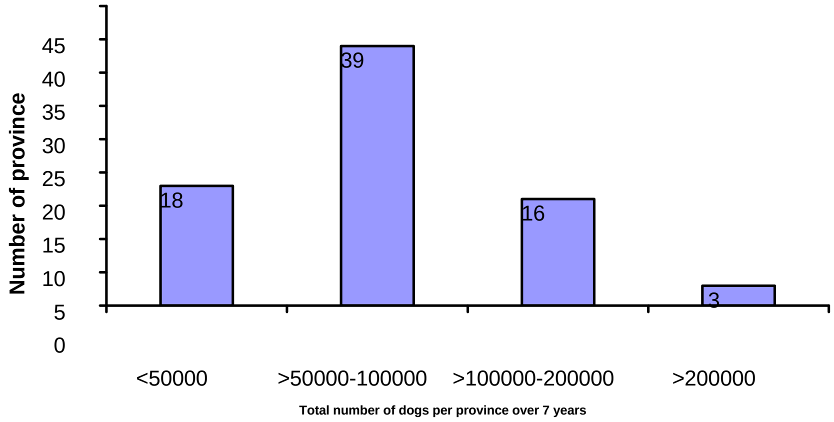


Figure 4-15. Frequency histogram of median of dog population in each province in Thailand during the period from 1993 to 1999

There were three provinces that had an median total dog population greater than 200,000 and 16 provinces had a median dog populations between 100,000 to 200,000. Thirty nine provinces had median total dog populations between 50,000 to 100,000 and 18 provinces had median total dog populations lower than 50,000. Province 10 had the highest median dog population (492,159). Province 30 had the second highest median dog population (261,530) and province 91 had the lowest median dog population (6006).

Vaccination

The number of dogs vaccinated per year in each province was calculated as a percent of the dog population in that province and categorised into four categories. Percentages of dogs vaccinated for the whole country in each year and a frequency histogram of numbers of provinces in each of four categories of vaccination level are shown in Figure 4-16 and Figure 4-17.

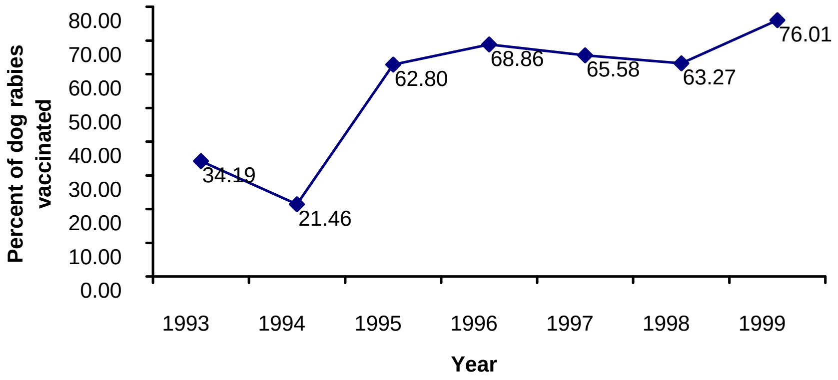


Figure 4-16. Percentage of total dogs vaccinated for the whole country from 1993 to 1999

The percentage of dogs vaccinated was about 34% in 1993 and fell to 21% in 1994, then rose up to 63% in 1995. From 1995 percentage of dogs vaccinated has been over 60% and reached 76% in 1999.

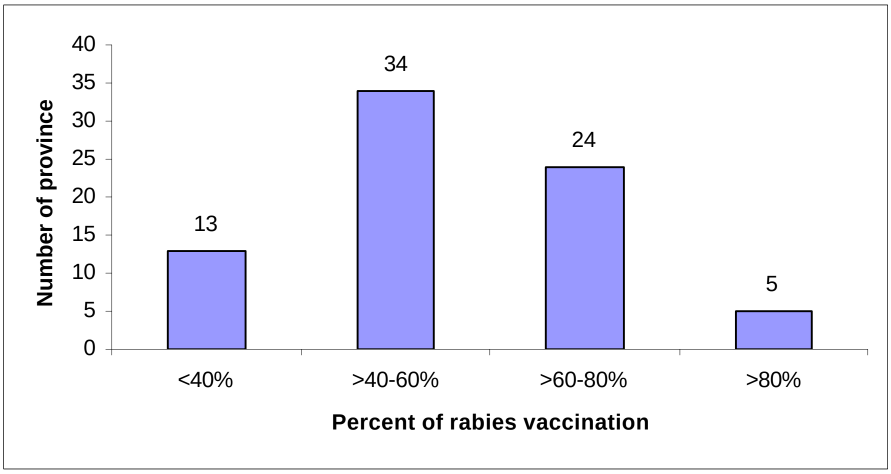


Figure 4-17. Frequency histogram of provinces for each range of total dog vaccinated from 1993 to 1999

There were five provinces that had more than 80% of dogs vaccinated. Twenty four provinces had more than 60% dogs vaccinated and 47 provinces had less than 60% dogs vaccinated. Province 10 had the highest median number of dogs vaccinated (340,237) which was about 70% of the dog population. Province 91 had the lowest median number of dogs vaccinated (3,195) which was about 53% of the dog population.

Province 75 had the highest percentage of dogs vaccinated (99%) and province 93 had the lowest percentage of dog vaccinated (23%).

Hormonal injection

The number of dogs injected by hormone per province per year divided by the annual province dog population estimate, provided an estimate of the proportion of dogs treated with hormone in each province in each year. The proportion of all dogs treated with hormone by year, is shown in Figure 4-18. A frequency histogram of province treatment proportion is shown in Figure 4-19.

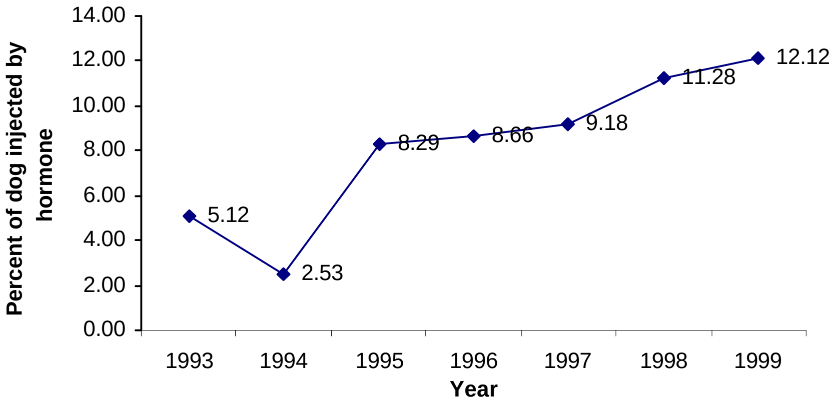


Figure 4-18. Percentage of dogs injected by hormone for the whole country in each year

The percentage of dogs injected with hormone was 5% in 1993 and fell to 2% in 1994. Since 1995 the percentage of dogs treated with hormone has increased, reaching 12% in 1999.

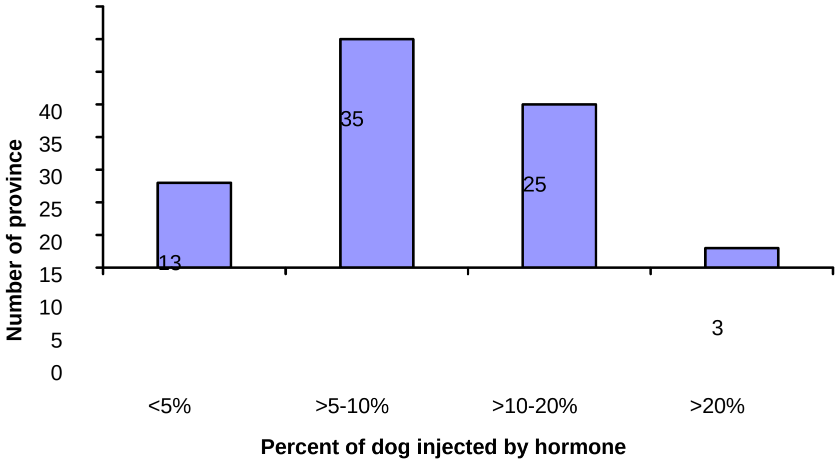


Figure 4-19. Frequency histogram of percentage of dogs injected by hormone from 1993 to 1999 in each province

There were three provinces that treated greater than 20% of dogs with hormone. Twenty five provinces treated 10 to 20% and 13 provinces treated less than 5%.

Province 31 had the highest number of dogs injected by hormone (n=22,413) but this represented only 12% of the dog population. Province 81 had the lowest number of dogs injected by hormone (n=1,389) which represented 4% of dog population.

Castration

The number of dogs castrated per province per year divided by the annual province dog population estimate, provided an estimate of the proportion of dogs castrated in each province in each year.

Percentage of dogs castrated for the whole country in each year and a frequency histogram are shown in Figure 4-20 and Figure 4-21.

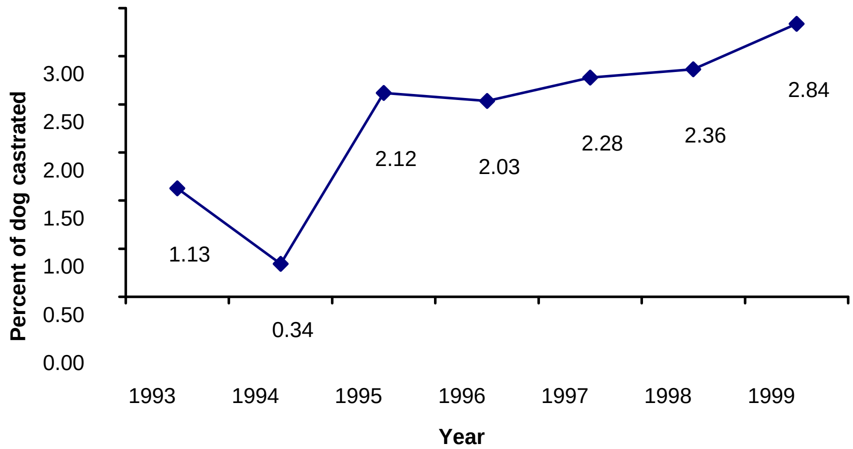


Figure 4-20. Percentage of dogs castrated from 1993 to 1999

The percentage of dogs castrated was 1% in 1993 and dropped to 0.34% in 1994. Since 1995 the proportion of dogs castrated has increased steadily to 2.4% in 1998 and up to 2.8% in 1999.

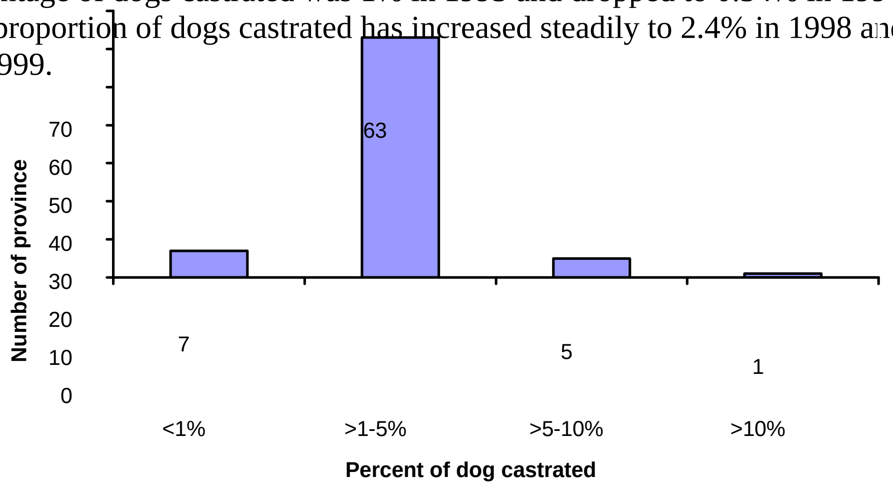


Figure 4-21. Frequency histogram of percentage of dog castrated from 1993 to 1999 in each province

There was only one province that achieved a castration rate of greater than 10%; five provinces castrated between 5 and 10% of dogs, 63 provinces castrated between 1 and 5% and seven provinces castrated less than 1% of dogs. Province 43 had the highest number of dogs castrated (n=3,735) which represented 4% of the total dog population. Province 93 had the lowest number of dogs castrated (n=503) which represented 0.73% of the total dog population.

Province 91 had the highest percentage (15%) of dogs castrated and province 10 had the lowest (0.27%) of dogs castrated.

Speys

The number of dogs speyed per province per year divided by the annual province dog population estimate, provided an estimate of the proportion of dogs speyed in each province in each year. The percentage of dogs speyed for the whole country in each year and a frequency histogram are shown in Figure 4-22 and Figure 4-23.

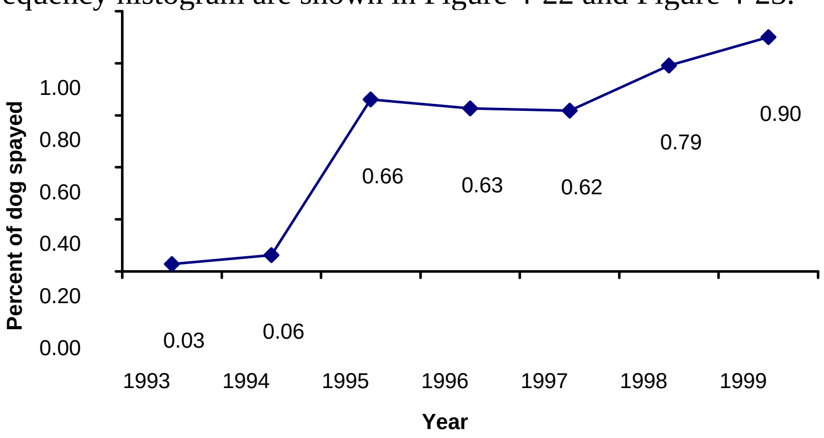


Figure 4-22. Percentage of dogs speyed from 1993 to 1999

The percentage of dogs speyed was 0.03% in 1993 and rose to 0.34% in 1994, to 0.66% in 1995 and 0.9% in 1999.

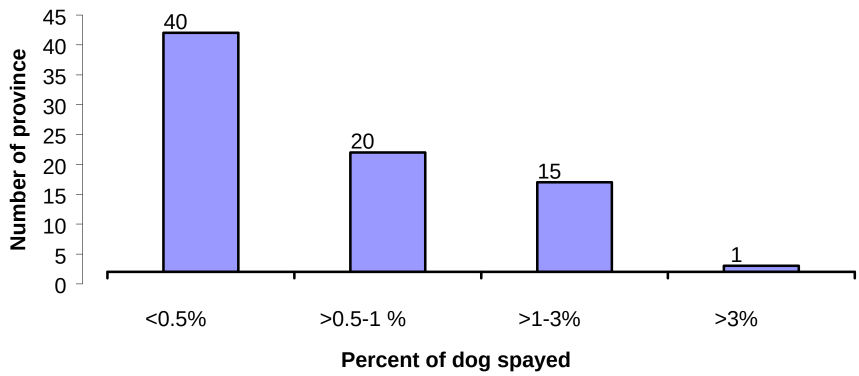


Figure 4-23. Frequency histogram of percentage of dogs speyed from 1993 to 1999 in each province

Only one province speyed more than 3% of the dog population. Fifteen provinces speyed between 1 to 3% of dogs, 20 provinces speyed between 0.5 to 1% of dogs and 40 provinces speyed less than 0.5%.

Province 80 had the highest number of dogs spayed (n=2,776) which was 3% of the total dog population. Province 58 had the lowest number of dog spayed (n=46) which was 0.1% of the dog population.

Euthanasia

The number of dogs euthanased per province per year divided by the annual province dog population estimate, provided an estimate of the proportion of dogs euthanased in each province in each year. The percentage of dogs killed for the whole country in each year and a frequency histogram are shown in Figure 4-24 and Figure 4-25.

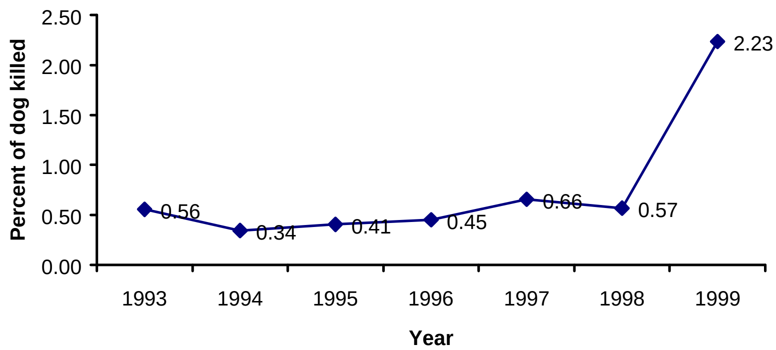


Figure 4-24. Percentage of dogs killed from 1993 to 1999

The percentage of dogs killed was less than 1% from 1993 until 1998 (0.56%–0.57%) then increased to 2.3% in 1999.

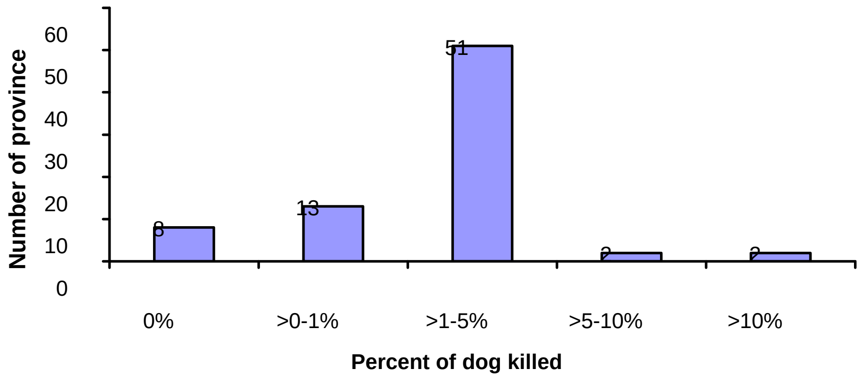


Figure 4-25. Frequency histogram of percentage of total dogs killed from 1993 to 1999

There were two provinces that euthanased greater than 10% of the dog population per year, two provinces euthanased between 5 and 10% and 13 provinces euthanased less than 1%. Eight provinces report no euthanasias.

Province 43 had the highest number of dogs euthanased (n=3,735) which was 4% of the total dog population. Province 93 had the lowest number of dogs euthanased (n=503) which was 0.7% of dogs killed.

Public Relations Activity

Public relations consisted of four types of activities: audio media, visual media, audio-visual media and education and training. Education activities were divided into eight types. The activities were: (1) village amplifier, (2) newspaper, (3) exhibition, (4) radio broadcasts, (5) other public relations (all kinds of published documents such as handbooks, sticker, folders, posters etc), (6) television broadcasts, (7) villager training and (8) village volunteer training. These activities were recorded in 1997 only. Records of each activity are shown in

Table 4-33.

Table 4-33. Records of total Public Relations activity in 1997

Types of Public Relations	Number recorded
Village amplifier	51,506
Newspaper	4,510
Exhibition	924
Radio broadcast	1,577
Other PR	366,995
TV Broadcast	521
Villager trained	189,260
Village volunteer trained	28,920

Of the eight of public relations activities, published documents were the most numerous. Villager trained and village amplifier also had high numbers recorded. Other media, radio, TV and newspaper activities were recorded with frequency. Counts of the number of times of each activity was recorded in a province in 1997 are shown in Table 4-33.

Table 4-34 Frequency of province in each type of PR activity in 1997.

Count of activity	Number of province
Audio media	
Village amplifier	
0	4
>0-100	18
>100-1,000	35
>1,000	19
Radio	
0	16
1-10	26
>10-100	33
>100	1
Visual media	
Exhibition	
0	19
>1-10	39
>10-100	16
>100-200	2
Newspaper	
0	40
>1-10	27
>10-1,000	7
>1,000	1
Other PR	
0	18
>1-1,000	6
>1,000-10,000	50
>100,000	2
Audio-Visual media	
TV broadcast	
0	52
1-10	22
>10-100	1
>100	1
Education and training	
Villager trained	
0	16
1-1,000	30
>1,000-10,000	27
>10,000	3
Village volunteer trained	
0	14
1-500	44
>500-1,000	14
>1,000	4

Disease measurement

Human rabies cases

The cumulative incidence (CI) of human rabies per year from 1993-1999 is shown in Table 4-35.

Table 4-35. Human deaths from rabies per 100,000 population per year Cumulative Incidence)

YEAR	Human death from rabies per 100000 population (CI)		
	Total	Male	Female
1993	0.13	0.17	0.09
1994	0.10	0.14	0.07
1995	0.10	0.13	0.07
1996	0.09	0.12	0.07
1997	0.09	0.11	0.07
1998	0.09	0.12	0.06
1999	0.11	0.14	0.08

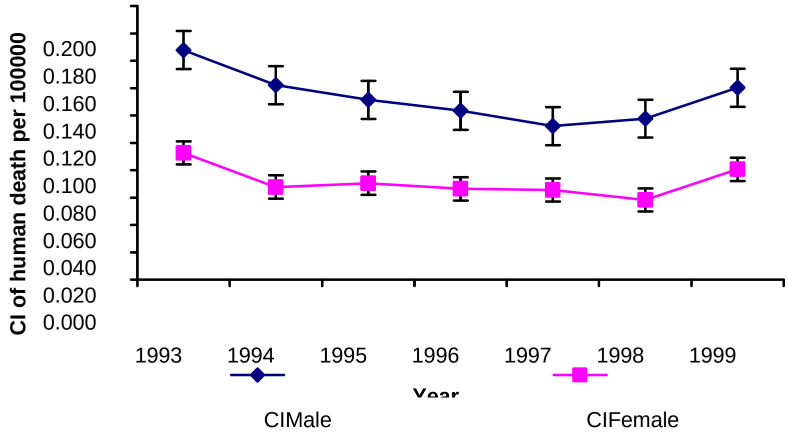


Figure 4-26. Human deaths from rabies per 100,000 population by gender per year from 1993 to 1999 with 95% confidence intervals added

The cumulative incidence of human deaths due to rabies was about twice as high in males than females in every year.

