Malignant Catarrhal Fever in Asian Livestock

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Epidemiological Aspects of Malignant Catarrhal Fever in Indonesia

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Abstract

Indonesia has a huge rural economy, with over 90 million people depending on agriculture for a living. The large ruminant population has been estimated at 6.5 million cattle and 2.5 million buffalo. Current government planning promotes the use of indigenous breeds such as the Bali cattle. Field observations indicate that malignant catarrhal fever (MCF) is a major disease problem endemic in many areas. The buffalo and the Bali cattle seem to be more susceptible than other breeds, and sheep have been identified as a probable source of infection. Where Bali cattle are introduced into contact with sheep through programs involving large numbers of animals, epidemics of MCF have occurred. Experimental transmissions have confirmed the susceptibility of the Bali cattle.

Abstrak

Peranan ekonomi pedesaan bagi Indonesia sangat penting, mengingat 90 juta penduduk menggantungkan hidupnya dalam bidang pertanian dan mereka tinggal di pedesaan. Ruminansia besar, yang di perkirakan terdiri atas 6,5 juta sapi dan 2,5 juta kerbau mepunyai andil yang sangat berarti bagi ekonoi pedesaan dan pemerintah sedang barusaha untuk mengembangkan ternak asli Indonesia, misalnya sapi Bali. Berdasarkan penelitian lapangan MCF merupakan penyakit endemik yang banyak menimbulkan masalah di beberapa daerah. Sapi Bali dan kerbau rupanya merupakan ternak yang lebih peka terhadap MCF dibanding ternak lain. Apabila pada lokasi sapi Bali ditempatkan juga domba, biasanya kejadian MCF secara endemic muncul. Percobaan transmisi telah memperkuat dugaan kepekaan pada sapi Bali tersebut.

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Introduction

Malignant catarrhal fever (MCF) is distributed widely in Indonesia. It is recognised by the animal health authorities as an important disease and by farmers as a familiar clinical syndrome resulting in deaths of large ruminants. It has been suggested (Anon. 1986) that accurate estimates of disease incidence and prevalence are difficult to obtain. The situation could not be expected to be otherwise in this country, considering the low ratio of veterinary field staff to the rural-based population.

Nonetheless, when allocating animal health research priorities, it is essential to ensure that funds are allocated to areas of genuine need. One of the aims of the AARD/ACIAR Collaborative Project on MCF has been to collect and analyse such data as are available as a prelude to further research. There is a pressing need to clarify aspects of epidemiology that could influence any control measures the veterinary services may be able to take, for it is certain that such control measures will affect the financial opportunities of rural smallholders in the field of livestock raising. This paper describes briefly the role of ruminants in the national economy and their value to farmers. Indonesian literature on MCF and official reports are reviewed, and new field and experimental observations are discussed.

The Rural Economy

An overview of the rural economy potentially affected by ruminant diseases can be extracted from data assembled in a recent major review of the Indonesian livestock sector (Anon. 1986). Of a population of 162 million people, 90.4 million (55.7%) in 17.6 million households

depend directly on agriculture for a livelihood, and their numbers and the total area farmed are increasing. Although only 25 to 30% of these households keep ruminants, and the numbers of animals per household are small, there are still more than 5 million family units containing over 28 million people involved with ruminants in some way for their financial well-being. The primary objectives of their animal husbandry are to have a store and a source of wealth, and a source of draught power.

At the national level, the major animal product is meat, with an annual production from large ruminants of more than 180 000 t and, from small ruminants, of more than 62 000 tons. The average annual per capita meat consumption of 4.33 kg is low. It is considered that the demand for meat will grow, that supply will not keep pace with demand, and that there will be an upward movement of prices for both meat and livestock.

As most households make little financial input into ruminant maintenance beyond the purchase price, ruminants offer a viable means of converting labour to wealth. The increasing demand for meat and draught power should ensure that such wealth will grow in the short and medium terms. At present the approximate value of mature cattle is US$400–450, of buffalo US$400, and of sheep and goats US$40.

To individual farmers the need for draught power is important, and must be recognised in estimates of the economic value of livestock. A pair of animals can earn US$2.50/day ploughing. It is estimated that 3.3 million cattle and 1.4 million buffalo are available for draught purposes and that in 1982 the value of their draught power was US$237 million. Animal manure as a by-product has been estimated to contribute US$40 per year per large ruminant to farm income.