The cumulative incidence of human deaths per 100000 population per year for 1993 to 1999 is shown for each geographic part of Thailand in Figure 4-27.

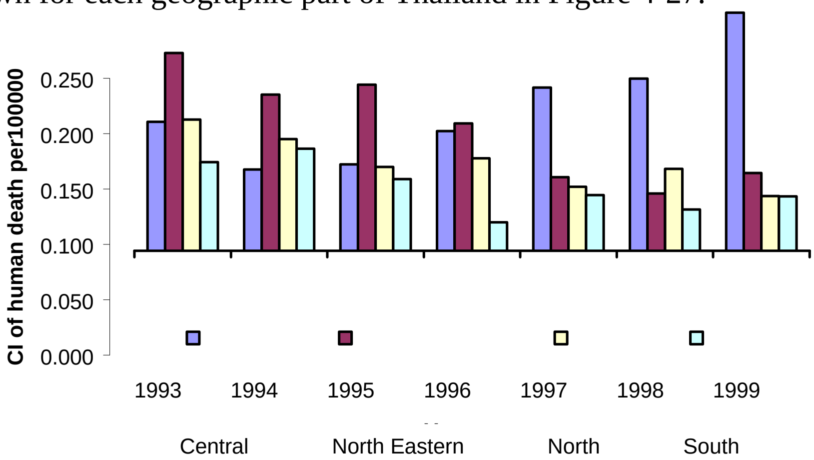


Figure 4-27. CI of human deaths per 100000 population per year for each geographic part of Thailand from 1993 to 1999

In 1993 the cumulative incidence of human deaths due to rabies was highest in the North-eastern and lowest in the Southern region of Thailand (0.17 and 0.08 per 100,000 population, respectively). In 1999 the cumulative incidence of human deaths due to rabies was highest in the Central region and lowest in the Northern and the Southern region (0.21 and 0.049 per 100,000 population, respectively).

The cumulative incidence of human rabies positive in each season from 1993 to 1999 is shown in Figure 4-28.

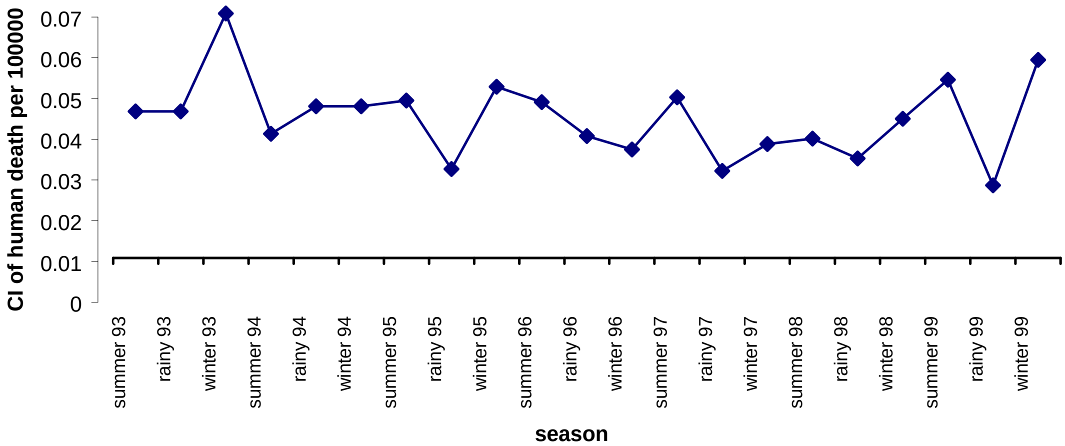


Figure 4-28. CI of human rabies positive in each season from 1993-1999

From 1993 to 1999, cumulative incidence of human deaths per 100,000 per season due to rabies was highest in winter (November to February) and lowest in the rainy season (July to October).

Bivariate analyses

Chi-squared analyses of the association between gender and rabies death in each year was performed with females used as the reference group in each year. Relative risks of rabies incidence for males versus females in each year are shown in Table 4-36.

Table 4-36. Association between gender and rabies death per year from 1993 to 1999 (female used as reference in each year)

Year	Relative risk Male vs females	95%CI Lower	Upper
1993	1.81	1.14	2.88
1994	2.1	1.25	3.53
1995	1.86	1.11	3.14
1996	1.84	1.08	3.4
1997	1.71	0.99	2.96
1998	2.02	1.16	3.51
1999	1.74	1.04	2.83
1993-1999	1.86	1.53	2.26

The results showed that males were about twice as likely to get rabies than females.

A Mantel-Haenszel chi-squared analysis of the association between age group and rabies deaths was performed, with gender as the stratification variable. All analyses used the 20 to 30 year age group as the reference. If the effect of strata (gender) was not significant a pooled RR was produced for that age group. Results of analyses are shown in Table 4-37.

Table 4-37. The effect of age group on risk of rabies death in human stratified by gender

Age category	MH Pooled RR	Lower	Upper	Strata different
<1-10 yrs	3.762	2.676	5.288	no
>10-20 yrs	1.542	1.043	2.278	no
>30-40 yrs	1.34	0.891	2.015	no
>40-50 yrs	2.001	1.326	3.02	no
>50-60 yrs	2.745	1.79	4.212	no
>60 yrs	2.8	1.832	4.279	no

Compared with 20 to 30 year olds, 1 to 10 year olds were 3.76 times (95%CI 2.676-5.288) more likely to get rabies. Compared with 20 to 30 year olds people over 50 years of age were 2.7 times (95%CI 1.79-4.21) more likely to get rabies.

A Mantel-Haenszel chi-squared analysis was performed on the association between year and rabies death while stratified on gender. All analyses used 1999 as reference. If the effect of strata (gender) was not significant a pooled RR was produced for that year. Results of analyses are shown in Table 4-38

Table 4-38. The effect of year on risk of rabies death in human stratified by gender

Year	MH Pooled			Strata different
	RR	Lower	Upper	
1993	1.179	0.85	1.635	no
1994	0.95	0.673	1.34	no
1995	0.914	0.646	1.293	no
1996	0.859	0.604	1.221	no
1997	0.805	0.563	1.15	no
1998	0.796	0.557	1.138	no

There was no effect of year on the risk of death due to rabies

A Mantel-Haenszel chi-squared analysis was performed to assess the association between region of Thailand and rabies death while stratified on gender. All analyses used the Northeast as the reference. If the effect of strata (gender) was not significant a pooled RR was produced for that region. Results of analyses are shown in Table 4-39.

Table 4-39. The effect of region on risk of rabies death in human stratified by gender

Part	MH Pooled			Strata different
	RR	Lower	Upper	
Central	1.185	0.956	1.468	no
North	0.722	0.542	0.962	no
South	0.52	0.354	0.764	no

Compared with the North-eastern part of Thailand, people in the South were 0.5 times (95% CI, 0.34-0.76) as likely to get rabies while people in the North were 0.72 times (95%CI, 0.54-0.96) as likely to get rabies. Both these effects were significant at the 95% level. These results suggested that the risk of rabies is higher in the Northeast and Central parts of Thailand, compared with the North and the South.

Animal

A chi-squared analysis was performed to investigate the association between the incidence of rabies in dogs and year in this analysis. 1993 was used as the reference year. The results are shown in Table 4-40.

Table 4-40. Number of dog rabies positive per 100,000 dog population per year from 1993 to 1999

YEAR	Dog CI per 100000	Relative risk	95%CI	
			Lower	Upper
1993	51.69	1		
1994	49.25	0.95	0.91	1
1995	40.83	0.79	0.75	0.83
1996	27.74	0.54	0.51	0.57
1997	20.27	0.39	0.37	0.42
1998	20.18	0.42	0.39	0.45
1999	20.54	0.4	0.37	0.42

Rabies incidence in dogs was highest in 1993 (51.69) and lowest in 1998. The annual cumulative incidence of rabies in dogs has fallen considerably since 1993 with the risk in 1999 being 0.4 times the risk in 1993.

A chi-squared analysis was performed to investigate the association between dog cumulative incidence of rabies and region of Thailand. The Central part was used as the reference part. The results are shown in Table 4-41

Table 4-41 Relative Risk for risk of rabies by region of Thailand from 1993 to1999

Year	Relative risk	95%CI	
		Lower	Upper
NE	0.91	0.95	0.88
N	0.55	0.57	0.52
S	1.34	1.27	1.41

Compared to the central part, rabies in dogs in the South were 1.34 times (95%CI 1.27-1.41) the risk of being diagnosed rabies while the risk of being diagnosed of rabies in dogs in the North was 0.55 times that observed in the Central part.

The cumulative incidence values of dog rabies positive per 100,000 dog population per month with 95% confidence intervals, using data aggregated by month over the seven year study period from 1993 to 1999, are shown in Figure4-29.

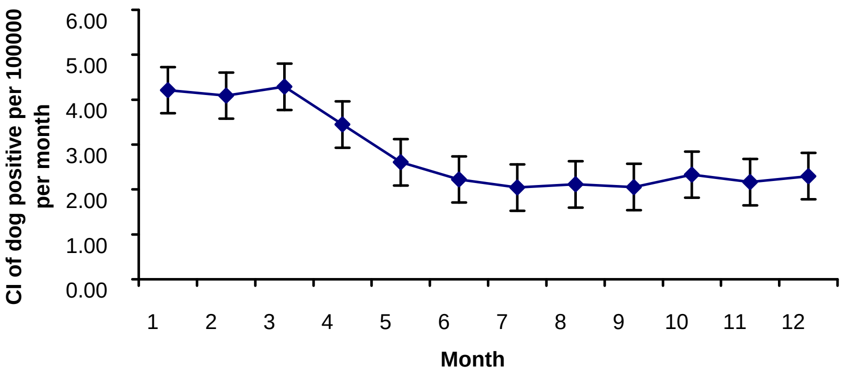


Figure 4-29. Cumulative incidence of dogs rabies per 100,000 by month

From 1993 to 1999 the highest incidence of rabies was in March and the lowest in July.

A pairwise scatterplot of the proportion of dogs vaccinated in each province against rabies versus human rabies cumulative incidence is shown in Figure 4-30. A pairwise scatterplot of the proportion of dogs vaccinated in each province against rabies versus canine rabies cumulative incidence is shown in Figure 4-31.

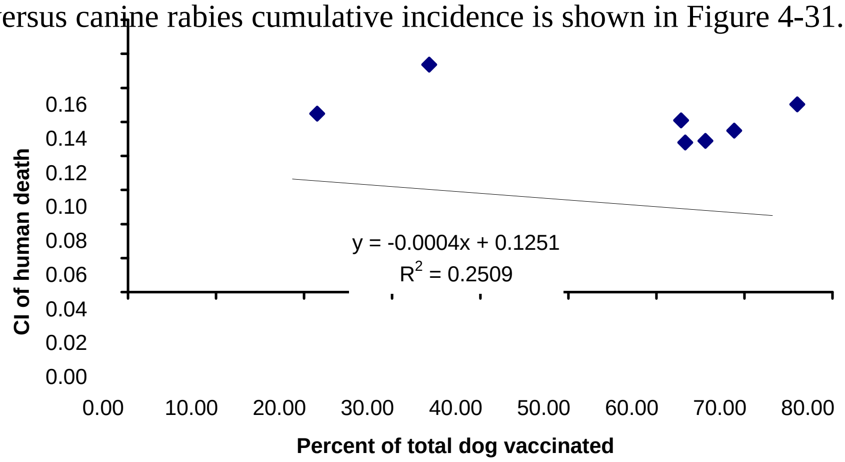


Figure 4-30 Association between percent of total dogs vaccinated and CI of human death

Figure 4-30 identifies little association between percent of dog vaccinated and human rabies incidence. Figure 4-31 shows that as the proportion of dogs vaccinated against rabies increases, the province-level cumulative incidence of canine rabies decreases.

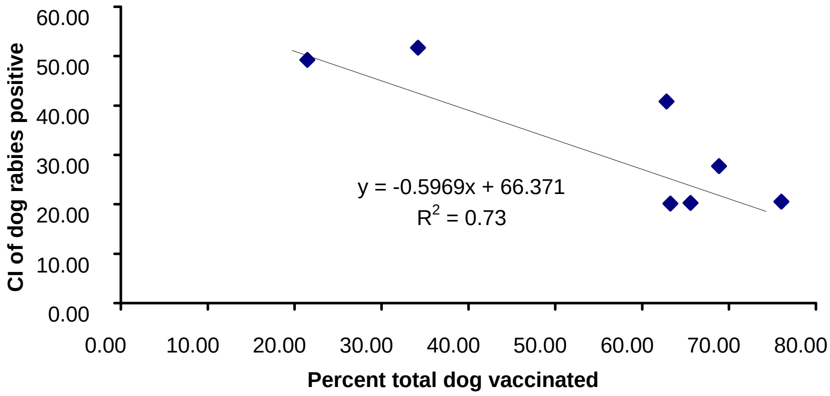


Figure 4-31 Association between percent of total dogs vaccinated and CI of dog rabies positive

Relative risk estimates of the association between characteristics of dogs and rabies are shown in Table 4-42.

Table 4-42. Relative risk for dog rabies by history of dog, method of animal death, rabies vaccination history, symptoms and other animal contact

Variable	Category	Disease		Relative risk	95%CI	
		positive	negative		Lower	Upper
History of dog	**owned**	**429**	**1280**	**1**		
	non-owned	153	131	2.15	1.84	2.5
Animal death	**natural death**	4016	8971	**1**		
	euthanasia	6792	5556	1.78	1.73	1.83
Vaccination history	**not vaccinate**	**605**	**1175**	**1**		
	vaccinated < 1 month	74	184	0.84	0.69	1.03
	vaccinated 1-6 months	40	283	0.36	0.28	0.47
	vaccinated >6 months-1 yr	27	209	0.34	0.25	0.46
	vaccinated > 1 yrs	53	153	0.76	0.6	0.95
	unknown	357	486	1.25	1.12	1.38
Symptoms	**furious**	**8235**	**3721**	**1**		
	dumb	1945	6511	0.33	0.32	0.35
	normal	631	3248	0.24	0.22	0.25
	fuirious and dumb	59	18	1.11	0.96	1.28
	other	95	368	0.3	0.27	0.33
	unknown	656	1937	0.37	0.39	9.35
Age of animal	**>12 months**	**378**	**904**	**1**		
	<3 months	201	565	0.89	1.03	0.77
	3-6 months	319	662	1.1	0.97	1.25
	>6-12 months	210	428	1.12	0.97	1.28
	unknown	485	971	1.13	1.01	1.26
Bite	**animal**	**6616**	**5094**	**1**		
	human	1892	2421	0.78	0.75	0.8
	none	1501	6633	0.33	0.31	0.34
	both animal and human	1140	88	1.64	1.58	1.71
	contact saliva	61	390	0.24	0.2	0.28
	unknown	411	1176	0.46	0.43	0.49

From the total of dogs suspected and submitted for rabies diagnosis, non-owned dogs were 2.15 times (95% CI 1.84 – 2.5) more likely to experience rabies than owned dogs. Euthanased dogs were 1.78 (95% CI 1.73 - 1.83) times more likely to be rabid dogs than dogs that were submitted following natural death. Compared to non-vaccinated dogs, dogs with unknown history were 1.25 times (95% CI 1.12 - 1.38) more likely to be rabid dogs while dog previously vaccinated more than one month and less than one year were 0.34 - 0.36 times less likely to be rabid dogs. Compared to dogs with furious symptoms, dogs showing dumb signs were 0.33 times (95% CI 0.35 - 0.27) as likely to be found rabies positive. Dogs that bit animals and humans were 1.64 times (95% CI 1.58 - 1.71) more likely to be rabid than dogs that bit other dogs or other animals only.

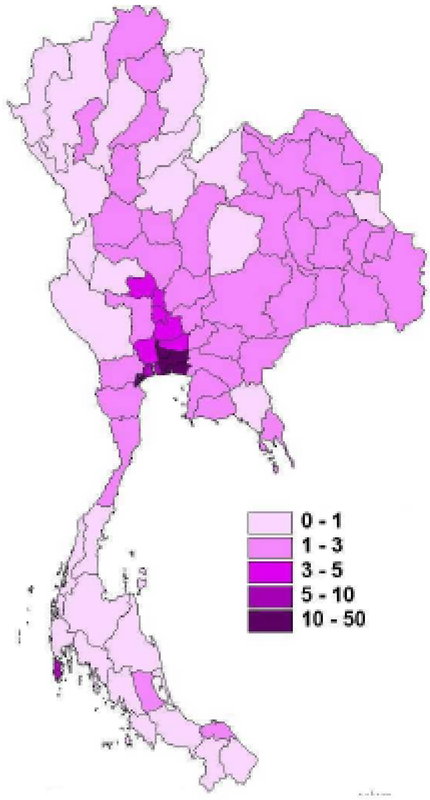
GIS and spatial analyses

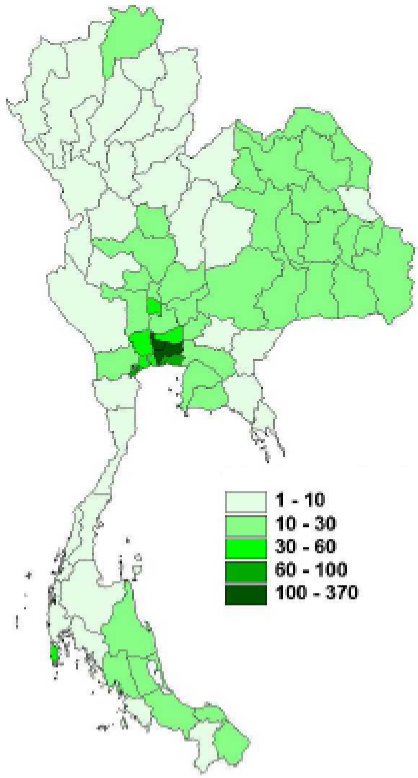
Descriptive spatial analyses

Spatial analyses of dog density and human density per square kilometre, cumulative incidence of dog and human rabies at the province level during the seven year period from 1993 to 1999 and cumulative incidence of dog and human rabies at the provincial level by year were plotted as chloropleth maps.

Dog density and human density per square kilometre

Average dog density and human density per square kilometre during the seven year period from 1993 to 1999 are shown in Figure4-32.





(A) Dog (B) Human

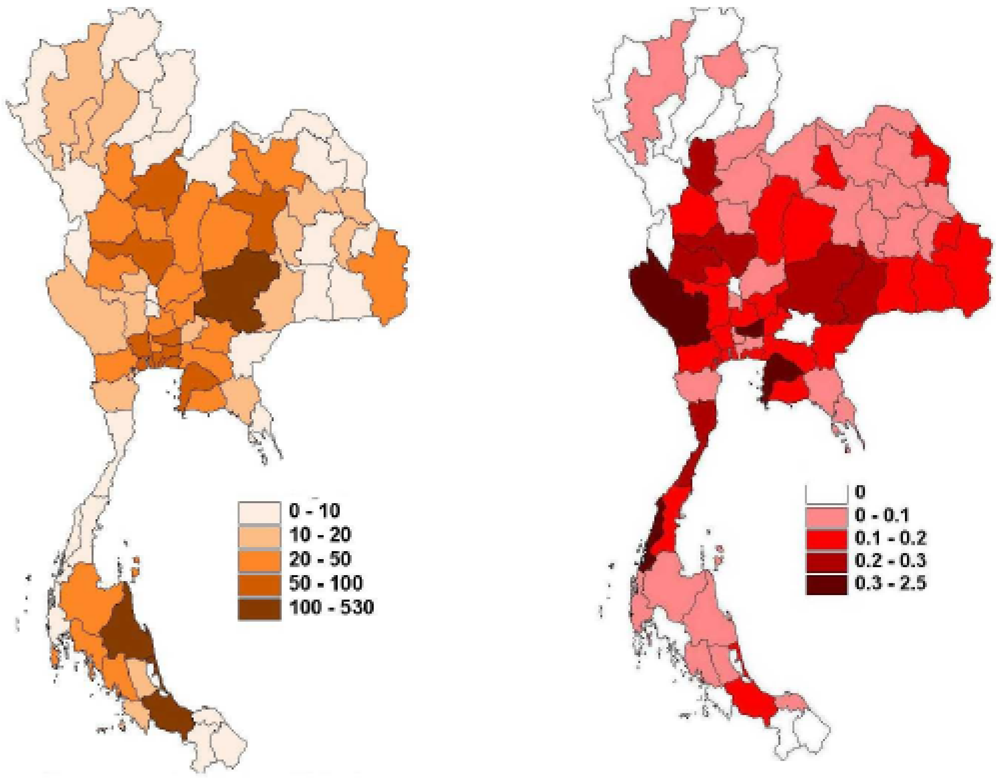
Figure 4-32. Average dog and human density expressed as numbers per square kilometre during seven year period from 1993 to 1999

The highest density of dogs from 1993 to 1999 was in province 10 (Bangkok), located in the central area (32 dogs per square kilometre). High dog density was also found in provinces surrounding Bangkok.

The highest density of humans was in province 10 (Bangkok) and surrounding provinces. Bangkok had 365 humans per square kilometre. Province 58, located in the North, had the lowest human density, which was 1.8 per square kilometre.

The cumulative incidence values for rabies in dogs and humans per 100,000 population by province during the 7 year period from 1993 to 1999 are shown in Figure.

The cumulative incidence of dog rabies and human deaths due to rabies in 1993 to 1999 are shown in Figures 4-34 to 4-40.