An important new development in livestock usage patterns is the distributions in transmigration programs. Bali cattle is the animal preferred by the recipients and the planners because of its perceived superior productive capacity. The health and welfare of these animals is a particularly significant development problem.

The planning for the development of Indonesia is through a series of 5-year plans. Repelita IV covers the period 1984–1988. The main objectives for the livestock sector are to increase farm income and employment opportunities, to meet domestic demand for animal services and products, to increase export earnings and reduce imports of livestock products, to meet the demand for draught animals and manure for crop production, to conserve indigenous breeds like the Bali cattle, and to increase the carrying capacity of grasslands through the establishment of better quality forages.

Research to help reduce losses due to MCF can be seen as an important contribution to achieving these aims, particularly as the indigenous breeds are more susceptible.

Literature Review

Historical Aspects

A major contribution to the knowledge regarding MCF in Indonesia has been the research of Mansjoer (1954). A summary of his review of the literature to that time gives a useful background for current research. Many of the citations were not formally referenced, but the sources of information were acknowledged in the text. Readers are referred to Mansjoer (1954) for further information.

MCF was first diagnosed near Kediri in East Java (Paszotta 1894). Three buffalo with MCF were seen and four others were reported. Passage was attempted by subcutaneous inoculation of blood and ascitic fluid to one buffalo, and by subcutaneous inoculation of blood and 'ventricle' fluid to two goats. Failure to reproduce MCF within 14 days was attributed to either too small a dose or too short an observation period.

The disease rapidly became recognised throughout Indonesia (Penning 1910, 1911—cited by Mansjoer 1954). Cattle were affected sporadically. Madura was frequently mentioned as a focus of infection (Penning 1915; Van der Poel 1916—both cited by Mansjoer 1954), with affected cattle suffering 100% mortality. It should be noted that the traditional cattle in Madura are Bali-cross animals. Cases from Central Java, Madura and Sumatra continued to be reported for a number of years.

The Research Institute for Veterinary Science (RIVS) in Bogor reported MCF in 1920, 1921 and 1926. In 1920, passage by intravenous and subcutaneous inoculation of blood from a cow

showing clinical signs was successful. Nijverheid and Handel (1920) (cited by Mansjoer 1954) reported the investigation of a disease of buffalo characterised by emaciation, a pale and fish-like skin, sunken eyes, pustules on the head and shoulders, and occasionally diarrhoea and dysentery. Transmission studies with blood from such animals produced disease with clinical signs of high fever, purulent oculo-nasal discharge, wasting, and diarrhoea. Examinations for piroplasms and trypanosomes were negative. Mansjoer (1954) arrived at the conclusion that these diseases were MCF, although in some cases atypical. It seems that a problem of differential diagnosis in the buffalo has existed for some time.

Schroots (1922) (cited by Mansjoer 1954) identified 10 cases in cattle in Lombok and attempted passage to cattle, rabbits, marmots and turtle doves without success. Blood submitted to RIVS also failed to transmit the disease to cattle. In the previous year inoculations to a dog, turtle dove, rabbit and sheep had not transmitted disease. In 1922 and 1924, the Livestock Services Office identified further cases in West Java, including Bogor and Sukabumi, as well as in Central and East Java. From 1925 to 1938, MCF was mentioned by various authors in annual reports as occurring in both cattle and buffalo. Cases were widely distributed: from Medan, Madura, northern areas of Java, Central Java, East Java, West Java, Sulawesi and Kupang.

In 1935, passage by intravenous inoculation of cattle with 10 mL of blood was attempted without success (Munnik 1935—cited by Mansjoer 1954). It is clear from the writings of Mansjoer that he regarded Lombok as an important focus of infection of MCF, and that over the years from 1918 to the time of his own research there was considerable interest in the problem by local staff in collaboration with RIVS.

In 1946, the Faculty of Veterinary Science in Bogor reported cases in buffalo. This may have been the stimulus for Mansjoer's own research, which involved the examination of 27 spontaneous cases with prominent meningoencephalitis. Successful passage of MCF to cattle, buffaloes, rabbits and chicken embryos was reported. Humans, monkeys, sheep, goats, pigs, rats, mice, ducks, fowl, carrier pigeons, turtle doves and zebra doves were reported to be resistant.

It is unclear when MCF in Indonesia was first associated with sheep. Soeparman (1940) (cited by Mansjoer 1954) attributed the low prevalence in central Lombok compared with other parts of the island to a small sheep population. In Bali, it was noted that MCF occurred in villages of ethnic communities raising sheep, but not in districts where pigs were preferred (Made Bagi Asna 1950—cited by Mansjoer 1954). Farmers believed that the disease was spread by sheep urine on the grass. Mansjoer (1954) concurred that sheep were the probable carrier, and recommended that note be taken of this observation throughout Indonesia.

A Disease with a Similar Pathomorphology

In considering the epidemiology of MCF in Indonesia, similar diseases unknown elsewhere must be noted. In 1964 and 1965, an epidemic involving Bali cattle and buffalo was reported in Bali. Fever, anorexia, depression, laboured respiration, rapid emaciation, markedly swollen lymph nodes, constipation or diarrhoea and dysentery, serous ocular and nasal discharges and erosions in the mouth were observed. Death usually occurred in 5 to 12 days. The spleen was enlarged and haemorrhages were present in the gastro-intestinal tract, with the abomasum being particularly affected and thickened. The disease was easily passaged to Bali cattle, but not to *Bos indicus*. It was tentatively called Jembrana disease (Adiwinata 1967).

Thousands of animals were reported to have died. No bacteria were isolated from cases, and treatment against trypanosomes was ineffective. The possible differential diagnoses were thought to be MCF, rinderpest or bovine virus diarrhoea–mucosal disease. MCF in Bali was previously known to occur sporadically, was characterised by severely diseased mucous membranes of the head and corneal opacity, and was not as easily passaged as was the disease of the outbreak. Hence, MCF was excluded (Pranoto and Pudjiastono 1967). Rinderpest was considered the most likely possibility, and the disease abated after a rinderpest vaccination campaign (Adiwinata 1967).

However, the diagnosis was not supported by

laboratory tests (Anon. 1977). Rickettsia-like organisms were noted in tissue sections and blood smears, and their isolation was reported (Hardjosworo and Budiarso 1973), but such organisms have not yet been firmly implicated in the aetiology.

Of epidemiological interest was that the disease changed character. While still presenting in outbreaks in which the morbidity was high, the mortality became much reduced, a completely different situation from the sporadic occurrence and 100% mortality normally associated with MCF. In other aspects the diseases remained similar, with no sex predilection and with young adults being the most susceptible age group. Only Bali cattle were affected (Anon. 1977).

It is beyond the scope of this paper to review Jembrana disease in great detail. The salient aspects of the disease as currently perceived in Indonesia are provided elsewhere in this volume. The similarities and differences of the two conditions will be debated until the aetiology of each is known.

Recent Publications

Ginting (1979) examined cases with clinical signs, postmortem findings and histology consistent with MCF in Bali cattle from two commercial operations in West Java, and from Balai Penelitian Ternak (BPT), the Research Institute for Animal Production at Ciawi. The recommendation was made that the husbandry of Bali cattle not be attempted in West Java, which has a large sheep population. Cases of Jembrana disease were also reported from BPT, Ciawi, at that time (Hardjosworo et al. 1978).

MCF has been a continuing problem at BPT (Hoffmann et al. 1984a, b). From 1979 to 1982, 50 of 177 buffalo died of a syndrome described as being MCF-like. This syndrome as described was very similar to that studied previously as MCF (Mansjoer 1954). The experimental facilities for large ruminants at BPT are close to those for small ruminants which reproduced all year round. Penning buffalo 400 m from the facilities stopped the development of new cases.

Bos indicus cattle (71) held under the same conditions as affected buffalo did not contract disease, indicating a difference in susceptibility between the two populations. Further Bali cattle (4 of 7) introduced to BPT died of MCF. The disease was transmitted by blood transfusions from buffalo to *Bos indicus* and Bali cattle (Hoffmann et al. 1984b).

MCF continued to be reported in Bali and successful transmission with blood and lymph node suspensions from Bali cattle to Bali cattle was reported (Ramachandran et al. 1982).