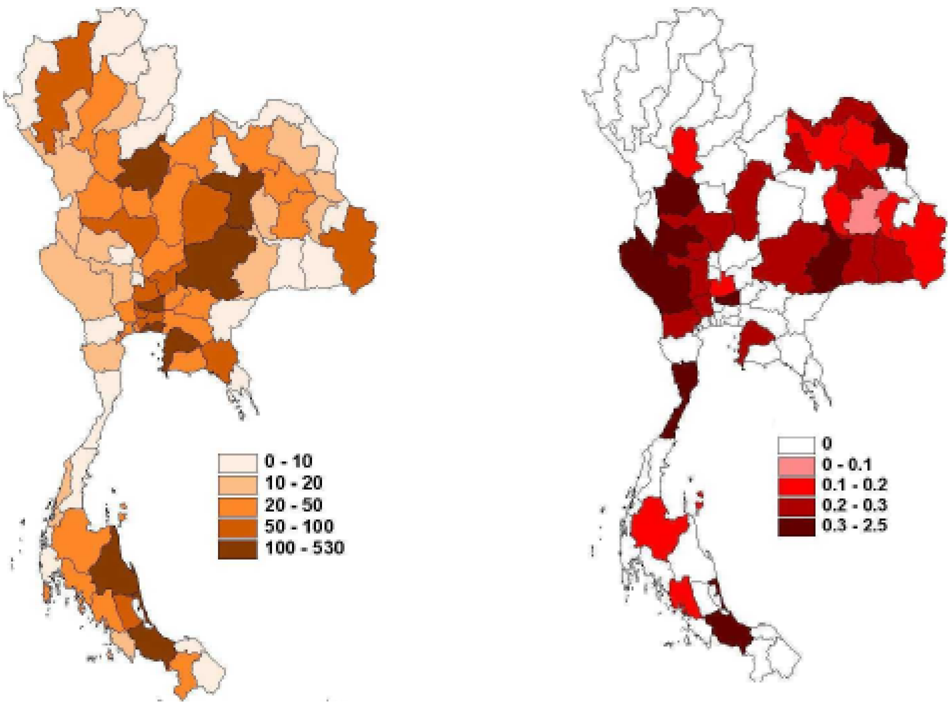


A) Dog B) Human

Figure 4-33. Annual cumulative incidence of rabies in dogs (A) and humans (B) per 100,000 population per year by province during the 7 year period from 1993 to 1999

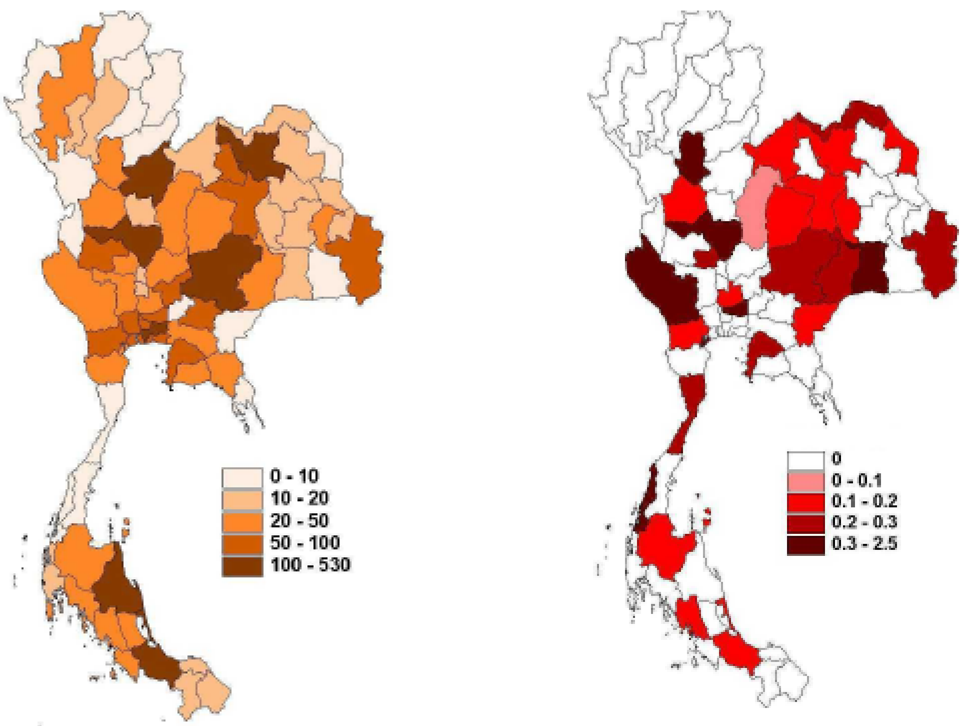
The cumulative incidence of rabies in dogs during the seven year period from 1993 to 1999, was highest in province 80, located in the South (177 dogs per 100,000 dog population) and lowest in province 58 (1 dogs per 100,000 dog population). Province 65 had the highest incidence of rabies in dogs in the North (77 dogs per 100,000 dog population). Province 30 had the highest incidence of rabies in dogs in the North-eastern (116 dogs per 100,000 dog population). Province 13 had the highest cumulative incidence of rabies in dogs in the Central part (76 dogs per 100,000 dog population).

The cumulative incidence of rabies in humans during the seven year period from 1993 to 1999 was highest in province 85, located in the South (0.48 human deaths per 100,000 human population). Province 61 had the highest cumulative incidence of rabies in humans in the North (0.26 deaths per 100,000 human population). Province 31 had the highest cumulative incidence of rabies in humans in the North-eastern (0.22 deaths per 100,000 human population). Province 20 had the highest incidence of rabies in humans In the Central (0.416 deaths per 100,000 human population).



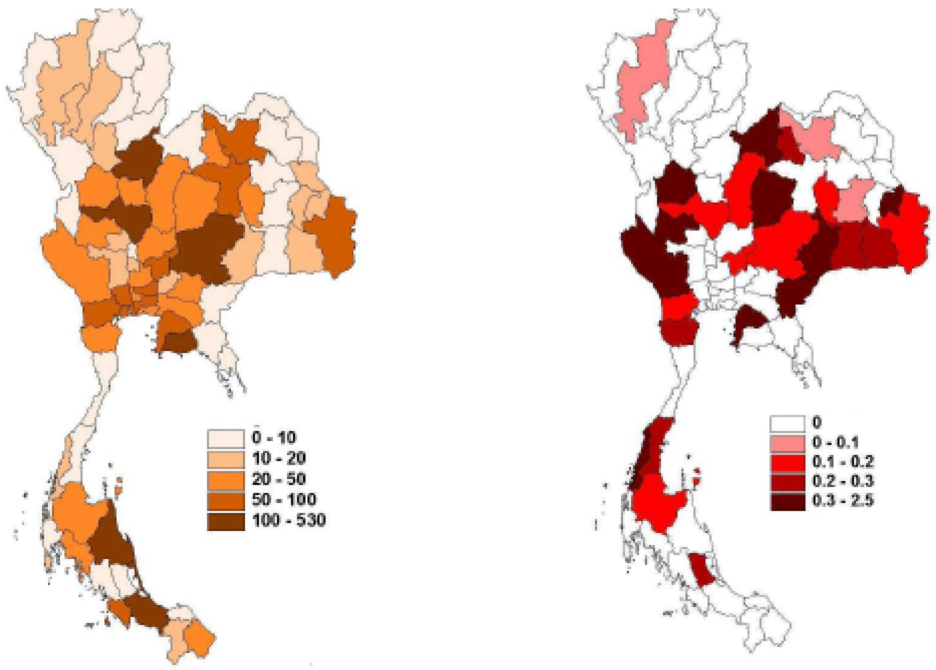
A) Dog B) Human

Figure 4-32. Annual cumulative incidence of rabies in dogs (A) and humans (B) per 100,000 population by province in 1993



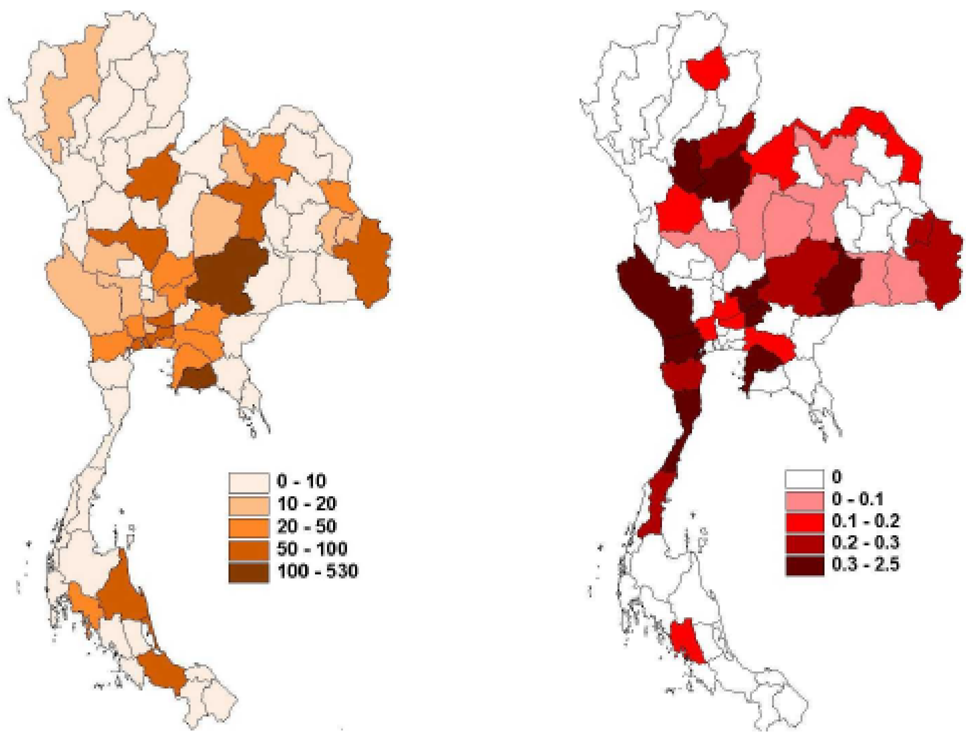
A) Dog B) Human

Figure 4-33. Annual cumulative incidence of rabies in dogs (A) and humans (B) per 100,000 population by province in 1994



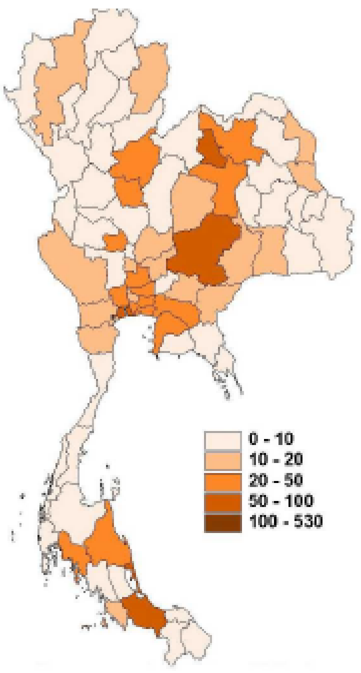
A) Dog B) Human

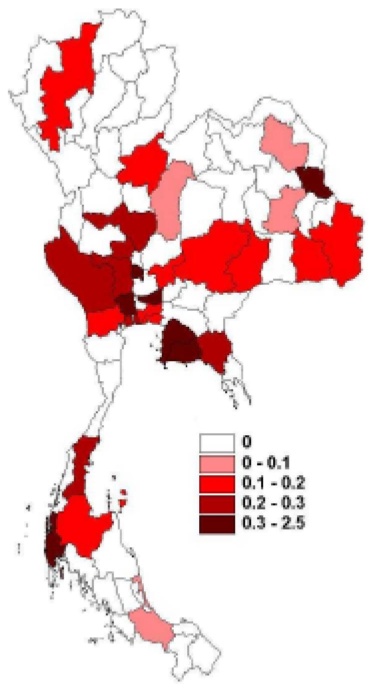
Figure 4-34. Annual cumulative incidence of rabies in dogs (A) and humans (B) per 100,000 population by province in 1995



A) Dog B) Human

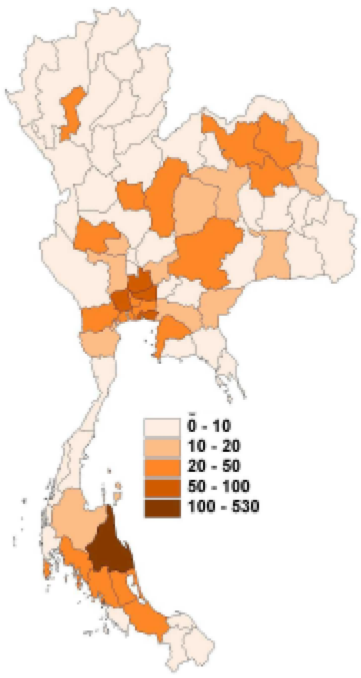
Figure 4-35. Annual cumulative incidence of rabies in dogs (A) and humans (B) per 100,000 population by province in 1996

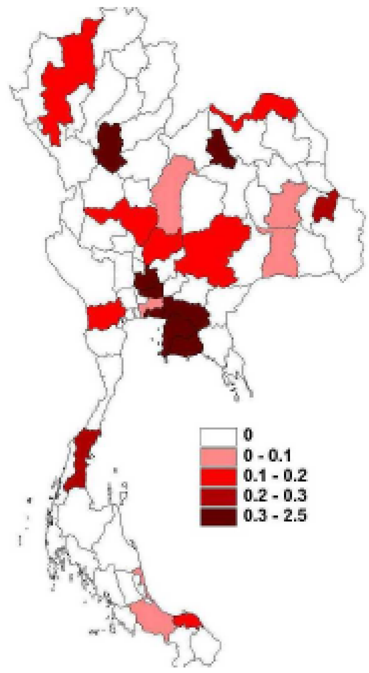




A) Dog B) Human

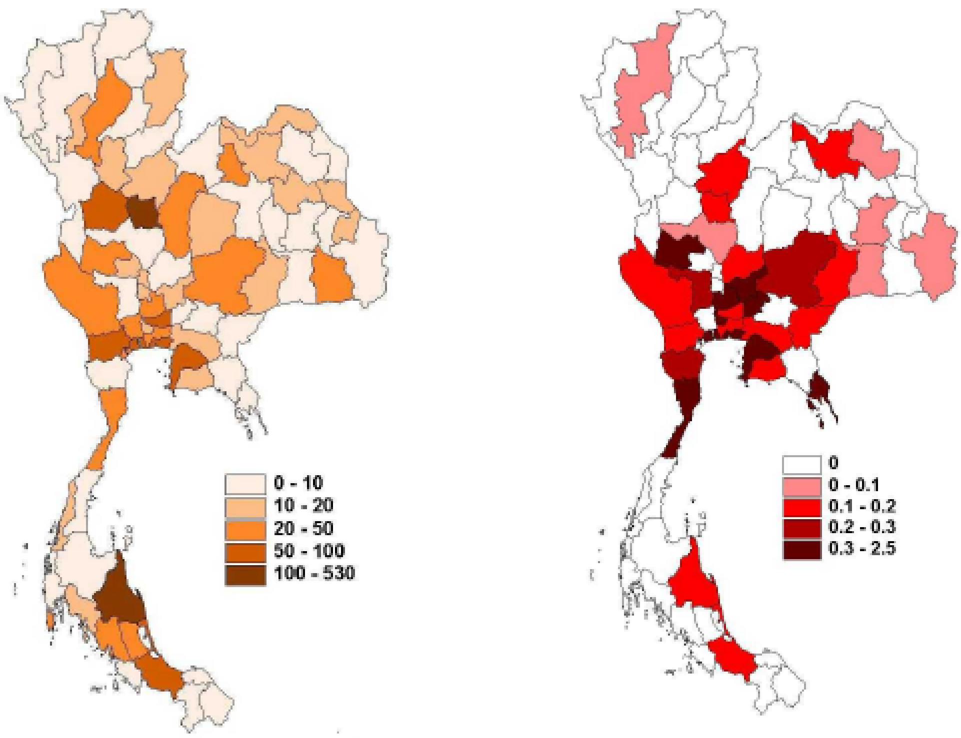
Figure 4-36. Annual cumulative incidence of rabies in dogs (A) and humans (B) per 100,000 population by province in 1997





A) Dog B) Human

Figure 4-37. Annual cumulative incidence of rabies in dogs (A) and humans (B) per 100,000 population by province in 1998



A) Dog B) Human

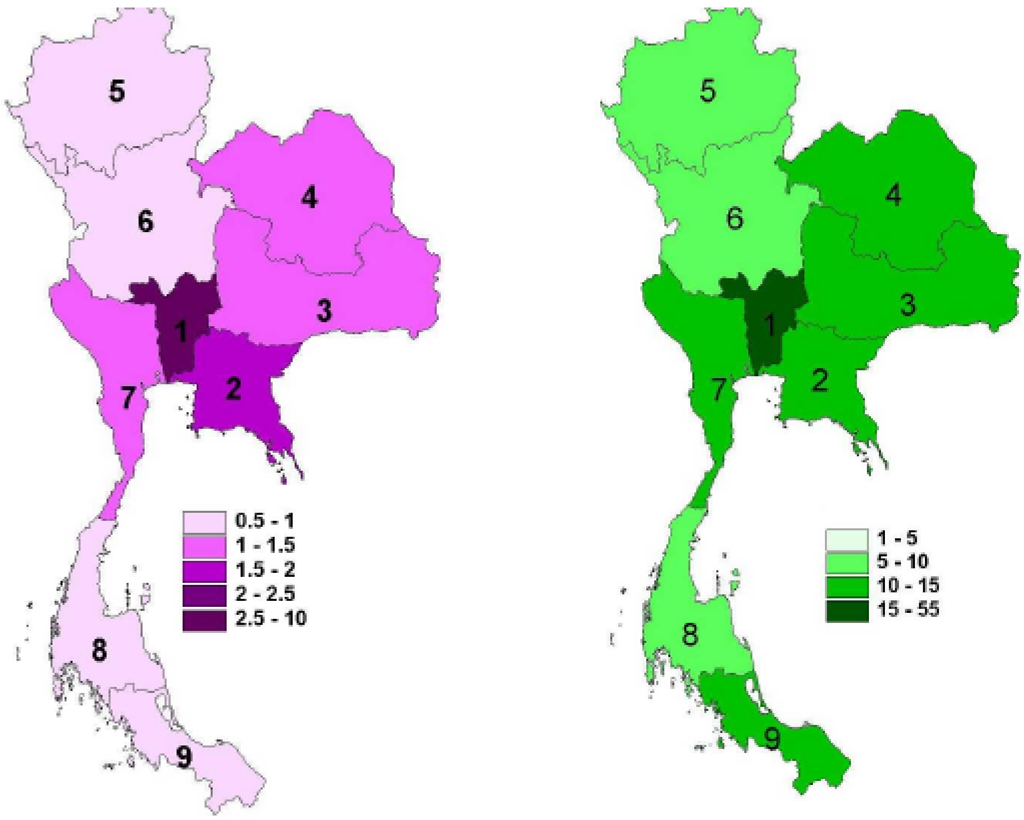
Figure 4-40. Annual cumulative incidence of rabies in dogs (A) and humans (B) per 100,000 population by province in 1999

In 1993 cumulative incidence of dog rabies was high in two provinces in the South (province 80 and 90) which were 521 and 292 cases per 100,000 dog population respectively. There were two provinces in the North-eastern part which had high cumulative incidence of dog rabies (province 30 and 40) which were 198 and 185 cases per 100,000 dog population respectively. Four provinces in the Central part (11, 20, 13 and 10) had high cumulative incidence of dog rabies, which were 282, 127, 120 and 97 cases per 100,000 dog population respectively and two provinces in the North had high cumulative incidences of dog rabies (65 and 50), which were 112 and 94 per 100,000 dog population respectively. High cumulative incidences of dog rabies were found in these provinces every year until 1999. Since 1996 the cumulative incidence of rabies reduced in most areas of Thailand but those provinces with high rates of rabies remained high.

From 1993 to 1996 provinces with higher cumulative incidences of human deaths due to rabies were in the North-eastern part, the western part of the central region and some parts in the South. Province 13, 20 and 71 in the Central, province 61 and 62 in the lower North region, province 31 in the North-eastern and province 77 and 90 in the South had high cumulative incidences of human deaths due to rabies per 100,000 human population. There was no report of human deaths due to rabies in the upper North region in 1993 and 1994. From 1995 there were reported deaths in some provinces of the North region. In 1999 the disease moved down and clustered in provinces in the Central region. These maps showed that two provinces, 20 and 30 had high cumulative incidences of human deaths due to rabies over the 7 year period.

Dog and human density per square kilometre and cumulative incidence of rabies in dogs and humans per 100,000 population by region from 1993 to 1999

Average dog and human density per square kilometre by region during the seven year period by region from 1993 to 1999 are shown in Figure4-41.

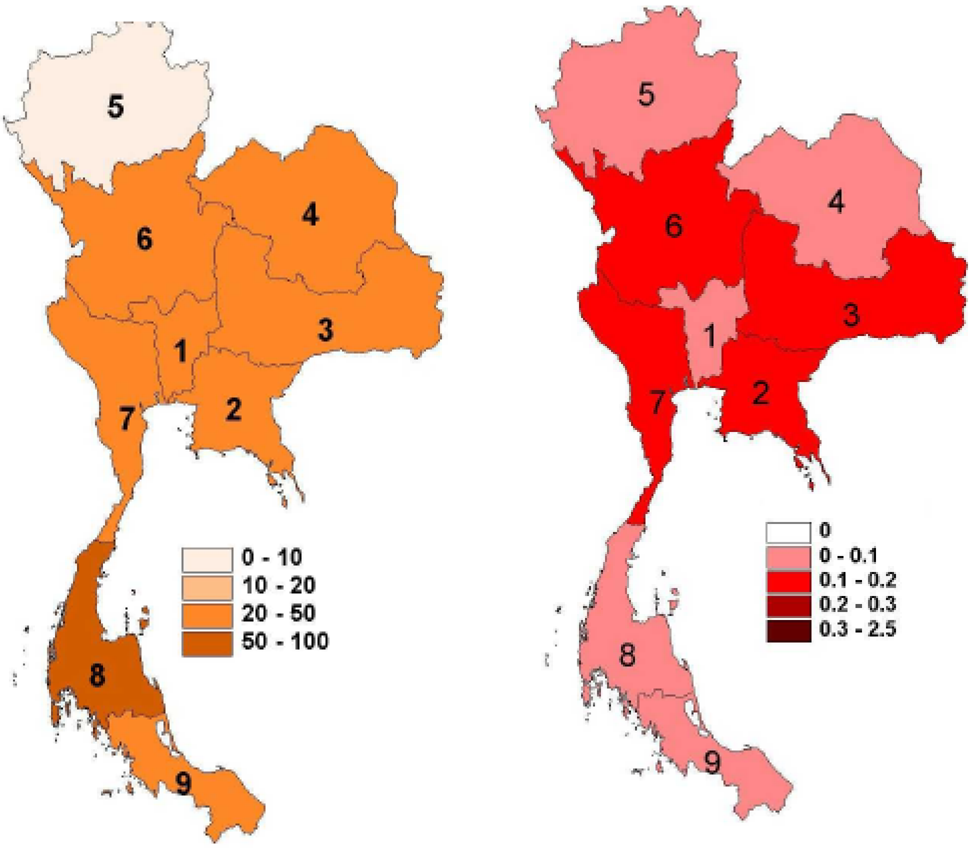


A) Dog B) Human

Figure 4-41. Average dog density (A) and human density (B) per square kilometre by region during the 7 year period from 1993 to 1999

The highest density of humans during the seven year period was in region 1 (49 humans per square kilometre). Region 6 had the lowest human density (7 humans per square kilometre).

Cumulative incidence of rabies in dogs and human per 100,00 population during the seven year period by region from 1993 to 1999 are shown in Figure4-42.



A) Dog B) Human

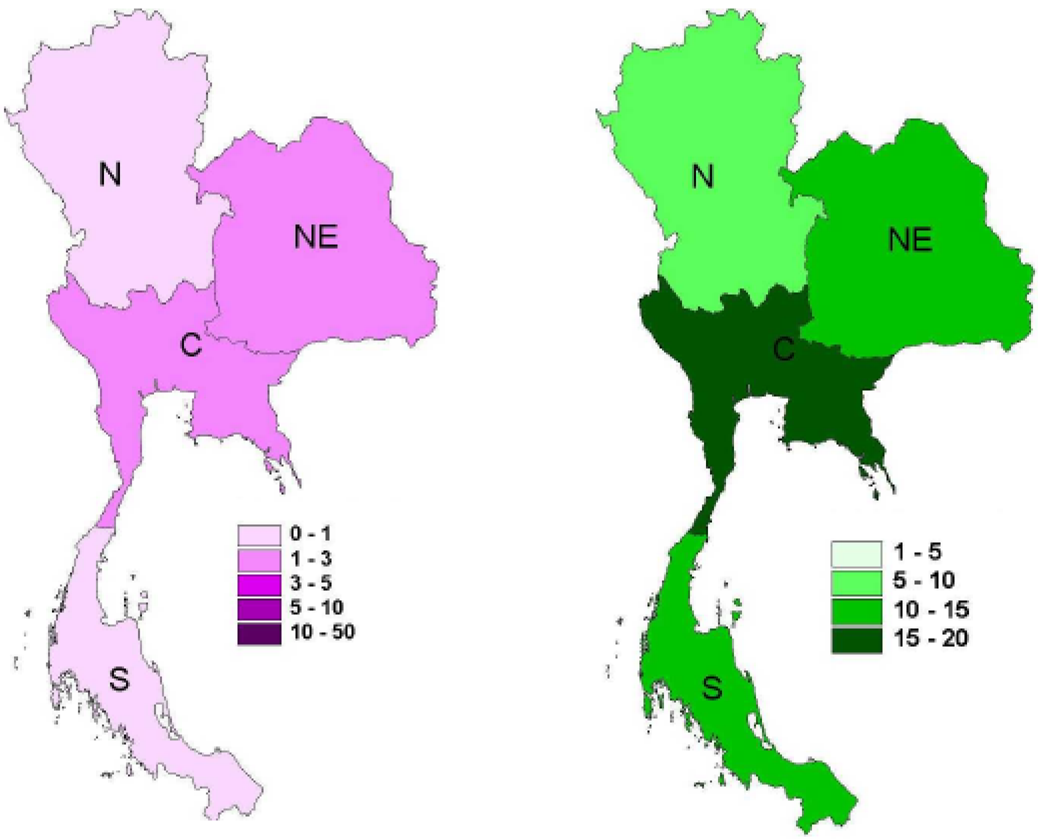
Figure 4-42. Cumulative incidence of rabies in dogs (A) and human (B) per 100,000 population during the seven year period from 1993 to 1999

The cumulative incidence of rabies in dogs during the seven year period from 1993 to 1999 was highest in region 8 located in the South (61 dogs per 100,000 dog population) and lowest in region 5 (9 dogs per 100,000 dog population).

The cumulative incidence of rabies in humans during the seven year period from 1993 to 1999 was highest in region 7, located in the Central (0.17 human death per 100,000 human population).

Dog and human density per square kilometre and cumulative incidence of rabies in dogs and human per 100,000 population by part from 1993 to 1999

Average dog and human density per square kilometre during the seven year period by part from 1993 to 1999 are shown in Figure4-43.



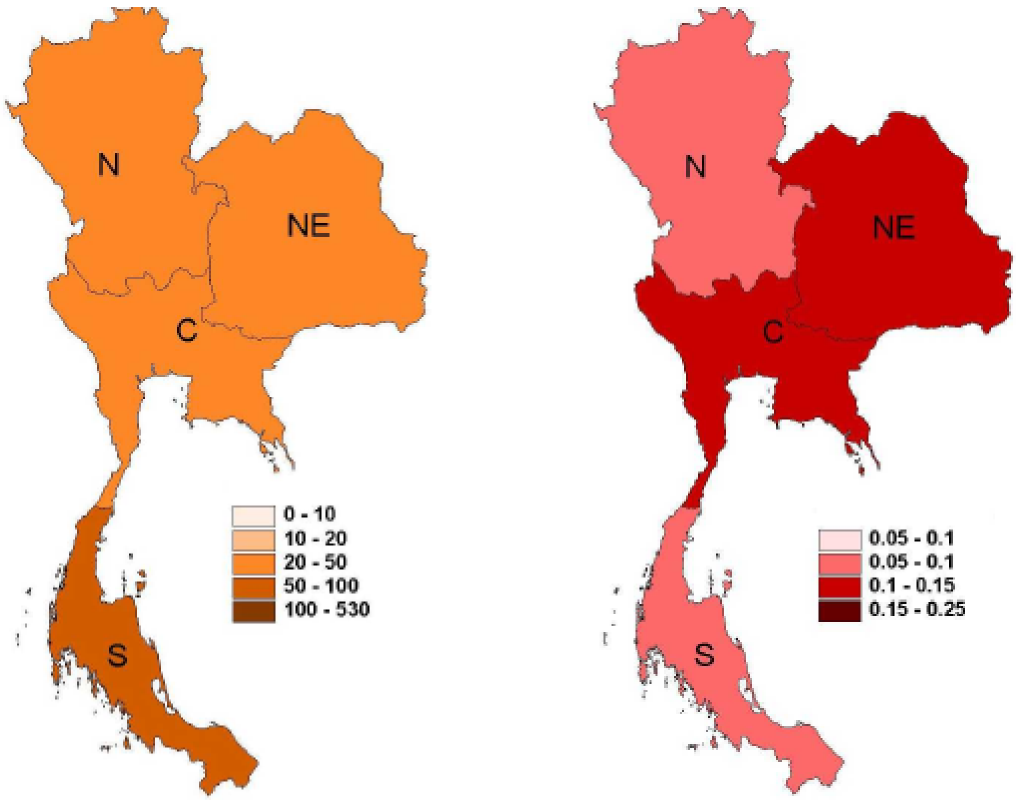
A) Dog B) Human

Figure 4-43. Average dog density (A) and human density (B) per square kilometre during the seven year period from 1993 to 1999

The highest density of dogs from 1993 to 1999 was in the Central (2 dogs per square kilometre). The South had the lowest dog density (0.76 dog per square kilometre).

The highest density of humans was in the Central (19 humans per square kilometre). Region 6 had the lowest human density (7 humans per square kilometre).

Cumulative incidence of rabies in dogs and humans per 100,000 population during the seven year period by part from 1993 to 1999 are shown in Figure4-44.



A) Dog B) Human

Figure 4-44. Incidence of rabies in dogs (A) and human (B) per 100,000 population during the seven year period from 1993 to 1999

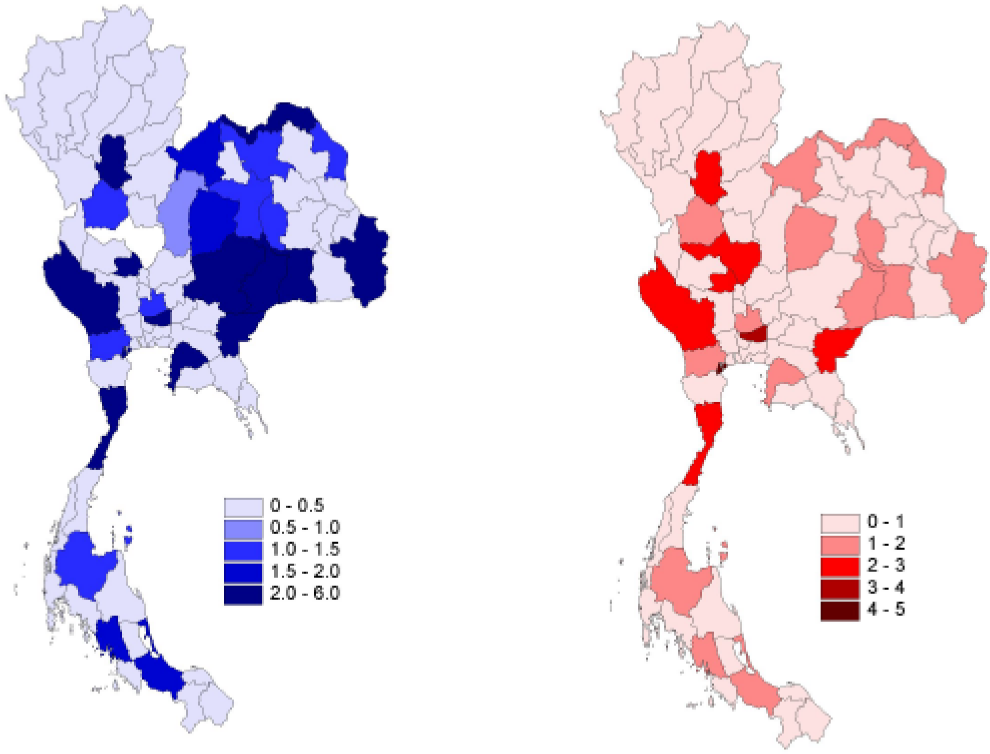
The cumulative incidence of rabies in dogs during the seven year period from 1993 to 1999 was highest in the South (50 dogs per 100,000 dog population) and lowest in the North (20 dogs per 100,000 dog population).

The cumulative incidence of rabies in human during the 7 year period from 1993 to 1999 was highest in the Central (0.128 human death per 100,000 human population) and lowest in the South (0.056 per 100,000 human population).

Spatial analyses

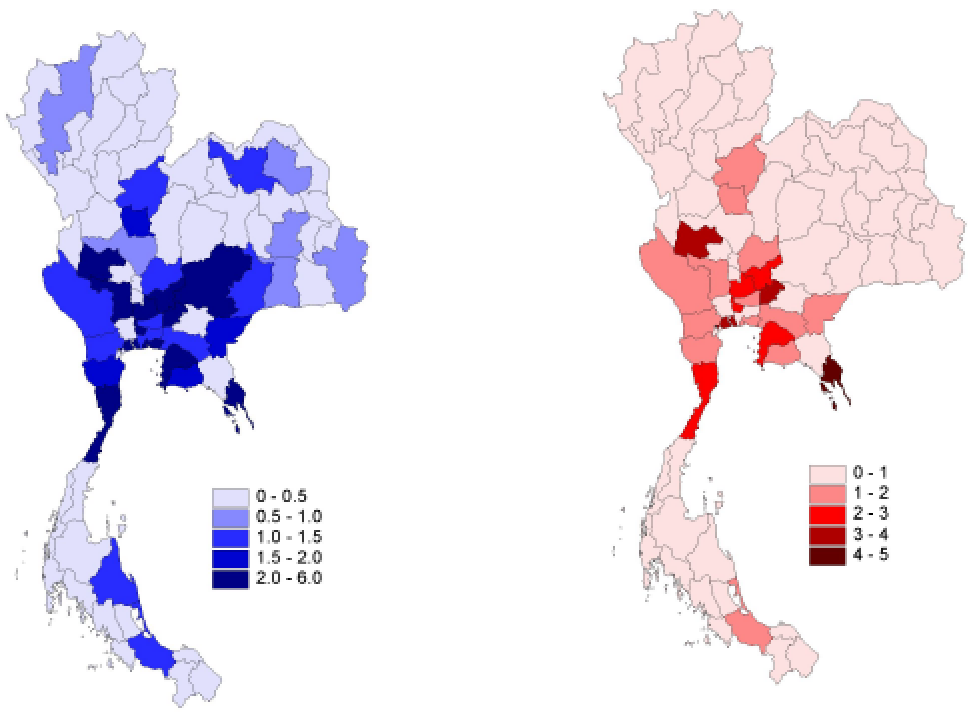
Human rabies

Chloropleth maps of province-level SMR for human rabies for 1994 and 1999 are shown in Figure4-45 and Figure4-46.



(A) Crude SMR estimate (B) SD of the crude SMR estimate

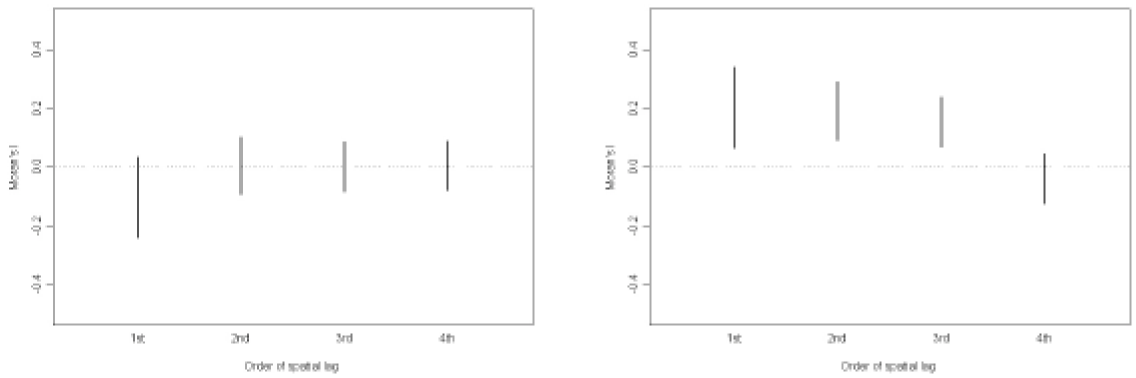
Figure 4-45. Province-level standardised mortality ratio (SMR) for human rabies in 1994



(A) Crude SMR estimate (B) SD of the crude SMR estimate.

Figure 4-46. **Province-level standardised mortality ratio (SMR), crude SMR estimate and the standard error of the crude SMR estimate of human rabies in 1999**

A spatial correlogram computed for province-level human rabies risk for the 1994 and 1999 data is shown in Figure4-47.



(A) 1994 (B) 1999

Figure 4-47. Spatial correlograms computed for province-level human rabies risk for the 1994 and 1999 data, for each lag the 95% CI of the Morans I is shown

There was no evidence of spatial autocorrelation in the province-level estimates of human rabies SMR for the 1994 data (A). In contrast, significant spatial autocorrelation was evident in spatial adjacency matrices based on first, second, and third order lags for the 1999 data (B).

For the Bayesian regression analyses conducted using the 1994 and 1999 data, the Markov Chain Monte Carlo sampler was run for 20,000 iterations and the first 1,000 ‘burn-in’ samples were discarded. Posterior sample sizes were determined by running sufficient iterations to ensure the Monte Carlo standard error of the mean estimate was at least one order of magnitude smaller than the posterior standard deviation for each parameter of interest. In the models presented 40,000 iterations of the Markov Chain Monte Carlo sampler were used.

Global Moran’s I statistics computed using the residual terms from each of the fixed-effect models show that the 1994 dataset had no significant spatial autocorrelation present in the residual terms. For the 1999 data set significant spatial autocorrelation was present in the residual terms. On the basis of these findings, a mixed-effect model was applied to the 1999 data, in an attempt to account for the spatial autocorrelation in the data.

Regression coefficients from the fixed-effect Poisson model of human rabies risk for 1994 and 1999 and mixed effect Poisson model for 1999 are shown in Table 4-43.

Table 4-43. Posterior means and posterior standard deviation (SD) of the regression coefficients in the fixed-effect Poisson model of factors influencing the risk of rabies in humans in Thailand in 1994 and 1999 and in the mixed-effect Poisson model of factors influencing the risk of rabies in humans in Thailand in 1999

Explanatory variable	Posterior mean	SD	MC error [a]	Relative risk	95% CI [b] of relative risk
Fixed effect Poisson model					
1994					
Intercept	0.5659	0.5016	0.0118		
Proportion of dogs vaccinated [c]	-0.0011	0.0141	0.0003	1.00	0.97 - 1.03
Human density [d]	-0.2356	0.0905	0.0044	0.80	0.65 - 0.92 [e]
Dog density [d]	0.4721	0.2247	0.0106	1.58	1.07 - 2.58
Ratio of observed to expected dog rabies	0.2765	0.1165	0.0026	1.32	1.04 - 1.65
1999					
Intercept	-0.6552	0.5192	0.0157		
Proportion of dogs vaccinated [c]	0.0017	0.0091	0.0003	1.00	0.98 - 1.02
Human density [d]	-0.1136	0.0368	0.0017	0.89	0.83 - 0.96
Dog density [d]	0.3595	0.1016	0.0047	1.44	1.16 - 1.73
Ratio of observed to expected dog rabies	0.2955	0.0868	0.0018	1.35	1.13 - 1.59
Mixed-effect Poisson model					
1999					
Intercept	-0.8464	0.3648	0.0217		
Human density [c](population per square metre	-0.1340	0.0527	0.0048	0.88	0.79 - 0.96
Dog density [c]	0.4071	0.1343	0.0121	1.49	1.17 - 1.98
Ratio of observed to expected dog rabies	0.3782	0.1174	0.0065	1.45	1.18 - 1.86
Structured heterogeneity [f]	0.4350	0.4825			
Unstructured heterogeneity [f]	0.2298	0.3197			

[a] Monte Carlo error.
[b] Bayesian credible interval.
[c] Freeman-Tukey transformed.
[d] Square-root transformed.
[e] For unit increases in the square root of human population density, there was 0.8 times the province level relative risk of human rabies (95% Bayesian credible interval 0.65 to 0.92).
[f] Variance of heterogeneity term

Table 4-43 shows the posterior means and 95% Bayesian credible intervals of the regression coefficients for the fixed effect and mixed-effect model of human rabies risk for the 1994 and 1999 data.

In 1999, province-level relative risk of human rabies was positively associated with canine density and the canine SMR for rabies. Province-level relative risk of human rabies was negatively associated with human population density. For each one unit increase in the square root of canine population density the province-level relative risk of human rabies increased by 1.49 (95% CI 1.17-1.98). For each one unit increase in the ratio of observed canine rabies cases to expected, the province-level relative risk of human rabies increased by 1.45 (95% CI 1.18-1.86). For each one unit increases in the square root of human population density the province-level relative risk of rabies decreased by 0.88 (95% CI 0.79-0.96).

Variance of the spatial heterogeneity terms were approximately twice that of the unstructured heterogeneity terms. This implies that, in 1999, there were groups (or spatial aggregations) of provinces where the relative risk of human rabies was not explained by human population density, canine population density, or the canine relative risk of rabies.

The relative risk estimates calculated from the posterior estimates of the spatial heterogeneity terms are shown in Figure 4-48.