Banyuwangi is the portion of East Java immediately adjacent to Bali. It was reported (Anon. 1982) that 400 cases of MCF were diagnosed there in 1978 and 1979. Again in 1982 approximately 150 cases were recorded. Seventy-four of these above cases were diagnosed histologically at the DIC, Denpasar, between 1979 and 1982, and most cases were submitted in the months of November and December, which is the wet season and the ploughing season. Ages of cases ranged from 1 to 9 years. Cattle and buffalo were affected. The disease of Bali cattle and their crosses in Banyuwangi had also been thought in 1979 to be Jembrana disease (Anon. 1984).

Reports of cases and outbreaks in the southern provinces of Sumatra have been published. Between 1982 and 1985, cases were reported from Lampung, South Sumatra and Bengkulu (Prabowo and Soesilo 1986), with the outbreak in Bengkulu having been reported in greater detail (Husin et al. 1985). In Bengkulu, the incidence between June 1983 and December 1984 was over 4% in imported Bali cattle. Sheep were present in five of the affected villages, but not in three others.

A disease very similar to MCF has also been reported in southern Sumatra, in the province of Lampung. Called Rama Dewa, its similarities with Jembrana Disease have been emphasised (Soeharsono and Darmadi 1976). Some descriptions of Rama Dewa (Prabowo and Ishitani 1984) also indicated considerable similarity with MCF. The characteristic feature was marked lymphoproliferation and lymphoid vasculitis. Encephalitic changes were present in fewer than 50% of cases, but necrotic changes of the oral mucosae were said to be a feature. In addition, purulent nasal discharges and corneal opacity were described, indicating that at least some of the cases showed a resemblance to the head-and-eye form of MCF. The disease was transmitted with 50 and 100 mL volumes of infected blood by Prabowo and Ishitani (1984),

and with 5 and 15 mL by Soeharsono and Darmadi (1976), volumes which seem small for MCF. Ramachandran et al. (1982) passaged the disease in Bali cattle with 50 mL of blood plus 25 ml of 20% lymph node suspension. The minimum volume necessary to transmit MCF in Bali cattle has not yet been titrated. Prabowo and Ishitani (1984) proposed that the two diseases—Rama Dewa and MCF—be considered as part of the MCF complex of diseases. The high prevalence of these similar diseases in the transmigration areas of southern Sumatra makes the MCF complex a problem of considerable magnitude.

Hence, in three locations outside Bali—at BPT, Ciawi, in Banyuwangi in East Java, and in Lampung in the south of Sumatra—Jembrana-like diseases and MCF have been reported at similar times. From the time of the earliest reports of Jembrana, MCF has been considered in its differential diagnosis (Pranoto and Pudjiastono 1967), but from then until now the two clinicopathological syndromes have been considered distinct (Soeharsono 1988). The occurrence of the two diseases in such populations indicates the susceptibility of the Bali cattle to diseases of this type. Conversely, this susceptibility is a further point of similarity between the two syndromes. As noted, Prabowo and Ishitani (1984) considered that in fact there was only one disease in Lampung, an MCF complex. Dharma et al. (1985) discussed the pathology of Rama Dewa, Banyuwangi disease, Jembrana and MCF and came to the conclusion that there were no important differences between the syndromes, that were each characterised by generalised lymphadenopathy and lyphoproliferation with mitotic figures.

More recently, an active centre of research into MCF has arisen at the DIC, Medan in Northern Sumatra. Buffalo deaths previously attributed to infectious bovine rhinotracheitis (IBR) (Noor et al. 1983) were rediagnosed as probable MCF on the basis of the clinical signs consistent with the head-and-eye form of MCF (Peranginangin et al. 1986a). Virus isolations were attempted from new cases. A virus of similar description to that isolated by the project at RIVS (Sudarisman et al. 1985) was isolated by co-cultivation of buffy coat cells from cases in buffalo. Transmissions with blood to buffalo, sheep and goats were reported in all cases to result in mild disease but not death. In each case, a virus was isolated from buffy coat cells and lymphoid tissues when the animals were killed for postmortem examination (Peranginangin et al. 1986a). No pathology was described in the animals in the transmission experiments or in the field cases. Infected cells were reported to fluoresce in an indirect immunofluorescence test with an antiserum to WA-MCF virus supplied by Plum Island (Perangingangin 1986b), but perhaps further information is needed on this point.