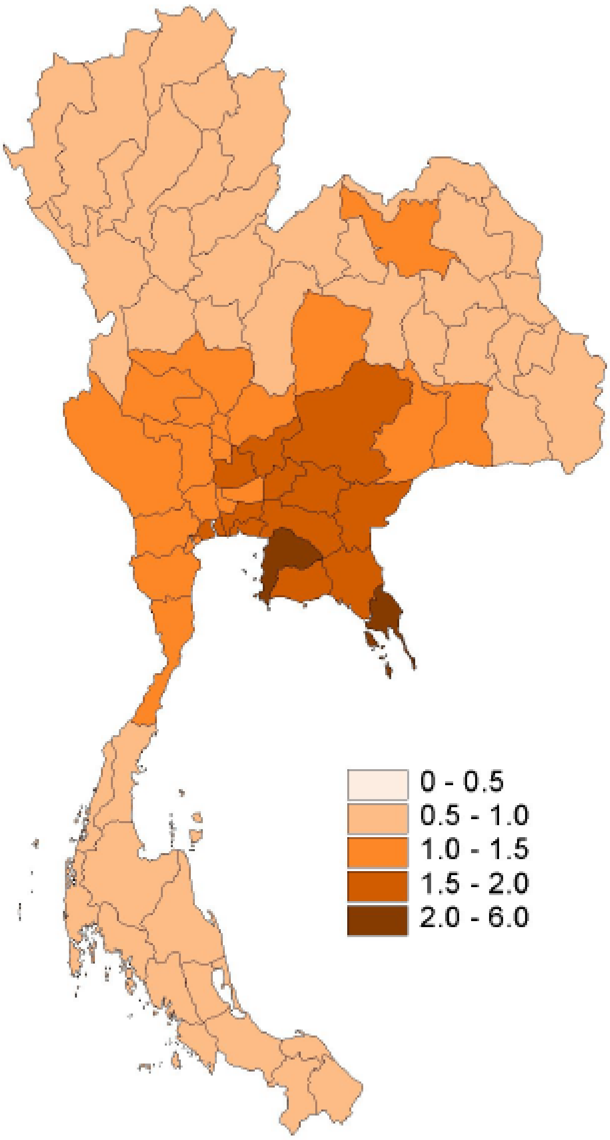
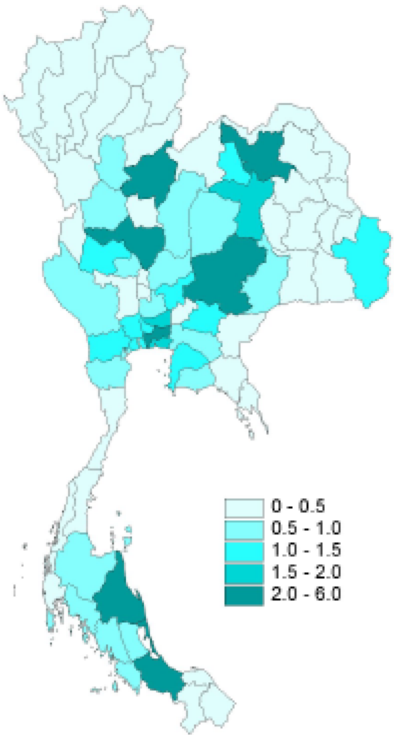


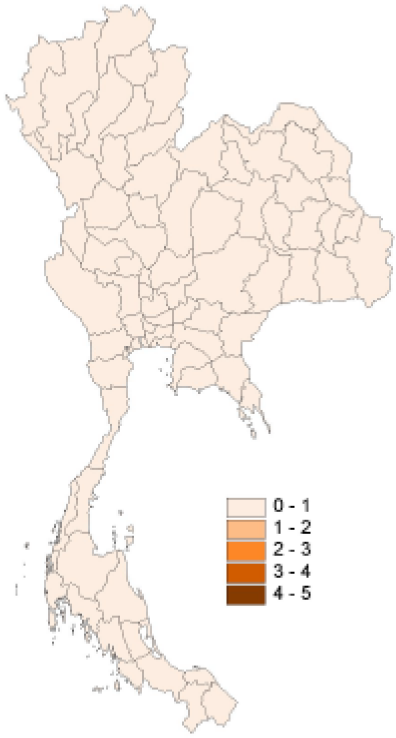
Figure 4-48. The relative risk estimates calculated from the posterior estimates of the spatial heterogeneity terms

Figure4-48 shows an aggregation of provinces in the south east of the central part of Thailand identifying in 1999 an excess of rabies incidence not explained by proportion of dog vaccinated, human density, dog density and ratio of observed and expected dog rabies.

Canine rabies

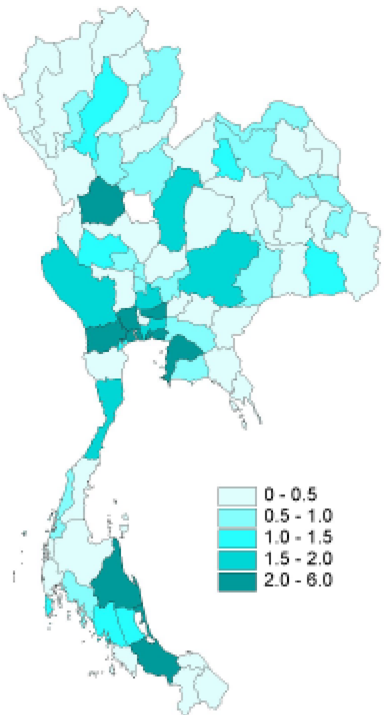
Chloropleth maps of province-level SMRs for canine rabies for 1994 and 1999 are shown in Figure 4-49 and Figure4-50, respectively.

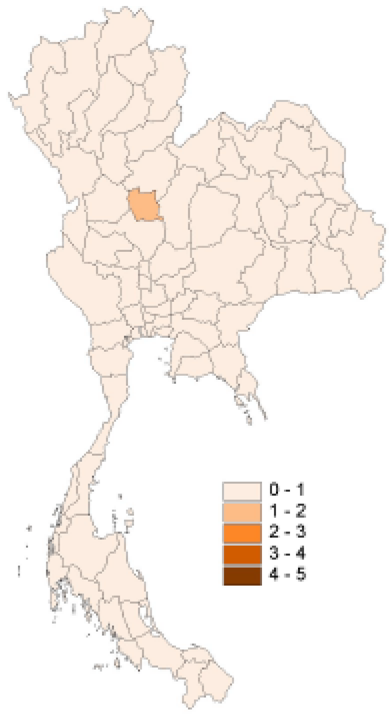




(A) Crude SMR estimate (B) SD of the crude SMR estimate

Figure 4-49. Province-level standardised mortality ratio (SMR), crude SMR estimate and the standard error of the crude SMR estimate of canine rabies in 1994.





(A) Crude SMR estimate (B) SD of the crude SMR estimate

Figure 4-50. Province-level standardised mortality ratio (SMR) for canine rabies, crude SMR estimate and the standard error of the crude SMR estimate of canine rabies in 1999

There was no evidence of spatial autocorrelation in the province-level estimates of canine rabies SMR for the 1994 and 1999 data.

Regression coefficients from the fixed-effect Poisson model of canine rabies risk are shown in Table4-44.

Table 4-44. Posterior means and posterior standard deviation (SD) of the regression coefficients in the fixed-effect Poisson model of factors influencing the incidence of rabies in dogs in Thailand.

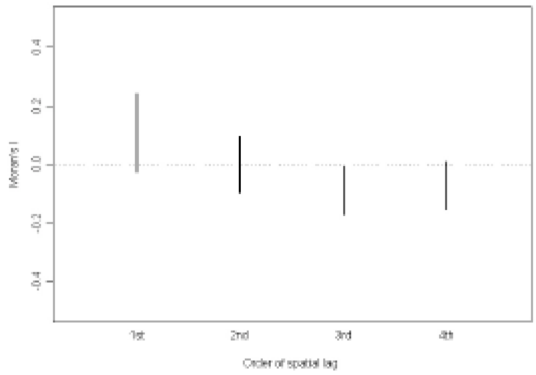
Explanatory variable	Posterior mean	SD	MC error [a]	Relative risk	95% CI [b] of relative risk
1994					
Intercept	-0.4079	0.0449	0.0008		
Proportion of dogs vaccinated [c]	0.0035	0.0018	0.0000	1.00	1.0 - 1.01
Dog density [d]	0.0595	0.0060	0.0001	1.06 [e]	1.05 - 1.07
1999					
Intercept	-1.7270	0.1376	0.0041		
Proportion of dogs vaccinated [c]	0.0264	0.0021	0.0001	1.03	1.02 - 1.03
Dog density [d]	0.0399	0.0046	0.0001	1.04	1.03 - 1.05

[a] Monte Carlo error.
[b] Bayesian credible interval.
[c] Freeman-Tukey transformed.
[d] Square-root transformed.

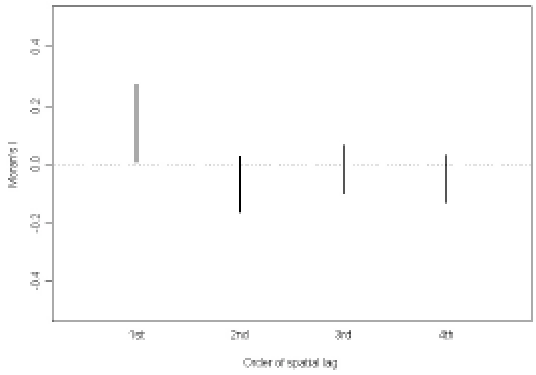
[e] Interpretation: for every unit increase in the square root of canine population density, the province-level relative risk of canine rabies increased by 1.06 (95% Bayesian credible interval 1.05 to 1.07).

The global Moran's I statistics computed using the residual terms from each of the fixed-effect models failed to identify the presence of spatial autocorrelation in the residual terms from either model.

Spatial correlograms computed for province-level canine rabies risk for the 1994 and 1999 are shown in Figure4-51.



(A) 1994



(B) 1999

Figure 4-51. Spatial correlograms computed for province-level canine rabies risk for the 1994 and 1999 data, for each lag the 95% CI of the Morans I is shown

A spatial correlogram of canine rabies risk for the 1994 and 1999 data shows showed no evidence of spatial autocorrelation of canine rabies SMR in 1994 and weak evidence of spatial autocorrelation in 1999.

Chapter 5

Discussion

Data quality

Errors were identified at all steps in the process of obtaining, entering and preparing data for analysis.

Most of the data quality assessment concentrated on the control activity data sets because they were the only data where it was possible to collect paper record forms close to the origin of the data.

Data retrieval was a major problem in that it was often not possible to obtain data for control activities at the level of detail desired which were records of control activities performed in each month, in each district. District officers submitted monthly reports in paper form to their Provincial Office. In some cases, data may not have been collected and submitted. In other cases, data were submitted to the Provincial Office for aggregation to the Province level. Record storage and retrieval systems varied between different Provincial Offices. Some offices were able to provide access to stored copies of District reports for each month of each year during the study period. In many cases, District report forms were discarded after information had been aggregated to Provincial level. In other cases, District reports were not able to be located. Many Provincial Offices did not maintain records for each month of every year, preferring instead to record data in the form of an annual Province report of control activities which had taken place during the past year.

Electronic databases for storage and retrieval of control activity data were introduced into Provincial Offices in 1995, and electronic reporting forms in 1997. Difficulties in adoption and implementation of computerised procedures are also likely to have contributed to loss of data from District and Province level records.

Control activity data obtained from Provincial Offices also varied greatly in physical condition. Some were printouts of processed data. Others were copies of original handwritten paper reports. Some paper records were faded and unclear and in others, hand-writing was difficult to decipher.

Diversity of reporting form design was also a problem. Changes in the design of the reporting form occurred irregularly during the study period and made interpretation of data more difficult. There did not appear to be a standardised manner of recording data with different symbols being used without clear definitions of their meanings. Different organisations and different levels of organisations are involved in collecting and reporting control activity data. Numbers of activities in a province reported in an annual report by one organisation, were not the same as those reported by another organisation. This is largely due to the overlap in responsibility for control activities between different organisations which contribute to rabies control in Thailand.

Errors performed at the time of collection and recording of data by District Officers, were mainly associated with missing data and numerical errors. Collection of control activity data represents one of many tasks allocated to District Officers and their staff or assistants. On occasion report forms may be filled in by villagers or farmers assisting the District officers. Understaffing and heavy workloads may have contributed to numerical errors including recording the wrong number or recording a number in an incorrect column. The monthly reporting form is also long, relatively unwieldy, asks for a lot of information and it changed in design several times during the study period. It is highly likely that these factors contributed to difficulties in completing the form in its entirety, each month. These same attributes may have contributed to a lowering of motivation by District Officers to provide detailed data on every variable in the form.

An effort was made by the author to minimise data entry error. A purpose designed database with a data entry form was used for data entry. The data entry form was designed to mimic the format of the latest control activity report form obtained from Thailand prior to data collection. Data entry personnel were selected by the author based on their familiarity with the task and with rabies control activities. They received training prior to entering data. Errors identified in randomly selected records suggested that data entry rate was low (less than 1.5% for 3 operators and 2.5% for the remaining operator). These findings agree with those of Tri Satya (Tri Satya Putri Naipospos-Hutabarat, 1995). Data entry errors were associated with the following factors:

?? Difficulties in matching the report forms and the pre-designed, interactive data entry form. The data form developed for data entry was based on the latest control activity report form and contained 72 variables. Most paper report forms obtained from Thailand differed from this format and generally contained between 10 and 45 variables. This problem was made worse by the changes in design of the paper reporting forms used during the study period.

?? Keystroke or typographical errors were the other main cause of data entry errors. Four types of errors were found during the entry process: insertion by adding extra characters, deletion by omitting some characters, substitution by typing the wrong characters and transposition by typing the correct characters but in an incorrect order.

Similar errors are assumed to exist in the electronic file data, however the only errors that could be identified were missing data and duplicate records.

It is considered likely that data collected on control activities in this study, actually underrepresented the level of control activity which occurred in Thailand during the study period. Discrepancies are due to a combination of errors and omissions apparent in the data collection, storage and retrieval process and the fact that the reporting system did not capture activities performed by private services.

Errors occurring in data entry of control activity data, were corrected where possible. Inspection of control activity data revealed that valid data for monthly activities at the district level, were not present in sufficient numbers to warrant analysis. This was largely due to problems in data storage and retrieval in Thailand. It is likely that failure of some Districts to submit reports may also have contributed to this lack of District level data. As a result, a decision was made to aggregate District monthly activity data to the Province level for further analyses. However, sufficient data for analysis of control activities within Provinces, at a monthly level in this study, could only be obtained for 10 of the 26 Provinces which had been targeted.

Control activity data in annual reports from each Province, were readily available and further analyses were then performed on these yearly reports for each of the 76 Provinces.

Assessment of the quality of the data collected during this study, has both confirmed the importance of high quality data and the need to assess data quality (and correct errors where possible), prior to analysing data. In addition it has highlighted several issues which are relevant to the future planning and monitoring of rabies control activities in Thailand.

Collection, storage and retrieval of high quality data are necessary for the implementation and monitoring of an effective rabies control strategy. There were no Provinces which were able to provide complete datasets for control activities during the study period. The major problems associated with the incomplete nature of the data, occurred at data collection and data retrieval.

There have to be sufficient, trained personnel available within each district, to collect activity data each month.

District Officers and their staff must be encouraged to complete the reporting form in its entirety, each month. This would be greatly facilitated by attending to the design of the reporting form to produce a standardised and simplified reporting form which is reviewed at intervals not less than 1-2 years. The current reporting form is too long and unwieldy to facilitate collection of complete and accurate data. This increases the workload for District Officers and reduces the likelihood of the form being completed. Overall data quality and usefulness is believed to have been adversely affected by poor form design.

Reporting forms should be designed to collect specific information aimed at meeting objectives defined by users of the information. The major use of the information is to assist in the control of rabies in animals and humans. Information collected in the reporting form should contribute to this goal in a variety of ways including: monitoring disease patterns in either animals or humans, identifying risk factors associated with the disease, assisting in the allocation of resources to aspects of control, and monitoring the success of the programme.

Variables or questions which are included in the reporting form, should be chosen carefully and kept to a minimum. Variables should be selected for inclusion based on two main criteria: contribution of the information they convey to an overall goal of rabies control, and, ease with which accurate data can be collected. If it is difficult for a

District Officer to collect data on a particular variable, then it is likely that data on that variable will be incomplete and erroneous. A uniform form design should be adopted across all provinces for recording control activity data. While review of form design is important, it is suggested that this be done no more frequently than on an annual or bi-annual basis to allow reasonable consistency of data collection. Production of a simplified report form, containing fewer questions (or variables), and of a uniform design across the entire country, will greatly increase the completeness and quality of data collected. A draft of a modified form design is presented in this thesis.

Storage and retrieval of control activity data should be reviewed and changed where necessary. Implementation of an effective, computer database, for storage and retrieval of data, would overcome many of the problems experienced during this study. The system adopted should be simple and should be implemented across the country to facilitate the development of a uniform and standardised method of storing and retrieving data.

Data analyses and reports should be performed regularly and summary reports presented to all levels of the system. Effective use of data will increase motivation levels of all staff involved and assist in maintaining collection of complete and high quality data.

Finally, collection of high quality data on rabies control in Thailand would be facilitated by a greater level of co-operation and collaboration between different organisations responsible for aspects of rabies control. It appears that some of the problems in the collection of data were associated with the fact that certain control activities and collection of data regarding those activities, are the responsibilities of different organisations or different levels within a single organisation. This is believed to have contributed to inconsistencies regarding estimates of control activities or estimates of human rabies cases for example, in reports produced by different organisations or different levels within an organisation.

The general methodology employed in modifying the systems for rabies monitoring and surveillance could then be applied to other projects.

Descriptive analysis

Surveillance data

Rabies positive cases per year

Data concerning all records cases of rabies in animal and people in Thailand between 1993 and 1999 were included in this thesis. Human rabies cases are likely to represent the true pattern of the disease in Thailand. Animal rabies cases depend on submission of suspected cases for definitive diagnosis and data in this thesis are likely to under represent the actual cumulative incidence of animal rabies over the study period.

In addition not all cases of rabies in animals or people, are diagnosed based on results of laboratory tests. Variations in test performance (sensitivity and specificity) for those tests used to diagnose rabies, may also influence the relationship between reported cases and the true disease pattern.

Cumulative incidence measures as reported in this thesis, are also dependent on estimates of population time at risk. Human population data is considered to be reasonably reliable but estimates of dog populations are likely to be crude approximations. These factors suggest that cumulative incidence estimates in the dog population in particular, are likely to be crude approximation.

Percentage of rabies cases submitted per year that are positive has been decreasing since 1994 but became steady from 1998 and is currently down to less than 30% of animal cases submitted. This finding is in agreement with Wasi et al (1997) that the positive rate of submitted cases for rabies diagnosis declined from 65% in 1980 to 45% in the 1990s (Wasi et al., 1997). The number of submissions was also decreasing which might have resulted from the fact that people exposed to suspected animals immediately had post exposure treatment and ignored submission of animals for diagnosis. The other reason might be to avoid the inconvenience of specimen submission due to packing process, transportation, and cost of submission, particularly from remote areas where no diagnostic laboratory is available. Extending diagnostic laboratory services is not an effective way to solve the problem compared to improvement of specimen delivery, as the maintenance cost of a diagnostic laboratory is higher than submission expenses.

Throughout the year canine rabies occurred in two peaks, during December to February and during September to October. Cases were lowest in June and July. This agreed with Tepsumethanon 1997 that dogs rabies was high during January to April while Choomkasien reported in 1988 that dog rabies cases were high in two peaks during December and March and during July and August. The report was presented in a different period of time and with different numbers of data but showed a similar pattern.

It has been agreed that rabies is spread during the mating seasons which occur during two periods of time each year, late October to January and May to June particularly in male dogs which are fighting for the female (Tepsumethanon et al., 1997). Malaga et al. (1979) also found that in developing countries higher numbers of dog rabies occurred during periods of mating behaviour.

With an incubation period of one to three months, dogs exposed during the mating season then show signs of rabies during December to February, which is summer time in Thailand. This makes people believe that rabies is caused by hot weather and occurs in summer only.

There was no record of sex of animal in the surveillance dataset but from the records of dogs submitted for diagnosis at the Rabies Centre during 1979-1985, two thirds of the positive cases were male dogs (pers. comm, Panichabhongse 2001, Unpublished data).

Rabies cases per district and province appear to be much varied. All provinces reported cases but the cumulative incidence varied widely. One hundred and ninety five districts that submitted specimens for diagnosis had no rabies case reported while 62 districts had more than 80% of rabies positives from cases submitted and 288 had not submitted dog specimens for rabies diagnosis. This may be due to multiple factors such as geographic, religious, demographic, and/or political, etc. Capability in specimen submission, knowledge of people in that province and the priority of office work compared to other livestock projects, which need to be concentrated in that province, were other important factors affecting regional variation in reported dog rabies positive cases.

Active surveillance

The active surveillance data available in this study showed no evidence of rabies. In the past, Srisongmuang et al. (1994) studied rabies carriers in rodents in Bangkok and adjacent areas and found 1% rabies positive in rat (4/384), 0 % in squirrel (0/52) and 20% in tree shrew (2/10). The report also referred to two studies by Puangsab and Lawhasawat who found 15% and 13% of rats positive to rabies in rats trapped from Chieng Mai and all over the country in 1964 and 1977 respectively. Other reports cited by Srisongmuang et al. included studies by Smith et al. (1968) who found 4% positive rabies in rodents and Sajaotz (1968) who found 8% rabies positive in rats in eastern part of Thailand. In contrast Sawasdikosol (1976) (cited in Srisongmuang et al., 1994). found no rabies in rodents from 3 provinces in the western and southern part of Thailand (Srisongmuang et al., 1994). In 1997 Kamoltham et al. (1997) studied a carrier status in dog, *Hipposiderous bicolar* bats and house rats in Petchaboon and found no rabies positive case.

Types of animal

More dogs were submitted than other animals and a greater proportion of dogs were positive compared with other animals. This agreed with previous opinion that dogs are the main reservoir of rabies in Thailand. Dogs accounted for 87% of animal submissions and 94% of total positive cases. Kingnate et al. (1997) reported that dogs are the main transmitter of rabies (>96%) in Thailand and Singhchai (1998a) reported that in Bangkok dogs accounted for 96% rabies positives from animal submissions. In the neighbouring countries such as Myanmar, Aye (1997) also reported that dogs were responsible for 95% of total rabies positive cases.

Animal history

Submissions from non-owned dogs and dogs with unknown ownership status were more likely to return a positive test than owned dogs. This is consistent with evidence indicating that vaccination can reduce the transmission cycle of rabies and owned dogs are more likely to be vaccinated than strays. Mitmoonpitak et al. (1997) reported that rabies tended to occur more in domestic dogs than strays but the ratios of positive cases to submissions were the same.