Apart from the obvious virological interest of these reports, they show that MCF is a frequent cause of death in buffalo in North Sumatra. Peranginangin (1986) reported that 180 cases had been observed in buffalo in the seven years 1978 to 1984, equivalent to 4.86 cases per 1000. Only two cases were observed in a similar number of *Bos indicus* in the same period. Both males and females were affected, and mature animals more than young animals. No cases were reported in calves. There was a close association with sheep in each case.

Official Reports

The Government Veterinary Services each year prepare figures on the diagnosis of disease in the provinces. These data are, of necessity, based mostly on clinical examinations, which affect their accuracy, and also represent only those cases seen by the veterinary services field staff, which means it is possible that the figures are an underestimate of the true situation.

Data derived from such sources for the last 5 years were given by Partadiredja et al. (1988). During this time, cases have been reported in 15 of the 27 provinces, confirming the widespread distribution of the disease. In terms of number of cases, some inconsistencies can be noted. Southeast Sulawesi, which claims to have a significant problem, is unrepresented in the figures. Central Java reported only two cases in 5 years, but the experience of the authors and of the DIC at Jogyakarta (Wisynu and Unruh, pers. comm.) is that sporadic MCF is endemic there.

These comments are not intended to be criticism of the reportings from the provinces named, but rather attempt to illustrate the difficulties that veterinary authorities still have in formulating an accurate estimate of the epidemiology of animal diseases. Such problems

are being overcome, but at present still exist. In summary, it seems certain that official records of MCF in Indonesia underestimate the true situation.

Field Observations

As is widely appreciated, MCF occurs in two epidemiologically distinct forms throughout the world (Plowright 1984). Susceptible species develop MCF either after contact with wildebeest (WA-MCF), or in situations where there are no wildebeest. Field observations in many countries have led to the hypothesis that sheep are the silent carriers of the MCF agent in these circumstances, and hence this latter form of the disease is called sheep associated MCF (SA-MCF). The question of the reservoir host is one of the aspects that epidemiological studies should attempt to address. As there are no wildebeest in Indonesia, note has been made where possible of any association with sheep.

Through field work in some of the districts where MCF has been reported, such as in West Timor, Banyuwangi and Central Java, and through interpretation of other government reports and personal communications, the authors have developed an appreciation of the pattern of occurrence of MCF in Indonesia.

It seems reasonable to identify two categories of disease occurrence; endemic, where the reports of disease are of a true sporadic nature, and epidemic, where there is a grouping of cases in particular herds at an incidence level above the expected norm.

Endemic MCF

In the endemic situation a low incidence is normal, although certain geographical locations experience a higher incidence of MCF. The investigation of a field case in Boyolali, Central Java, identified features of the normal Indonesia situation. A farmer who owned three buffalo reported one sick and showing classical clinical signs. MCF was confirmed by histopathology. This animal was the only animal in the immediate district known to be affected at that time and was housed adjacent to sheep including lambs. The farmer reported the loss of other buffalo from the same disease syndrome in previous years, and apparently similar cases occurred from time to time in the district. Paraveterinary staff had thought the disease to be trypanosomiasis, and had so diagnosed previous cases with similar clinical signs. Because of logistical problems histopathological confirmation of diagnoses of sporadic cases of disease was not normally sought. In this district, MCF is therefore underdiagnosed.

Similarly, a field case close to Bogor was investigated when a laboratory worker reported disease in one of his family's buffaloes. The case was clinically consistent with MCF. The buffalo was sold for emergency slaughter without the researchers being advised, and in spite of their known interest. Hence, no postmortem confirmation of diagnosis was possible.

This farmer was also familiar with this disease, and had sent animals to emergency slaughter, or had had them die, on previous occasions. He reported that others in the district shared his experience. It seems probable that again MCF is underdiagnosed and underreported. A farmer may be most reluctant to jeopardise the salvage of some of his capital by involving the authorities in the disposal of an affected animal.

In Banyuwangi, East Java, MCF is also endemic, occurring sporadically but with an apparently higher prevalence (Anon. 1982). Subsequent field work by the present authors found the paraveterinary staff in this area to be well-organised and active.

Cases, although clustered a little in certain districts, occurred thoughout the whole kabupaten. It was not the pattern that one particular village was more affected than others, or that many cases occurred in one place at the one time.