Age of animal

From this study, age of animal appeared to have little effect on likelihood of a rabies positive result. Perry (1995b) commented that young dogs may play a major role in rabies transmission cycle as young dogs are frequently excluded from vaccination programmes. Kasempimolporn et al. (1996) studied rabies antibodies in Thai puppies (1-4 month olds) and found that there were no protective antibodies even in the puppies from vaccinated dams. This agreed with Mitmoonpitak (1997) that 14% of rabid dogs were less than 3 months old and 62% were under six months (Eng and Fishbein, 1990). Moreover more than 60% of domestic rabid dogs were less than 12 months old as they are more active and are most likely unvaccinated (Mitmoonpitak et al., 1997). However nearly 30% of the data of age of animal available for this study were unknown, as it was difficult to specify age of animals.

Vaccination history

Vaccination within the last year prior to submission appeared to reduce the likelihood of a positive result with the exception of animals vaccinated within the month prior to submission. This is consistent with vaccination being protective against rabies. The risk of a positive result in animals vaccinated more than one year prior to submission appeared to rise compared with those vaccinated within the previous 12 months. This supports the idea that protection from the vaccine wanes after 12 or more months and therefore revaccination should be an important part of the control programme.

Symptoms

Animals submitted showed either furious or dumb symptoms. Animals which showed furious signs, were far more likely to return a positive test (65-70%), compared with animals showing dumb signs or no abnormal symptoms.

Furious signs were the highest risk and more hazardous compared to dumb symptoms and other signs as the animals attacked other animals and spread the disease or attacked people seriously. Furious symptoms also raise public awareness for people exposed to suspected dogs, and encourage both post-exposure treatment and for people to vaccinate their dogs. However dumb rabies might reduce awareness and cause ignorance in post-exposure treatment.

Other animals contact

It seems logical to expect that most animals submitted for diagnosis should have some history of contact with another animal or person. However a large proportion of animals are submitted with no evidence of contact. This may be due to heightened awareness amongst people to submit animals showing any abnormal behavioural signs rather than concentrating only on animals which have attacked other animal or people.

It is also interesting to note that animals which do attack other animals or people, and in particular if they attack both, have a much higher risk of being rabies positive than animals with no history of contacts.

From this study 53% of dogs which were rabies suspected and killed were rabies positive. In stray dogs, Singhchai (1998a) reported that 2/29 of stray dogs that naturally died while caged for euthanasia were found to be rabies positive while of 2% (3/141) the ones which were killed were found rabies positive.

Human death

Reports of human deaths showed that the number of human deaths declined from 77 in 1993 (0.13 per 100,000 population) to 54 in 1998 (0.09 per 100,000), rose up to 68 (0.11 per 100,000) in 1999 and fell again to 48 deaths (0.07 per 100,000 population) in 2000. This might be due to the continuous control activity and co-operations among organisations involved in rabies control in Thailand. Higher percentage of dog vaccination, public relations and other control activities appeared to be effective at reducing rabies incidence. Changes in submission rates of suspected animals over time may also account for some of the perceived decline in dog cases. However, inadequate control activity particularly in stray dogs, and budget constraints, are still problems which need to be solved. The numbers of human deaths decreased in every part of Thailand but became higher in the central area. The monthly pattern shows a rise in January and February and April and a low point in July to October.

Dogs were far more likely than any other species to be associated with human deaths due to rabies. This supports the notion that dogs are the primary reservoir of rabies.

Almost all provinces reported at least one death but there are only a small number of provinces with more than 5 deaths. This variation in risk is explored more in the multivariate analysis. Again it is possible that risk-based control concentrating in high-risk regions, may be an effective way of continuing the fight against rabies.

From the author's experience, almost all of the deaths did not receive post-exposure treatment due to lack of knowledge about rabies, ignoring minor wounds or exposures, being treated by traditional treatment or difficulty in transportation for vaccination. However, Puanghat (2001) reported that amongst patients that received treatment before they died, thirteen deaths received both vaccine and immunoglobulin, of those two had lower dose of immunoglobulin than recommended, and two had intradermal vaccination, sixteen deaths received only vaccine and two deaths received correct treatment for category 3 wound. This agreed with Wasi (1997) that delayed vaccination, inappropriate wound care, serious wounds with multiple bites on the face, and absence of rabies immunoglobulin were considered to be the causes of treatment failure (Wasi et al., 1997).

These problems were also found in almost all the countries in Asia. In Vietnam, Xuyen (1997) reported that most of the deaths (94 to 97%) were due to no or late vaccination or use of traditional medicine. Yongxin and Qing (2001) reported that rabies associated deaths in China were due to patients living in remote areas receiving no, delayed, incorrect or incomplete post-exposure treatment.

Human age and gender

These analysis showed that males were about twice as likely to get rabies than females. This was similar to many neighbouring countries, in Myanmar the ratio of male: female was 3:1 (Hla, 2001) the same as in Sri Lanka (Wimalaratne, 2001). Fekadu et al (1982) reported that most of people in Ethiopia who died of rabies are under 40 years and among adults, the majority were males (Srisongmuang, 1992).

In these analyses, people under 10 years (33%), and over 50 years old (20%), were about three times more likely to get rabies than people aged between 20 and 30 years and there was no difference between males and females with respect to the age association with rabies risk.

Increased risk in children might be due to childhood behaviours such as touching or playing with puppies, dogs or other animal with accidental or intentional provocation resulting in the child being bitten by the animals. If the bite wound was not serious, the children would not let parents or teachers know until it was too late.

The risk of rabies is higher in the Northeast and Central part of Thailand than in the North or the South. Puanghat (2001) reported that from 48 deaths in 2000, 25 were in the central region, 11 in the north-eastern and 6 in the northern and the southern region respectively. Most of the deaths were associated with dogs, of these 47% were from strays and 57% were from pets. Puppies under 3 months of age accounted 18 to 31% of these deaths.

Control activities

Dog population

Bangkok has a much higher dog population (579,603 in 1999), than any other province. There is much variation in estimates of dog population between provinces. Since dogs are the primary reservoir for rabies, it seems logical to consider concentrating animal based control activities in these provinces with higher dog population density.

Vaccination

Vaccination against rabies appears to follow a definite seasonal pattern in activity with most vaccine being administrated in March and April (summer time). This is due to two main reasons: public awareness that rabies usually occurs only in summer stimulates dog owners to vaccinate the dogs in summer, a large number of vaccine doses obtained by DLD budget for free vaccination are distributed during February for rabies vaccination campaign due to the fiscal year budget process. Tepsumethanon et al. (1997) suggested that mass vaccination should be done during October or before as it can reduce transmission cycle during the mating season. However, from the author’s experience, changing people’s attitude about rabies in summer is less likely to be successful after ten years of public relations encouraging February and March vaccination. To take advantage of people’s attitude, rabies vaccination campaigns are programmed and promoted in March, which is summer time.

The total number of vaccinations administered each year has risen dramatically since 1993. However only relatively few provinces appear to be exceeding the recommended minimum 70-80% vaccination coverage. In addition it is not known what proportion of animals receive follow up vaccinations in subsequent years.

Vaccination is believed to be the most effective way to control rabies. In spite of a relatively high proportion of dogs being vaccinated against rabies the incidence of rabies in Thai dogs is still relatively high. There are many reasons which need to be considered and solved. These reasons include:

Inadequate accessibility to vaccinate target animals for vaccination

Most of the dogs vaccinated were owned dogs which could be restrained while stray dogs are mostly inaccessible for vaccination. Perry et al. (1995b) suggested that the major constraints to effective dog vaccination programmes are poor accessibility of dogs for vaccination, inadequate availability of vaccines in some countries and the relative high cost of vaccines. The author was involved with a survey of attitudes of people participating in a rabies vaccination campaign in temples and slum areas in Bangkok during the rabies vaccination campaign in 1995. The results showed that three main reasons owned dogs were not vaccinated were dog owners had no time to take the animal to a clinic or vaccination site, the animals could not be restrained, and inconvenience associated with transportation of animals to vaccination site (unpublished data).

To increase coverage of vaccination, mobile vaccination units or door to door vaccination and timing vaccination to coincide with school holidays should also be considered. In addition ecological studies should be performed in urban communities to identify ways of improving vaccination delivery and coverage (Perry et al., 1995).

Oral rabies vaccination is an alternative option to solve some of these problems. Sagarasaeranee et al. (2001) studied efficacy of the oral rabies in non-initial immunity Thai stray dogs and found that both neutralising antibody (Nab) and Cell-Mediated Immunity (CMI) could be detected on day 30, peaked on day 180 and started decreasing on day 360.

Knowledge and attitude of people toward rabies vaccination

Limlamthong et al. (1994) surveyed the attitude of people who participated in rabies control in temples and slum areas in Bangkok and found that 60% thought that only dogs and cats can get rabies and 69% thought that rabies was caused by hot weather and occurs only in summer.

In Bangkok and some areas there were numbers of dogs vaccinated twice or three times a year as the owners took the dogs to a clinic to vaccinate and then to a vaccination site for free service during the campaign. In contrast some dogs were vaccinated only once during their life, as some owners believed that only one rabies vaccine injection could protect the animals for life. Moreover most of the dogs vaccinated were not confined in the premises, most of them contact and fight with other dogs particularly strays in mating season. Singhchai (1998a) studied dog ecology in Bangkok and found that stray dog euthanased by BMA and submitted for rabies diagnosis in 1989 and 1997 returned 2 and 10% rabies positive. Increased exposure risk in vaccinated dogs under the belief that they are immune to infection may explain some of the rabies cases in these animals.

Immune response due to vaccination

There are many factors affecting immune response in animals vaccinated with rabies vaccine. Efficacy, duration of immunity and safety of vaccine used for vaccination are very important for mass vaccination campaigns. Moreover routes and techniques of injection and age of animal might have an effect on immune response. The protective threshold of rabies neutralising antibody defined by WHO is 0.5 IU/ml (Chomel B. et al., 1987).

Chomel et al., (1988) studied a serological survey of vaccinated dogs in the massive vaccination campaign in Peru in 1985 using tissue culture rabies vaccines under field conditions. They found that the vaccine induced neutralising antibody titre of >= 0.5 IU/ml which lasted for at least 1 year in 97% of vaccinated dogs. This decreased the number of animal rabies cases from an average of 292 per year since 1980 to 3 after the campaign. Bingham et al. (1999) also reported that there was a significant negative relationship between the annual number of rabies vaccine doses administrated nationally to dogs and the annual number of dog rabies cases the following year.

In Thailand Choomkasien et al. (1991) reported a 100% seroconversion rate of >0.5 IU/ml on day 60-75 in dogs vaccinated by single dose cell culture vaccine intramuscularly. The same outcome was seen regardless of whether the dog had been vaccinted before or not. Sagaraseranee et al. (1992) reported that seroconversion rate of >0.5 IU/ml was detected in 97% of dogs with no prior rabies vaccination by day 30 after vaccination with cell culture vaccine and that this level of immunity lasted for 730 days. There was no significant difference among age groups nor parasitic condition. Tepsumethanon et al. (1991) also reported that age and parasitaemia had no effect on neutralising antibody titre in dogs vaccinated subcutaneously by tissue culture vaccines but the titre rapidly declined (lower than 0.5 IU/ml) by day 60 after vaccination.

Soares et al. (1992) studied responses to vaccination in three groups of dogs vaccinated and kept in various conditions and found that after vaccination dogs in good condition had higher antibodies against rabies than dogs in bad condition. This may explain why vaccinated stray dogs might have insufficient immunity to protect against rabies.

Perry (1995a) commented that young dogs may play a major role in the rabies transmission cycle and should be vaccinated before three months of age. Cliquet et al. (2001) found that puppies under three months responded to vaccination without interference between active and passive immunity and suggested that parenteral vaccination should be given to dogs of all ages in a mass vaccination programme.

Failure of rabies vaccine protection is another factor causing unsuccessful control programme. Okoh (1982) reported 14 rabies positive cases in 1,200 vaccinated dogs submitted for diagnosis in Nigeria during 1970 to 1980. Seventy one percent (10 /14) were due to vaccine failure and about 18% (4/10) were suspected to be induced from modified live vaccine. Tepsumethanon et al. (1991) also reported that 9% of the dogs found to be rabies positive had been vaccinated within the previous year.

Other rabies reservoirs particularly cat and rodents also help to maintain rabies transmission cycle and are associated with human deaths. Field (2001) reported two human deaths in 1997, one was associated with a cat and the other with a chipmunk. In 1998 one human death was reported associated with a wild civet and one with a cat and in 1999 two human deaths were associated with cats.

It is the author's opinion that the general public does not seem to be aware that they can get rabies from these animals. Public relations and education are to be considered.
Singhchai, 1998 reported that from the dog population survey in Bangkok in 1997 that the ratio of female to male dogs in Bangkok was about 3:2 in non-owned dogs and 2:3 in owned dogs. Birth rate was about 7% and death rate was about 3%.
WHO recommendations stress the importance of adequate vaccination coverage. It appears that the vaccination programme, whilst greatly improving in coverage during the study period, is still not achieving recommended targets. More efforts and resource needs to be put into the vaccination programme. Currently non-government organisations, private practitioner participation, trained village volunteers, community funds in tourist areas and subdistrict have been implemented in many provinces.

Dog population control

Other control activities aimed at dog population control seemed to be not effective as they were applied to low percentages of the total dog population for the whole country. Difficulties in applying population control activities include the methods of dog control such as surgical methods, castration and spey, need for special equipment, skills and are time consuming. In addition, only a small percentage of province dog populations are subjected to other forms of control (hormone injections and killing). These methods are highly unlikely to be contributing, to the control or eradication of rabies in the dog population. An exception will be those provinces where a larger proportion of the dog population is subjected to control methods on an ongoing basis.
Dog removal in some countries including Thailand is difficult and city-wide dog removal is not affordable, practical or acceptable. In the past dog killing programs have not decreased the dog population over time, but often have exacerbated the problem by removing older, possibly vaccinated dogs and allowing younger, more rabies-susceptible dogs to replace them. The most important concept for the approach is to maintain stability of the dog population while vicious and rabies suspected animals are removed. The vaccination program should be carried out to reach as many dogs as possible (70 to 80%) to break the dog to dog transmission cycle.

As euthanasia is seriously objected to Thailand, other practical methods for dog sterilisation of both male and female should be considered. Lohachit and Tanticharoenyos (1991) mentioned four methods of male dog control. These methods are surgical methods, chemical sterilisation by injecting a chemical substance into the testis or epididymis to stop sperm production or block the sperm pathway, medical sterilisation by injecting or feeding a hormone or medical substance to stop sperm production and mechanical method by using a locking clamp applied with a burdizzo. The two possible and more practical methods which might be acceptable and make less complication, are vasectomy and medical contraception by feeding with a local herb powder for a few weeks. (Lohachit and Chatdarong, 1997)) suggested that a modified vasectomy clamp used in humans is a fast, easy and successful method suitable for field and mass sterilisation. Currently the Bangkok Metropolitan Administration has started this method instead of castration.

Lohachit and Tanticharoenyos (1992) also mentioned six methods for birth control in bitches. Oariohysterectomy, the currently used surgical methods seems to be the most effective method. Pharmacologic contraception by using hormones such as medroxyprogesterone to inhibit estrous or ovulation may be more practical and cheap but needs to be given at an appropriate time followed by repeat injection every 6 to 12 months. Traditional contraception using local herbs have been used by local people in some remote areas and may represent another choice for mass contraception.

Lohachit and Tanticharoenyos (1992) and (Fayrer-Hosken et al., 2000) reported immunocontrol in dogs by vaccinating with purified zona pellucida (ZP) glycoproteins which initially leads to immunocontraception and then to irreversible changes or immunosterilisation. The principle is inducing anti-ZP IgG antibodies by injecting reproductive ZP glycoprotein. The anti-ZP IgG primarily block fertilisation at the sperm-zona interaction site. This produces an immune response which destroys oocyte and granulosa cell complexes causing ovarian follicular atrophy and leads to immunosterilisation. This method is recommended to be an effective and practical technology for worldwide dog population control.

According to WHO, two basic approaches to canine rabies control have been used to manage dog population control. All dogs in the city should be owned by individual households and the dog population should be stabilised and controlled by each dogs’ owner. Dogs should be restricted to their own premises or be on a leash when off the owners’ premises.

Currently the Department of Livestock Development in co-operation with the Department of Communicable Diseases Control, the Tourism Authority and the Thai Red Cross Society have launched a pilot project of dog passports in Samui Island in the South of Thailand which is the second tourist island declared to be a rabies free zone (the fist one is Samed Island in the East). The passport restricts the dogs to be in a Rabies Free Zone to assure the tourist of the rabies free status. This project will be extended to other areas all over the country (Leelaluckana, 2001).

Consideration could be given to improving the control methods which are more practical and acceptable, providing mobile units with low cost charges or focusing on rabies high risk areas with the initial goal being to at least to maintain the dog population number.

Public relations

The author strongly believes that education is the most effective way to control rabies and reduce the number of human deaths. As mentioned above several studies have suggested more than 90% of human deaths were due to no post-exposure treatment and improper or delayed treatment which might be due to lack of knowledge about rabies and rabies control.

More than ten types of public relations media such as videotapes, tape cassettes, handbooks, brochures, stickers, exhibition sets and slides, television spot advertisement etc were created by the author to suit target groups particularly the high risk groups (primary school children). These media were distributed to the DLD local officers and other organisations responsible through the village volunteers, primary school and communities for more than seven years.

The data of public relations activity were not recorded in a manner conductive to analysis due to difficulties in enumerating the unit of the activity, and were available only in 1997. This form of activity is believed to be effective but could not be assessed due to the lack of completeness of the data. However the beliefs in traditional treatment in some groups of people particularly in remote areas are difficult to change.

GIS and Spatial analysis

GIS

The results of the analyses conducted on the 1994 data show that increasing percentage of dog vaccination was associated with an increased the risk of rabies in humans. This might be explained as follows:

Most of the dogs vaccinated were owned dogs and a higher number of human deaths due to rabies in that area may have stimulated the dog owners to vaccinate their dogs. Singhchai (2001) reported that an approximate yearly incidence of human rabies in Bangkok is 0.1-0.125 per 100,000 population. All of those were bitten by unvaccinated stray dogs and none had post exposure treatment. This might have resulted from Bangkok having the highest population number (523,230 owned and 110,584 strays in 1999) and that about 86% of owned dogs were vaccinated. The BMA policy for rabies control is based on Thai religious and cultural beliefs for public co-operation.

Another reason is the belief that vaccinated dogs would not get rabies resulting in people ignoring or delaying the post exposure treatment. Three people bitten by vaccinated dogs died of rabies, two due to no post exposure treatment and one due to delayed treatment.

Singhchai (1998b) studied dog ecology in Bangkok and found that rates of rabies in human and dogs were increasing in the areas which had higher density of stray dogs.

Spatial analysis

Standardised mortality ratios (SMR) may be used for presenting mortality data for populations when the data are organised on a geographic basis. For a single time period (internally standardised) SMR plots allow one to identify regions of high risk of disease relative to the ‘average’ risk for all regions. By definition, the interpretation of the SMR plots presented in this chapter differs from the cumulative incidence plots that have been used elsewhere in this thesis. Whereas plots of cumulative incidence estimates show absolute values, allowing one to assess the change in the spatial pattern of rabies over time, internally standardised SMR plots are generally more suitable for identifying regions with excess risk of disease for single time frames of investigation.

In 1994 human rabies SMR estimates showed considerable variation across the country. Because disease counts for each province are low it should be noted that there is considerable error associated with each province-level estimate of rabies SMR. In 1999 provinces with elevated human rabies SMR are predominantly clustered around the centre of the country. These interpretations are supported by the spatial correlograms shown in Figure 4-47. In Figure 4-47, for the 1994 and 1999 data a global Moran's I statistic (and 95% confidence interval for the statistic) has been calculated to quantify the degree of spatial autocorrelation in human rabies SMR at various spatial lags. In this context, a global Moran's I statistic calculated using a first order spatial lag identifies how similar the SMR estimate is for adjacent provinces and a Moran's I statistic calculated using a second order spatial lag identifies how similar the SMR estimate is for provinces separated by one other province.

In 1994 there was no evidence of spatial autocorrelation in human rabies SMR (the 95% confidence intervals for all Moran's I statistics include zero). In contrast, the spatial correlograms computed for the 1999 data identify significant positive spatial autocorrelation in human rabies SMR (that is high rabies SMR provinces are likely to be near other high rabies SMR provinces and low rabies SMR provinces are likely to be near other low rabies SMR provinces). The 1999 data shows an element of spatial clustering of the disease that was not apparent in 1994.

Initial fixed-effect Poisson models included only non-spatial information as explanatory variables. To identify non-accounted for spatial heterogeneity in the data, the degree of spatial autocorrelation present in the residuals from the fixed-effect models was assessed. Where spatial autocorrelation did not exist in the residuals terms, it was conceded that the fixed-effect model adequately explained rabies SMR. Where spatial autocorrelation existed in the residual terms produced by the fixed-effect model, I proceeded to fit a mixed-effect Poisson model including spatially structured and unstructured random effect terms (Besag et al., 1991). In the analyses presented, the fixed-effect model for the 1994 data showed no evidence of spatial autocorrelation in the residual terms (Moran's I -0.58; P = 0.56) whereas significant autocorrelation was present in the residual terms produced for the 1999 data (Moran's I 2.13; P = 0.03).

Results of the fixed-effect models produced for the 1994 and 1999 data were similar. For both time periods the proportion of dogs vaccinated in a province showed no relationship with human rabies SMR. Increases in human population density were associated with a small reduction in the province-level relative risk of rabies. For each one unit increase in the square root of human population density the province-level relative risk of rabies was 0.80 (95% CI 0.65 - 0.92) and 0.89 (95% CI 0.83 - 0.96) for the 1994 and 1999 data, respectively. In contrast, dog density and the SMR for canine rabies was strongly associated with human rabies relative risk. For each one unit increase in square root of dog population density the province-level relative risk of rabies was 1.58 (95% CI 1.07–2.58) and 1.44 (95% CI 1.16–1.73) for the 1994 and 1999 data, respectively. For each one unit increase in square root of the estimate of canine SMR the province-level relative risk of rabies was 1.32 (95% CI 1.04–1.65) and 1.35 (95% CI 1.13–1.59) for the 1994 and 1999 data, respectively.

A mixed-effect model was applied to the 1999 data in an attempt to explain some of the spatial components in the pattern of rabies incidence. In the mixed-effect model the term describing the proportion of dogs vaccinated against rabies was dropped because it was not significant in the fixed-effect model. The relative risk estimates from the mixed-effect model were similar to those reported in the fixed effect model but the confidence intervals were greater, reflecting the effect of incorporating random variation into the model.

The greater variance of the spatial heterogeneity term relative to the variance of the unstructured term implies that there was a spatial component in rabies risk across Thailand in 1999. To investigate this further, the spatial random effect terms were plotted (expressed as a relative risk) as a chloropleth map in Figure 4-48. Figure 4-48 identifies a well-defined area in the south of the central region of Thailand where, after controlling for the effect of human population density, dog population density, and province-level SMR for canine rabies, there was elevated risk of human rabies.

The changes in human rabies incidence from 1994 to 1999 are considered to be a result of the control measures applied throughout this period. In 1999 human rabies showed a distinctively clustered pattern with the highest SMR of disease in the centre of the country. These analyses show that the risk of human rabies was elevated in provinces with a high density of dogs and provinces where the SMR for canine rabies was high.

Additionally, in 1999 the south of the central region of Thailand demonstrated an elevation in the risk of rabies that was not associated with these factors. Studies specifically focussed at this 'problem' area should enable other risks for human rabies to be identified and controlled.

New design for data reporting form

Basic variables needed in data recording form

The goals of a successful rabies control and eradication programme are no human deaths due to rabies, and no incidence of rabies in any animal. The principle control methods are animal vaccination against rabies, animal population control and education or Public Relations.

Perry (1996) has commented that quality of data collected in many countries, particularly in developing countries, is less than optimal, either due to excess unwanted data or not enough important data. These difficulties are often due to a lack of epidemiological knowledge or the fact that a data collection form has been designed for too many different purposes.

Recording forms often incorporate a broad range of factors or variables, which may or may not be useful in interpretation and analysis of results associated with a particular outcome. A form with unnecessary or insufficient variables should be re-designed.

To be able to perform epidemiological analyses and control programme evaluation, essential and accurate data are needed. One essential requirement to improve the quality of information is to develop the form based on standardised data requirements for disease reporting; outlined in WHO (1992). This should include key data such as age, location, etc which are concise, clearly defined and simple to complete.

Essential data for analysis

For data analysis, outcome variables, numerators and risk factors are needed. The outcome variables, which are indicators of the success of the programme, are cumulative incidence of human death due to rabies and animal rabies.

Epidemiologic and economic data required for monitoring rabies are incidences of confirmed dog and human rabies, temporal and spatial distribution of cases, case data and number and cost of post-exposure treatment in human and control costs in dogs (WHO, 1992). According to the analysis of rabies data in Thailand from 1993 to 1999, dogs accounted about 96% of rabies in human and cats did about 3%. Five main sets of data required for epidemiological analysis and programme evaluation are

?? Human deaths due to rabies

?? Human population or human density

?? Dogs rabies positive data from animal surveillance

?? Dog population or dog density data

?? Rabies control activities which are dog vaccination, dog population control and public relations

Human deaths due to rabies data and associated data

Numbers and details of human deaths due to rabies are needed, including age, gender, geographic location of exposure, anatomical site of wound or exposure and date of exposure, type of post exposure treatment, date of death, species of animal associated including, age, sex, vaccination history, and status of animal. This form is the responsibility of Ministry of Public Health, and is generally quite complete except some missing values in animal associated details.

Human population data

This set of data serves as denominator data and is well organised and publicly accessible from http://www.dola.go.th Yearly human population numbers by gender are reported from provincial to sub district level including numbers in each range of age.

Dogs rabies positive (surveillance) data

The number of dog rabies cases is an important outcome variable to indicate animal rabies incidence. Both passive and active surveillance data are essential data required.

The current data form for both passive and active surveillance consists of 15 variables covering several associated risk factors. Sex of animal (dog) has not been recorded to date and may be associated with the risk of rabies in dogs.

Active surveillance involves gathering of brain tissue from samples of animals with no suspicion of being rabies positive. Over the last several years numbers of animals being submitted through the passive surveillance scheme have steadily declined. It was thought that active surveillance might help offset the decline in passive surveillance, maintaining an overall surveillance effort on rabies. However active surveillance targets have consistently never been met and active surveillance has not yet identified a single rabies case. There appears to be little doubt that a combination of active and passive surveillance is most suited to the continued effort to control rabies. Active surveillance as it is currently implemented, appears to be offering little real value to the rabies surveillance programme. It is suggested that the active surveillance programme be re-assessed to ensure that the programme does contribute information of value. One possible modification might be to target active surveillance to particular regions either on a rotating basis or according to assessment of risk. In addition, given the nature of the programme, less data may be collected on associated variables e.g. type of animal, sex, animal status and geographic location.

From the result of quality analyses of passive surveillance data from 1993 to 1999, age, ownership history and vaccination history of animal had high percentages of missing values. This may have resulted from development of the report form from year to year, with ownership and vaccination history only included from 1998 and 1999. Age of animal is a variable more likely to be missing or to have low accuracy due to difficulties in estimating the actual age. However age of animal is one of the essential variables which needs to be recorded. Instead of six categories of variable, this variable could be simplified to two categories, less than one year and greater than one year old.

Dog population data

Population numbers of dogs or other target species are required as denominator data for assessment of vaccination coverage and cumulative incidence. Dog population, which is the key denominator, should be recorded with high accuracy using a reliable method. As a dog census is costly and dog population is unlikely to change dramatically within two to five years, this might be done every 5 or 10 years and the numbers either used for the next 5-10 years or adjusted by estimating the birth, puppy survival rate, death rate and life expectancy. Alternative methods include extrapolating from human population by a common dog:human ratio estimated by (Bogel et al., 1984) (Bogel, 1984) (1:8 to1:11) or by standard statistical sampling methods.

The most essential data are total dog population, total number of owned and non-owned or stray dogs, total male and total female dogs.

Rabies control activities data

Rabies control activity recording is mainly under the responsibility of the Department of Livestock Development. Data from three main control activities, dog vaccination, dog population control and public relations are essential for control program evaluation at both provincial and district levels. Current recording forms used for rabies control activity at district and provincial levels consist of 72 and 42 variables respectively. Some of these overlap (e.g. number of dogs vaccinated and charged was the sum of number of dogs vaccinated and charged by DLD and number of dogs and vaccinated charged by other organisations). Some had details which were either difficult to access (e.g. number of dogs vaccinated charged by other organisations), or unnecessary for analysis (other animals vaccinated), as no population number was recorded.

The result of data quality analyses showed that only 17 variables in district data activity and 10 variables in province data activity contained greater than 80% valid data (data equal to 0 or greater than 0). Almost all of these variables represented overall totals for control activities in dogs. In this project only totals were used for analysis.

?? **Vaccination data**

Free and charged numbers of dogs vaccinated are required in the recording form.

?? **Dog population control data**

Total numbers of dogs injected by hormone, castrated, speyed and euthanased should be sufficient for data analysis.

PUBLIC RELATIONS

There were eight variables for public relations activity. Data for these were only recorded in 1997 provincial activity records. It is suggested that recording of public relations activities be simplified by reducing the number of variables into 3 broad categories.

These variables should be grouped into audio media which include radio broadcasts and village amplifiers, visual media which include newspaper and exhibition and education by training. These activities were done in small numbers or none in each month. Changing the way data are collected on these activities may also facilitate collection of accurate and complete data. One alternative may be to report most activities in categories e.g. none, 1-3 and >3. An exception to this may be village amplifier activity and numbers of exhibitions which could be recorded using an actual count of activities. In addition published documents as other public relations and training of both villagers and dog owners and village volunteers should be reported by number. TV broadcast is quite costly and mostly managed by head office (Rabies Centre). Number of education by training has been targeted per province per year with the budget provided. This activity per month depends on the local officer management but the total number should be close or same as the target.

New design for data recording form

A draft list of variables for collection of monthly rabies control activity data, is presented on the following pages.

Draft list: Variables included on control activity data collection form

Month
Year
District name District code
Province name Province code

Dog population summary

Dog owned male	(number)
Dog owned female	(number)
Dog non-owned male	(number)
Dog non-owned female	(number)

Control activity

Vaccination	
Number of dog vaccinated free	(number)
Number of dog vaccinated charged	(number)
Dog population control activity	
Hormonal injection	(number)
Total dogs received hormone injection	(number)
Castration	
Total dogs castrated	(number
Spey	
Total dogs speyed	(number)
Dog destruction	
Total dogs killed	(number)
Public relations	
Audio media	
Village amplifiers	None Done (number)
Radio programme	None 1, 1-3, >3
Visual media	
Newspaper	None 1, 1-3, >3
Exhibition	None Done (number)
Published documents	(number)
Training	
Villager trained	(number)
Village volunteer trained	(number)

Person entering
Date recorded

The data recorded in this form will be aggregated for province and region data. These data can be used for monthly, six-month period or yearly control programme evaluation in that province or region by adding some variables of surveillance, human death, and human population in the province or region. For rapid and effective reports, computer processing is recommended.

For the National Rabies Control Programme evaluation, overall yearly data of control activity, human deaths attributed to rabies, surveillance and human population from organisations responsible for the entire country should be aggregated and analysed.

Conclusion

This thesis represents an important contribution to the rabies control programme in Thailand, through analyses of data collected over a seven year period (1993 to 1999), by several organisations involved in the control programme. Although the data were incomplete, this does not in any way detract from the validity and usefulness of the conclusions.

A large amount of descriptive information is presented regarding the patterns of the disease in animals and people, including spatial patterns. This is of great use in understanding the epidemiology of rabies in Thailand and in designing an effective and ongoing control and eradication programme.

The incidence of rabies in animals and people has declined considerably during the 7-year period covered by this study. This decline can be attributed to the effectiveness of rabies control activities and in particular, dog vaccination, effective post exposure treatment and public awareness campaigns.

Several factors have been identified which collectively suggest that aspects of the rabies control programme would benefit from review. These include:

?? The rate of decline in annual cumulative incidence of rabies in people has slowed during later years.

?? Submissions of animals for rabies monitoring and surveillance under the passive surveillance scheme declined considerably during the 7-year period and present a threat to the continued collection of information critical to the control programme.

?? Vaccination coverage rates for dogs in many provinces are less than the recommended threshold of 70% of the population and poor vaccination coverage of non-owned dogs is thought to be a major reason for this.

?? Methods for collection of control activity data at the district and province level appear to be suffering from a non-standardised and unwieldy form design (with consequent incomplete data collection) and fragmentation of control and monitoring efforts between many different organisations and personnel.

?? There are several provinces in the central and eastern area of Thailand where an unexplained and elevated risk of rabies appears to exist. Further investigation in these areas is warranted to identify the reasons for this elevated risk.

It is critical that adequate resources be invested in the rabies control programme in order to ensure successful eradication of this devastating disease from Thailand.

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Appendix I

Data entry form for data collection

Data entry of control activities:

********************** {Today}'s date:<today>

* PROVINCE DETAILS * {Rec}ord number:<IDNUM>

********************** Person entering {name}

MONTH: ##

YEAR: ####

{PROV}INCE {NAME} ________________________ {PROVINCE} Code<A >

{DIST}RICT {NAME} ________________________ {DISTRICT} Code<A >

****

* DOG POPULATION SUMMARY * Data entry 1/8

****

{D}OG {O}WNED {MALE} ######

{D}OG {O}WNED {FEMALE} ######

{D}OG {O}WNED {TOTAL} ######

{D}OG {N}ON {MALE} ######

{D}OG {N}ON {FEMALE} ######

{D}OG {N}ON {TOTAL} ######

{D}OG {TOTAL} ######

{C}AT {O}WNED {MALE} ######

{C}AT {O}WNED {FEMALE } ######

{C}AT {O}WNED {TOTAL} ######

{C}AT {N}ON {MALE} ######

{C}AT {N}ON {FEMALE} ######

{C}AT {N}ON {TOTAL} ######

{C}AT {TOTAL} ######

CONTROL ACTIVITY

****

** VACCINATION * DATA ENTRY 2/8

****

WERE {D}OGS {VACCI}NATED? :<Y>

IF YES,

NUMBER {D}OG {V}ACCINATED {FREE} ######

NUMBER {D}OG {V}ACCINATED {CHARGE}D ######

NUMBER OF {D}OG {V}ACCINATED BY {DLD} ######

NUMBER OF {D}OG {V}ACCINATED BY {OTHER }? ######

{TOTA}L {D}OG {V}ACCINATED ######

WERE {C}AT {VACCI}NATED? :<Y>

IF YES,

NUMBER {C}AT {V}ACCINATED {FREE} #####

NUMBER {C}AT {V}ACCINATED {CHARGE}D #####

NUMBER OF {C}AT {V}ACCINATED BY {DLD}? #####

NUMBER OF {C}AT {V}ACCINATED BY {OTHE R }? #####

{TOTA}L {C}AT {V}ACCINATED #####

WERE {O}THER ANIMALS {VACC}INATED? <Y>

IF YES,

NUMBER {O}THER {V}ACCINATED {FREE} ####

NUMBER {O}THER {V}ACCINATED {CHARGE}D ####

NUMBER OF {O}THER {V}ACCINATED BY {DLD}? ####

NUMBER OF {O}THER {V}ACCINATED BY {OTHE R }? ####

{TOTA}L {O}THER {V}ACCINATED ####

****

*** HORMONAL INJECTION * DATA ENTRY 3/8

****

DID {D}OGS {R}ECEIVE {HORM}ONE INJECTION? :<Y>

IF YES,

NUMBER {D}OG RECEIVE {H}ORMONE {FREE} #####

NUMBER {D}OG RECEIVE {H}ORMONE {CHARGE}D #####

NUMBER OF {D}OG RECEIVE {H}ORMONE INJECTION BY {DLD}? #####

NUMBER OF {D}OG RECEIVE {H}ORMONE INJECTION BY {OTHE R}? #####

{TOTA}L {D}OG RECEIVE {H}ORMONE INJECTION #####

DID {C}AT {R}ECEIVE {HORM}ONE INJECTION? :<Y>

IF YES,

NUMBER {C}AT RECEIVE {H}ORMONE {FREE} ####

NUMBER {C}AT RECEIVE {H}ORMONE {CHARGE}D ####

NUMBER OF {C}AT RECEIVE {H}ORMONE INJECTION BY {DLD}? ####

NUMBER OF {C}AT RECEIVE {H}ORMONE INJECTION BY {OTHE R}? ####

{TOTA}L {C}AT RECEIVE {H}ORMONE INJECTION #####

********************************	
****CASTRATION *	DATA ENTRY 4/8
********************************	
WERE {D}OG {CASTR}ATED?	<Y>
IF YES,	
NUMBER {D}OG {C}ASTRATED {FREE}	#####
NUMBER {D}OG {C}ASTRATED {CHAR}GED	#####
NUMBER OF {D}OG {C}ASTRATED BY {DLD}?	#####
NUMBER OF {D}OG {C}ASTRATED BY {OTHE}R?	#####
{TOTA}L {D}OG {C}ASTRATED	#####
WERE {C}ATS {CASTR}ATED?	:<Y>
IF YES,	
NUMBER {C}AT {C}ASTRATED {FREE}	#####
NUMBER {C}AT {C}ASTRATED {CHARGE}D	#####
NUMBER OF {C}AT {C}ASTRATED BY {DLD}?	#####
NUMBER OF {C}AT {C}ASTRATED BY {OTHER}?	#####
{TOTA}L {C}AT {C}ASTRATED	#####
**********************************	
***** SPAY *	DATA ENTREY 5/8
**********************************	
WERE {D}OG {SPAYE}D?	:<Y>
IF YES,	
NUMBER {D}OG {S}PAYED {FREE}	#####

NUMBER {D}OG {S}PAYED {CHARGE}D #####

NUMBER OF {D}OG {S}PAYED BY {DLD}? #####

NUMBER OF {D}OG {S}PAYED BY {OTHER}? ####

{TOTA}L {D}OG {S}PAYED #####

WERE {C}AT {SPAYE}D? :<Y>

IF YES,

NUMBER {C}AT {S}PAYED {FREE} ####

NUMBER {C}AT {S}PAYED {CHARGE}D ####

NUMBER OF {C}AT {S}PAYED BY {DLD}? ####

NUMBER OF {C}AT {S}PAYED BY {OTHER}? ####

{TOTA} {C}AT {S}PAYED ####

****

****** DOG DESTRUCTION DATA ENTRY 6/8

****

DID THE {D}OGS {KILLE}D? : :<Y>

IF YES,

NUMBER OF {D}OGS {K}ILLED BY {DLD} #####

NUMBER OF {D}OGS {K}ILLED BY {OTHE}R? #####

{TOTA}L {D}OG {K}ILLED #####

****

******* PUBLIC RELATIONS *	DATA ENTRY 7/8

****

WAS {PUBLIC} RELATIONS DONE? :	:<Y>
IF YES,	
DONE BY {VIL}LAGE {AMP}LIFIER	####
DONE BY {NEWSPAP} ER	####
DONE BY {EXHIBIT} ION	####
DONE BY {RADIO} PROGRAM	####
DONE BY {OTHER} {PR} MEDIA	####

****

******** TRAINING *	DATA ENTRY 8/8

****

WAS {TRAINI} NG DONE?	:<Y>
IF YES,	
THE TARGETS WERE {VIL} LAGERS AND OWNERS {TRAIN}ED	#####
THE TARGETS WERE {VOL} UNTEERS {TRAIN}ED	#####

*******************************END***

Appendix II

Variable code of human population, human rabies and surveillance data

No.	Set of data	Variable	Category
	Human population		
1	YEAR	Year	1993-1999
2	PROVCODE	Code Of Province	76
3	HMALE	Male population	Number
4	HFEMALE	Female population	Number
5	HTOTAL	Total population	Number
	Human rabies		
1	YEAR	Year	1993-1999
2	RECNO	Record number of that year	
3	PROVCODE	Code Of Province	76
4	PROVINCE	Province name	76
5	DISTRICT	District name	983
6	DISTCODE	District code	983
7	MONTH	Month of death	1-12
8	HAGE	Age of the death	1-
9	SEX	Gender of the death	3*
10	TYPE	Type of animal associated to the death	18*
11	HISTORY	History of the bit animal	3*
12	VACC	Vaccination history of animal associated with the death	5*
13	AGE	Age of animal associated with the death	5*
	Surveillance		
1	MDY	Month/day/year recorded	
2	YEAR	Year	
3	LAB	Lab that the specimen submitted	38
4	WEEK	Week of diagnosis	1-52
5	MONTH	Month of the specimen submitted	1-12
6	PROVINCE	Province name	76
7	PROVCODE	Code of province	76
8	DISTRICT	District name	983
9	DISTCODE	District code of the specimen submitted	983
10	TYPE	Type of the animal submitted	18*
11	HISTORY	History of animal	3*
12	AGE	Age of animal submitted	5*
13	VACC	Vaccination history of animal submitted	6*
14	SYMPTOMS	Syptoms of animal before submitted	6*
15	BITE	Animal or human contacted before the animal died	3*
16	DEATH	How submitted animal died	3*
17	RESULT	Result of the diagnosis	4*

?? see detail of each category in Appendix III

Variable codes for province activity data (76 provinces)

No.	Province activity	Variable	Detail
1	REGION	Code of region	9
2	YEAR	Year recorded	1993-1999
3	PROVINCE	Province name	76
4	PROVCODE	Code Of Province	76
5	DOMALE	Dog Owned Male	number
6	DOFEMALE	Dog Owned Female	number
7	DOTOTAL	Total Owned Dog	number
8	DNTOTAL	Total Dog Non-owned	number
9	DTOTAL	Total Dog population	number
10	DVFREE	Dog Vaccinated Free	number
11	DVCHARGE	Dog Vaccinated Charged	number
12	TOTALDV	Total Dog Vaccinated	number
14	CVFREE	Cat Vaccinated Free	number
15	CVCHARGE	Cat Vaccinated Charged	number
16	TOTALCV	Total Cat Vaccinated	number
17	OVFREE	Other animal Vaccinated Free	number
18	OVCHARGE	Other animal Vaccinated Charged	number
19	TOTALOV	Total Other animal Vaccinated	number
20	DHFREE	Dog received Hormone Free	number
21	DHCHARGE	Dog received Hormone Charged	number
22	TOTALDH	Total Dog received Hormone	number
24	CHFREE	Cat received Hormione Free	number
25	CHCHARGE	Cat rceived Hormone Charged	number
26	TOTALCH	Total Cat received Hormone	number
27	DCFREE	Dog Castrated Free	number
28	DCCHARGE	Dog Castrated Charged	number
29	TOATALDC	Total Dog Castrated	number
31	CCFREE	Cat Castrated Free	number
32	CCCHARGE	Cat Castrated Charged	number
33	TOTALCC	Total Cat Castrated	number
34	DSFREE	Dog Spayed Free	number
35	DSCHARGE	Dog Spayed Charged	number
36	TOTALDS	Total Dog Spayed	number
38	CSFREE	Cat Spayed Free	number
39	CSCHARGE	Cat Spayed Charged	number
40	TOTALCS	Total Cat Spayed	number
41	DKDLD	Dog Killed by DLD	number
42	DKOTHER	Dog Killed by Other organisations	number
43	TOTALDK	Total Dog killed	number
45	VILLAMP	PR done by Village Amplifier	number
46	NEWSPAP	PR done by Newspaper	times
47	EXHIBIT	PR done by Exhibition	times
48	RADIO	PR done by Radio broadcast	times
49	OTHERPR	PR done by Other media (published media)	number
50	TV	PR done by TV broadcast	times
51	TRAINVIL	PR done by Villager Training	number
52	TRAINVOL	PR done by village Volunteer Training	number

Variable codes for district activity data (26 provinces)

District Activity Data	Variable	Category
YEAR	Year recorded	1993-1999
PROVINCE	Province name	76
PROVCODE	Code Of Province	76 (10-96)
DISTRICT	District name	983
DISTCODE	Code Of district	983
MONTH	Month recorded	1-12
DOMALE	Dog Owned Male	number
DOFEMALE	Dog Owned Female	number
DOTOTAL	Dog Owned Total	number
DNMALE	Dog Non-owned Male	number
DNFEMALE	Dog Non-owned Female	number
DNTOTAL	Dog Non-owned Total	number
DTOTAL	Total Dog population	number
COMALE	Cat Owned male	number
COFEMALE	Cat Owned Female	number
COTOTAL	Cat Owned Total	number
CNMALE	Cat Non-owned male	number
CNFEMALE	Cat Non-owned Female	number
CNTOTAL	Cat Owned Total	number
CTOTAL	Total cat population	number
DVFREE	Dog Vaccinated Free	number
DVCHARGE	Dog Vaccinated Charged	number
DVDLD	Dog Vaccinated Charged by DLD	number
DVOTHER	Dog Vaccinated Charged by Other organisations	number
TOTALDV	Total Dog Vaccinated	number
CVFREE	Cat Vaccinated Free	number
CVCHARGE	Cat Vaccinated Charged	number
CVDLD	Cat Vaccinated charged by DLD	number
CVOTHER	Cat Vaccinated charged by Other organisations	number
TOTALCV	Total Cat Vaccinated	number
OVFREE	Other animals Vaccinated Free	number
OVCHARGE	Other animal Vaccinated Charged	number
OVDLD	Other animals Vaccinated charged by DLD	number
OVOTHER	Other animals Vaccinated charged by Other organisations	number
TOTALOV	Total Other animals Vaccinated	number
DHFREE	Dog received Hormone Free	number
DHCHARGE	Dog received Hormone Charged	number
DHDLD	Dog received Hormone charged by DLD	number
DHOTHER	Dog received Hormone charged by Other organisations	number
TOTALDH	Total Dog received Hormone	number
CHFREE	Cat received Hormione Free	number
CHCHARGE	Cat rceived Hormone Charged	number
CHDLD	Cat rceived Hormone charged by DLD	number
CHOTHER	Cat rceived Hormone charged by Other organisations	number

Variable codes for district activity data (cont.)