The factors leading to the reported high prevalence could not be determined. Histological confirmations of diagnosis (Anon. 1982; staff, DIC Jogyakarta, pers. comm.) suggest that MCF is not overdiagnosed to any great degree. Sheep and goats are widely spread and are owned in traditional smallholder operations. Cases can occur all year but a higher incidence has been observed in November and December which is normally the wet season and which is also the ploughing season. The less susceptible ongole *(Bos indicus)* breed has a higher-than-normal case rate, suggesting that the disease agent may be spread particularly actively or be particularly virulent in this region.

Banyuwangi is a crossroads for livestock movements from East Java and other islands towards the market in Jakarta. The livestock markets in the various districts are very active, with much local trading. It is not known whether these factors can contribute to the prevalence of MCF.

Epidemic MCF

A different epidemiological picture was seen in some situations where there were movements of identifiable groups of livestock. The authors have assisted in the investigation of two outbreaks of MCF in West Timor. MCF confirmed by histopathology (Darmadi et al. 11985) occurred when deer and sheep were brought together, and when sheep from Roti Island were moved into contact with a herd of Bali cattle in West Kupang previously unexposed to sheep. In the first case, 65% of 55 deer died, and in the second case 20% of 300 Bali cattle were affected.

It seems that similar situations have occurred in transmigration areas with the movement of Bali cattle from the breeding areas where sheep are rare, such as West Timor, into new areas with established sheep populations. Cases of MCF reported from the provinces in central and southern Sumatra have mostly been in imported Bali cattle supplied by the government to new settlers (Prabowo and Soesilo 1986).

Transmission Experiments

In Indonesia, transmission experiments have long been used to study MCF (Paszotta 1894; Mansjoer 1954; Hoffmann et al. 1984b) and the similar diseases Jembrana (Adiwanata 1967, Hardjosworo and Budiarso 1973) and Rama Dewa (Soeharsono and Darmadi 1976; Prabowo and Ishitani 1984). Thus, the infectious nature of the disease in the affected animals can be confirmed, the infectivity and associated pathology of agents associated with various incidents compared, and fresh specimens obtained for laboratory investigations. Transmission experiments have continued to give valuable information on MCF in Indonesia (Sudarisman et al. 1985). These preliminary results of the authors and others will be discussed below together with more recently derived information. Experiments have been designed to provide epidemiological information.

Contact Transmissions

(a) A young male buffalo was housed with three lambing sheep. No MCF was observed after a 20-month observation period.

(b) Two adult males each of buffalo, *Bos indicus* and Bali cattle from South Sulawesi and two young Bali cattle from West Timor, were penned in close proximity to lambing sheep and goats at BPT, Ciawi. All Bali cattle died of MCF within 15 weeks, while the other species remained unaffected after 1 year of observation, except for one buffalo that showed a 2-week episode of mild nasal discharge and fever of 39–39.5°C approximately 7 months post-exposure. The second buffalo died of misadventure after 3 weeks of exposure, and therefore was not effectively involved in the experiment.

(c) Two young Bali cattle in Kupang, West Timor, were placed in contact with sheep that had been implicated in the outbreak of MCF in deer. No deaths occurred in the Bali cattle, but they underwent two periods of illness. Ten weeks after first exposure to the sheep the cattle showed nasal discharge and diarrhoea, but recovered. After 11 months of contact there was again obvious disease with fevers of up to 41.2°C and nasal discharge. Eighteen days after the fever subsided and the animals were clinically normal one was necropsied. There was ulceration of the abomasum and mild erosions and haemorrhages in the small and large intestines.

Histopathological changes in the central nervous system, lymphoid tissue, eye, lung, heart and kidney, while not severe, were similar in some respects to those seen in MCF. However they were not sufficiently advanced to support a diagnosis of MCF.

(d) A second pair of Bali cattle in West Timor was placed in contact with the sheep from Roti Island that had been implicated in the outbreak of MCF in the Bali cattle herd

in West Kupang district. No MCF occurred in the experimental cattle, but one died of other causes.

Experimental Transmissions: Blood Inoculation, Large Ruminants

(a) Blood from diseased Bali cattle in the contact transmission experiment at BPT, Ciawi, was inoculated into other Bali cattle. One to two litres maintained at 37°C were given on two occasions 2 days apart. Large volumes were used to maximise the chance of successful transmissions, and inoculations were performed within an hour of blood collection.