District Activity Data	Variable	Category
TOTALCH	Total Cat received Hormone	number
DCFREE	Dog Castrated Free	number
DCCHARGE	Dog Castrated Charged	number
DCDLD	Dog Castrated Charged by DLD	number
DCOTHER	Dog Castrated Charged by Other organisations	number
TOTALDC	Total Dog Castrated	number
CCFREE	Cat Castrated Free	number
CCCHARGE	Cat Castrated Charged	number
CCDLD	Cat Castrated Charged by DLD	number
CCOTHER	Cat Castrated Charged by Other organisations	number
TOTALCC	Total Cat Castrated	number
DSFREE	Dog Spayed Free	number
DSCHARGE	Dog Spayed Charged	number
DSDLD	Dog Spayed Charged by DLD	number
DSOTHER	Dog Spayed Charged by Other organisations	number
TOTALDS	Total Dog Spayed	number
CSFREE	Cat Spayed Free	number
CSCHARGE	Cat Spayed Charged	number
CSDLD	Cat Spayed Charged by DLD	number
CSOTHER	Cat Spayed Charged by Other organisations	number
TOTALCS	Total Cat Spayed	number
DKDLD	Dog Killed by DLD	number
DKOTHER	Dog Killed by Other organisations	number
TOTALDK	Total Dog killed	number
VILLAMP	PR done by Village Amplifier	times
NEWSPAP	PR done by Newspaper	times
EXHIBIT	PR done by Exhibition	times
RADIO	PR done by Radio broadcast	times
OTHERPR	PR done by Other media (published media)	number
TV	PR done by TV broadcast	times
TRAINVIL	PR done by Villager Training	number
TRAINVOL	PR done by village Volunteer Training	number

Appendix III

Category of surveillance and human rabies variables

No.	Variable	Detail	Category
	Type of animals		**TYPE**
1	1	Dog	
2	2	Cat	
3	3	Cow	
4	4	Buffalo	
5	5	Pig	
6	6	Goat	
7	7	Sheep	
8	8	Horse	
9	9	Monkey	
10	10	Gibbon	
11	11	Langur	
12	12	Rat	
13	13	Squirrel	
14	14	Rabbit	
15	15	Hare	
16	16	Chipmunk	
17	17	Other	
18	99	Unknown	
	History of animal		**HISTORY**
1	1	Owned	
2	2	None-owned	
3	9	Unknown	
	Age of animal		**AGE**
1	1	< 3 Months	
2	2	3-6 Months	
3	3	> 6-12 Months	
4	4	> 12 Months	
5	9	Unknown	
	Vaccination history		**VACC**
1	0	None	
2	1	< 1 Month	
3	2	1-6 Months	
4	3	< 6 Months -1 year.	
5	4	> 1 yr.	
6	9	Unknown	
	Symptoms		**SYMPTOMS**
1	1	Furious	
2	2	Dumb	
3	3	Normal	
4	4	Furious and dumb	
5	5	Other	
6	9	Unknown	

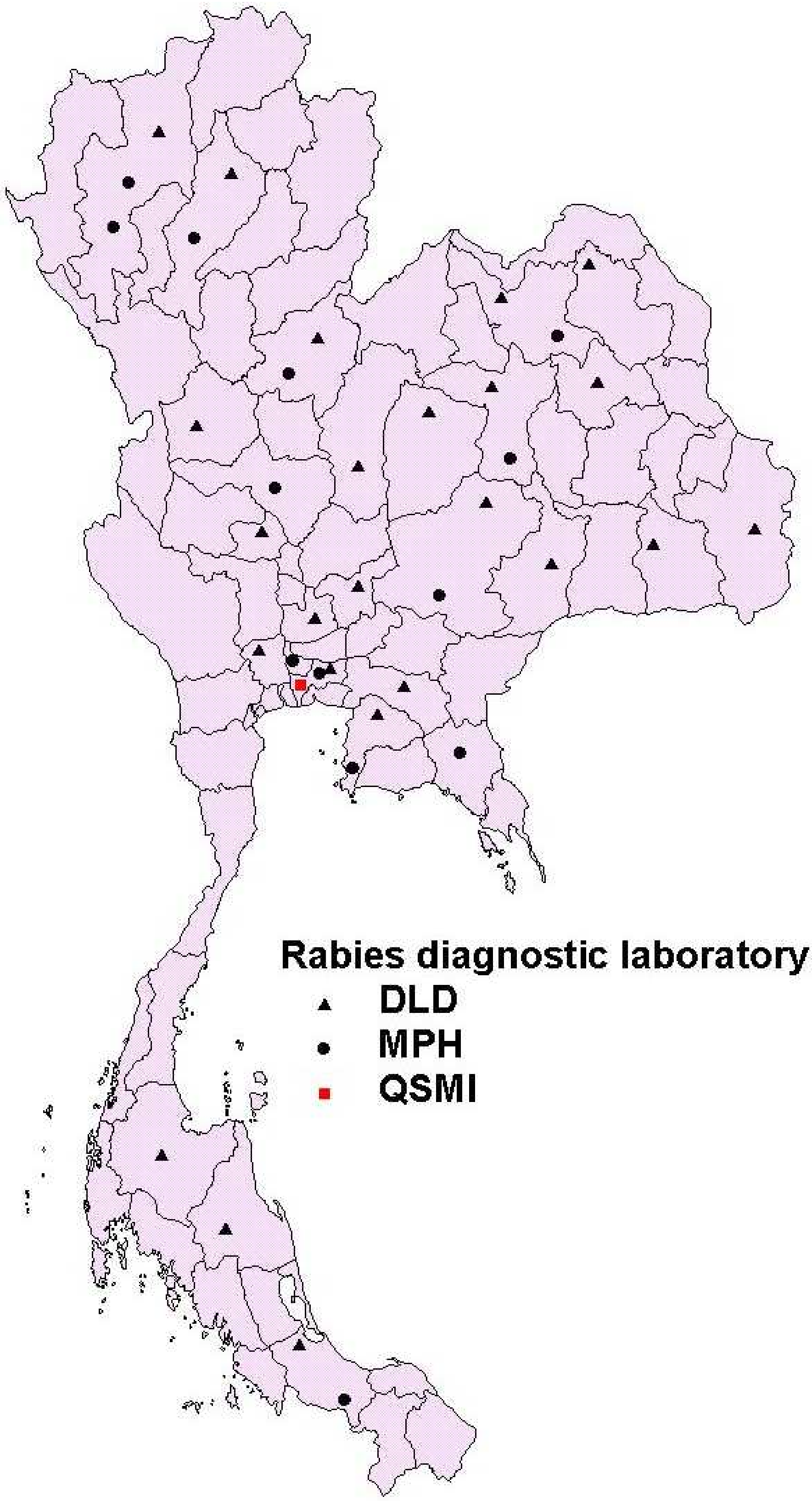
No.	Variable	Deatail	Category
	Bite		**BITE**
1	1	Animal	
2	2	Human	
3	3	None	
4	4	Both	
5	5	Contact saliva	
6	9	Unknown	
	Death		**DEATH**
1	1	Naturally death	
2	2	Was killed	
3	9	Unknown	
	Result		**RESULT**
1	1	Positive	
2	2	Negative	
3	3	Inconclusive	
4	9	Unknown	

Names and locations of rabies diagnostic laboratories in Thailand

No.	LAB	Province
1	RED CROSS*	Bangkok
2	VIRUS INSTITUTE**	Nonthaburi
3	VETERINARY DEP.***	Bangkok
4	SIRIRAJ HOSP.	Bangkok
5	CHIANGMAI HOSP.**	Chaingmai
6	SOUTH.VET.RES.CENTER***	Nakhon Si Thammarat
7	NORTHEAST.VET.RES**.CE***	Khon Kaen
8	MED.SC.CEN*.SONGKHLA**	Songkhla
9	MED.SC.CEN.CHIANGMAI**	Chaingmai
10	PRAPROKLOA HOSP.**	Chanthaburi
11	MED.SC.CEN.KHONKAEN**	Khon Kaen
12	MED.SC.CEN.NAKORN RA**	Nakhon Ratchasima
13	MED.SC.CEN.CHOLBURI**	Chon Buri
14	NORTH.VET.RES.CENTER***	Lampang
15	UBOL HOSP.**	Ubon Ratchathani
16	LAMPANG HOSP.**	Lampang
17	MED.SC.CEN.PHITSANUL**	Phitsanulok
20	SARABURI HOSP.**	Saraburi
21	UDORN HOSP.**	Udon Thani
22	EAST.VET.RES.CEN***	Chon Buri
23	LIV.REG***.1,AYUTTHAYA***	Phra Nakhon Si Ayutthaya
24	LIV.REG.2,CHACHOENGSAO***	Chachoengsao
25	LIV.REG.3,NAKHON RAT***	Nakhon Ratchasima
27	LIV.REG.5,CHIANG MAI***	Chaingmai
28	LIV.REG.6,PHITSAULOK***	Phitsanulok
29	LIV.REG.7,NAKHONPHATHOM***	Nakhon Pathom
30	LIV.REG.8,SURATTHANE***	Surat Thani
32	LIV.REG.9,SONGKHLA***	Songkhla
33	LIV.OFF****,CHAI NAT***	Chai Nat
34	LIV.OFF,KALASIN***	Kalasin
35	LIV.OFF,AMNAT CHAROEN***	Amnat Charoen
36	LIV.OFF,SRISAGATE***	Si Sa Ket
37	LIV.OFF,BURIRUM***	Buri Ram
38	LIV.OFF,PHETCHABUN***	Phetchabun
39	LIV.OFF,UDORN***	Udon Thani
40	LIV.OFF,CHAIYAPHOM***	Chaiyaphum
41	LIV.OFF,KAMPHAENG PHET***	Kamphaeng Phet
42	LIV.OFF,SAKON NAKHON***	Sakon Nakhon
99	Unknown.	

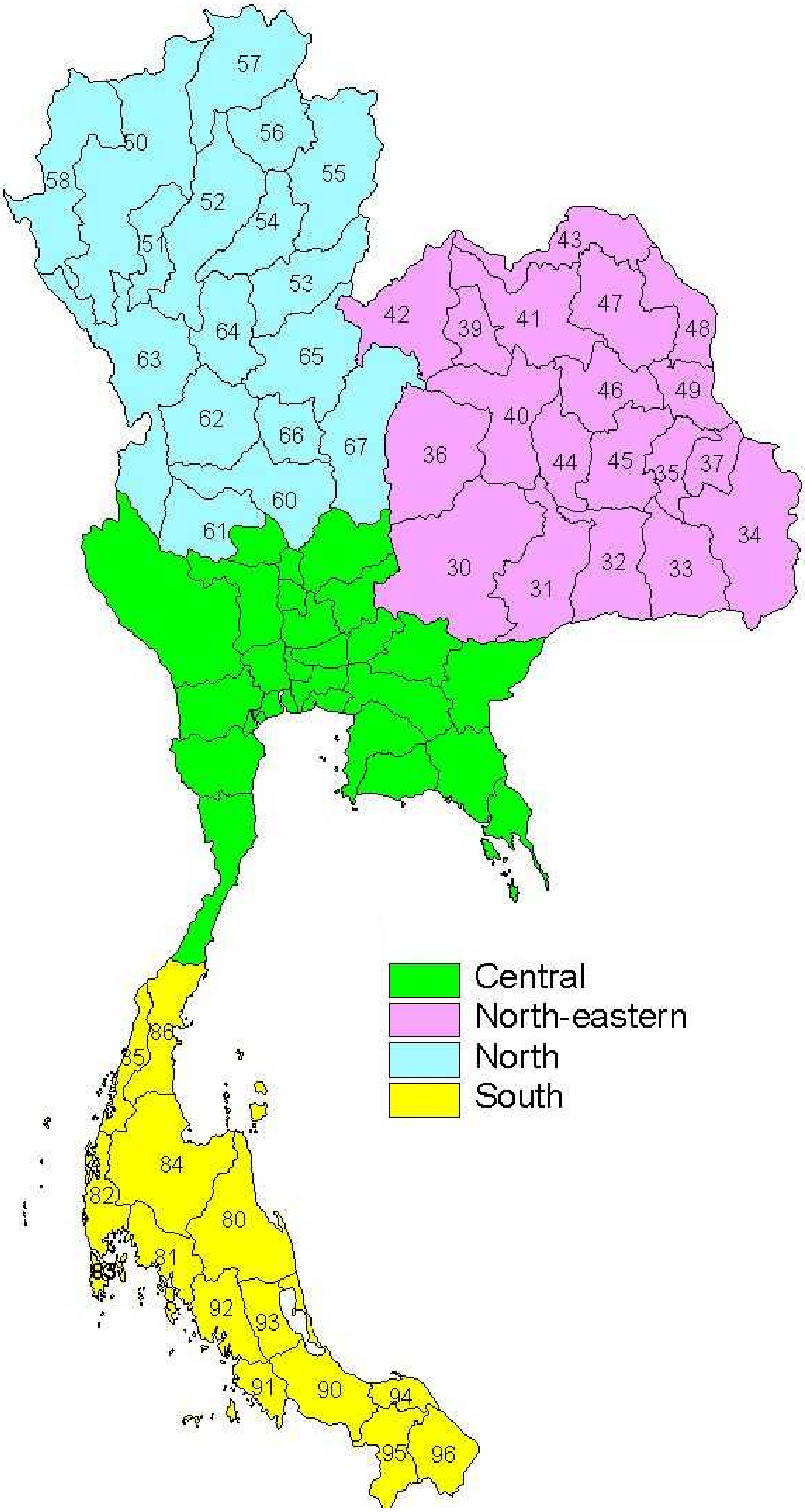
* WHO Collaborating Lab
** Ministry of Public Health
*** Department of Livestock development

Rabies diagnostic laboratory by province in 1999



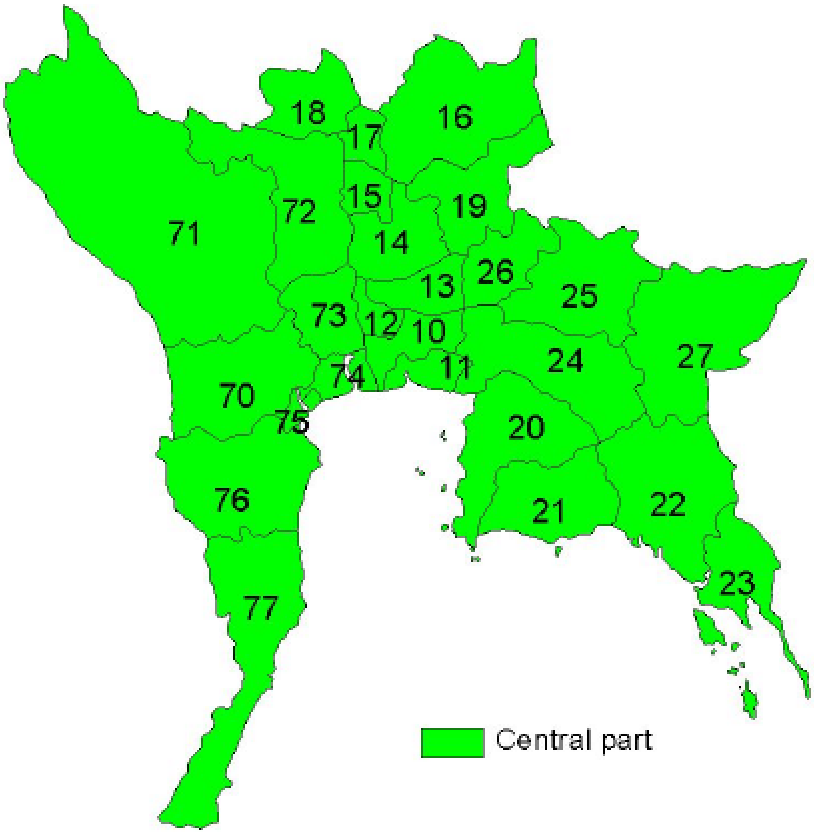
Appendix III

Thailand map and province codes and names



* Central part code is shown in the next page

Code of the provinces in the central part



Thailand province codes and names

PART	Region (REGION)	Province Code (PROVCODE)	Province name (PROVINCE)
Central			
	1	10	Bangkok
	1	12	Nonthaburi
	1	13	Pathum Thani
	1	14	Phra Nakhon Si Ayutthaya
	1	15	Ang Thong
	1	16	Lop Buri
	1	17	Sing Buri
	1	18	Chai Nat
	1	19	Saraburi
	2	11	Samut Prakarn
	2	20	Chon Buri
	2	21	Rayong
	2	22	Chanthaburi
	2	23	Trat
	2	24	Chachoengsao
	2	25	Prachin Buri
	2	26	Nakhon Nayok
	2	27	Sa Kaeo
North-east			
	3	30	Nakhon Ratchasima
	3	31	Buri Ram
	3	32	Surin
	3	33	Si Sa Ket
	3	34	Ubon Ratchathani
	3	35	Yasothon
	3	36	Chaiyaphum
	3	37	Amnat Charoen
	3	45	Roi Et
	4	39	Nong Bua Lam Phu
	4	40	Khon Kaen
	4	41	Udon Thani
	4	42	Loei
	4	43	Nong Khai
	4	44	Maha Sarakham
	4	46	Kalasin
	4	47	Sakon Nakhon
	4	48	Nakhon Phanom
	4	49	Mukdahan

PART	Region (REGION)	Province Code (PROVCODE)	Province name (PROVINCE)
North			
	5	50	Chiang Mai
	5	51	Lamphun
	5	52	Lampang
	5	54	Phrae
	5	55	Nan
	5	56	Phayao
	5	57	Chiang Rai
	5	58	Mae Hong Son
	6	53	Uttaradit
	6	60	Nakhon Sawan
	6	61	Uthai Thani
	6	62	Kamphaeng Phet
	6	63	Tak
	6	64	Sukhothai
	6	65	Phitsanulok
	6	66	Phichit
	6	67	Phetchabun
Central			
	7	70	Ratchaburi
	7	71	Kanchanaburi
	7	72	Suphanburi
	7	73	Nakhon Pathom
	7	74	Samut Sakhon
	7	75	Samut Songkhram
	7	76	Phetchaburi
	7	77	Prachup Khiri Khan
South			
	8	80	Nakhon Si Thammarat
	8	81	Krabi
	8	82	Phangnga
	8	83	Phuket
	8	84	Surat Thani
	8	85	Ranong
	8	86	Chumphon
	9	90	Songkhla
	9	91	Satun
	9	92	Trang
	9	93	Phatthalung
	9	94	Pattani
	9	95	Yala
	9	96	Narathiwat