Five Bali cattle previously unexposed to MCF that received whole blood from naturally induced MCF cases in Bali cattle contracted MCF and died. Four other Bali cattle that had been exposed to the MCF agent by blood transfusion from MCF-affected buffalo two years previously and that had survived (Young, pers. comm.) were also available. Second passages were attempted to these long-term survivors of the previous experiment, but only one developed MCF. Other second passages to a previously unexposed young Bali bull and a young male Bali cross were successful, but a young buffalo similarly infected at the same time remained disease-free 1 year later.

(b) Two young male buffalo were given blood transfusions from buffalo with clinical MCF at BPT Ciawi. No clinical MCF was observed, although each had a febrile period with some depression and anorexia several weeks post-inoculation. One subsequently failed to thrive, and died 12 months after inoculation. It showed no clinical signs other than anorexia and emaciation. At necropsy, the abomasum was found to be markedly ulcerated, with many erosions also present on the folds. In the rumen there was extensive loss of papillae. Individual papillae were haemorrhagic and sloughing off. Histologically, there was a necrotising vasculitis in the arteries of the abomasum.

(c) Other blood transmissions which demonstrate the infectious nature of the disease in buffalo have been conducted, primarily to further clarify the question of species susceptibility. Blood from a spontaneous case in a buffalo at BPT Ciawi was inoculated into a young Bali male, a local *Bos indicus* type (sapi Jawa), a Brahman type *Bos indicus* (ongole) and a buffalo. The buffalo, Bali yearling and ongole all developed MCF. The sapi Jawa died of non-MCF-related causes. Blood from the ongole was inoculated into four more animals of a similar range of species. None showed disease after 16 weeks of incubation.

Discussion

The primary epidemiological question regarding MCF in Indonesia is that of prevalence. There is no accurate estimate of the economic significance of the disease at the present time, nor can there be until prevalence data are obtained. The reviewed literature and field experience of the authors indicates that sporadic losses occur, and it is reasonable to assume that most of these go undiagnosed and unreported to central authorities. Compounding this problem is that of differential diagnosis, which has presented difficulties in both buffalo and Bali cattle, but for different reasons. This problem is the topic of other contributions.

Minor epidemics of MCF-like diseases occur in Bali cattle from time to time. Many are diagnosed as MCF, and there has been support for considering other named diseases such as Rama Dewa and Banyuwangi diseases as part of the MCF syndrome. Whether Jembrana is part of the same complex remains to be determined. Taken together these diseases represent one of the most visible and reported causes of death in cattle in Indonesia.

If adult animals are valued at approximately US$500, then the cash value of animals lost in Banyuwangi alone (Table 1) in each of the last two years has been US$0.25 million. Such a figure does not take into account the economic costs of lost production from loss of draught power and byproducts and lost reproductive capacity, as well as the financial hardship caused to the owners and the disincentive to others to raise livestock. Although Banyuwangi has reported a high prevalence of MCF, it is only a small fraction of one province, and there are at least 15 provinces in which the disease has been recognised. It can be concluded that the cost of MCF to Indonesia may be at least several million dollars per year.

Consideration of the field epidemiological data shows that MCF in Indonesia is SA-MCF. In all cases investigated by the authors, sheep could be implicated. The possible role of goats as a reservoir host remains unresolved. It is useful to consider the results of the experimental work in more detail, starting with the contact transmissions. In only one was contact with lambing sheep successful in reproducing MCF. Three factors in that experiment—at BPT, Ciawi—were different from the other three. Firstly, goats were involved. However, in Timor where goats are frequently kept with Bali cattle, no MCF occurs, except when sheep are imported. If goats can act as a reservoir, they do not do so in that province. A second factor was the number of reproducing small ruminants. Eleven sheep and twelve goats reproduced during the period of the experiment, whereas only two or three animals reproduced during the periods of exposure in the other experiments. The third factor was the spatial relationship of the experimental animals at Ciawi, where the cattle were penned close to the small rumimants. In this location they were maximally exposed to all fomites produced.

The second and third factors would have combined to give a large total exposure, or dose, to each animal. Alternatively, they could have resulted in a sufficiently contaminated environment for infection to occur. Consideration should be given to whether the former concept may be important. In the blood transmissions, success was achieved by using large volumes of blood. The dose of blood necessary to produce disease has not been titrated because of the cost of the animals, but it is reported widely in the literature that large volumes are necessary. Hence, one of the determinants of natural disease may be not only exposure to the reservoir host, but a quantitative effect of the dose of agent received. The sporadic pattern of natural disease could be governed either by the chances of contacting the agent in variably contaminated environments, or by the hypothesised necessity to be infected by a critical mass of agent sufficient to produce disease in a given observation period.

The transmission experiments have supported the evidence of the field observations of an ascending hierarchy of susceptibility from *Bos indicus* and *Bos taurus* breeds, through water buffalo, to Bali cattle and their crosses. All Bali cattle in the contact experiment at Ciawi died, while neither the buffalo nor the *Bos indicus* developed MCF. In the blood transmissions, the Bali cattle were the first to succumb, followed by the Bali-cross animal, and then the buffalo and *Bos indicus*, in that order. The fact that *Bos indicus* can be infected experimentally if the dose is large is of interest, for this species is not usually affected in the field, and then only in areas where MCF is particularly active (Anon. 1982).

Table 1. MCF in Banyuwangi, 1982–83 to 1985–86.

	Cases in		Emergency slaughter		Annual totals
	Cattle	Buffalo	Cattle	Buffalo	
1982–83	11	3	43	27	84
1983–84	62	40	7	6	115
1984–85	92	45	61	45	243
1985–86	148	110	25	1	284

Source: AARD/ACIAR Collaborative Project on MCF, Field Trip Report No. 11.

The species susceptibility is the essence of the MCF problem in Indonesia. The buffalo are preferred as draught animals in many areas, and the Bali cattle are preferred for livestock distribution schemes. Traditional forms of agriculture place these susceptible species in contact with the frequently implicated suspect carrier, the sheep. Confirming experimentally the impression gained in the field provides useful information for veterinary authorities for their efforts in disease control. The information is also useful for researchers, for the susceptible Bali cattle may confidently be used as a marker of infection. Further contact studies utilising this principle may be able to clarify the relative importance of goats as opposed to sheep as a reservoir host.

The development of the head and eye form of MCF in the Bali cattle placed at BPT, Ciawi, indicates that this institute is still a focus of infection under the circumstances in which large and small ruminants are housed, and that the disease in buffalo that regularly occurs there (Hoffmann et al. 1984a) is MCF. The passaging of MCF with blood from an affected buffalo to buffalo, Bali cattle and *Bos indicus* confirmed the diagnosis.

The patterns of disease observed in the transmission experiments where classical MCF was not produced may be important. Two Bali cattle in contact with sheep associated with the outbreak in deer at Kupang were reported to have nasal discharge and diarrhoea. About 1 year later, there was a second incident with fever and nasal discharge. In the absence of an agent on which to base a serological test, there is no way to link these disease occurrences to MCF, particularly as the histopathology in the convalescent period was equivocal. However, the incidents should be noted for comparative purposes. Recent transmission studies of Jembrana disease have also yielded mild disease (Ressang 1984). It is necessary to develop strategies to examine all such incidents rigorously so that incidental phenomena will not be mistaken for the disease under study.

The inconclusive pattern of disease after other blood inoculations should also be noted. Blood from buffalo inoculated into buffalo on the first two occasions produced fever, depression and anorexia. Mild forms of SA-MCF in experimental situations have been known for some time (Blood et al. 1961). One of the buffalo developed a chronic failure to thrive, and subsequently died. Chronic MCF has also been described in *Bos taurus* (Snowdon 1985).

Whether these two disease responses were MCF is of considerable epidemiological importance. If some of the buffalo that suffer chronic wasting conditions in the field have MCF, then the economic impact of the disease is even greater than supposed. However, one of the most intriguing epidemiological questions regarding MCF is whether animals in the field are regularly infected but show only a mild response. MCF is usually described as being sporadic in nature. Where cattle and buffalo are exposed to the reservoir host, usually only a few develop clinical disease. Are these the only animals infected, or are all infected? What are the determinants of infection and of disease? In the absence of a known aetiological agent, more intensive epidemiological studies and transmission experiments are necessary.

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