The incidence of BDD appears to be increasing worldwide (Brandt et al., 2011; Radostits et al., 2000). When first introduced into a dairy herd, the disease tends to spread in an epidemic pattern, affecting up to 75 percent of the herd. The typical presentation is of acute erosive lesions that cause severe lameness. First-lactation heifers are especially susceptible (Radostits et al., 2000; Read & Walker, 1998a). As the infection becomes more established in the herd a higher proportion of chronic lesions is seen.

Typical lesions are found singly on the plantar surface of the digits between the two claws and bordering the coronary band just above the bulbs of the heels (Parkinson et al., 2012; Holzhauer et al., 2008). Lesions occur most frequently on the hind limbs and are not seen above the level of the dew claws. Clinical signs include lameness and reluctance to move. In less severe cases weight-bearing may be shifted to the toes (Read & Walker, 1998a). Secondary weight loss, loss of fertility and decreased milk production can all be observed in affected herds (Radostits et al., 2000; Edwards et al., 2003). BDD should be differentiated from interdigital dermatitis (ID), which presents as a diffuse necrosis of the distal interdigital skin; and interdigital necrobacillosis (footrot), a trauma-associated necrotising cellulitis with swelling of the lower foot (Parkinson et al., 2012).

Over a period of weeks to months, lesions progress from a circumscribed ulcerative, exudative dermatitis with associated lameness, to a less painful proliferative verrucose dermatitis with a warty appearance. In the early stages lesions (1–6 cm in diameter) are typically ulcerated and red, with excessive granulation tissue that bleeds easily. Early lesions may have proliferation of filiform papillae. Older lesions are grossly grey or white to yellow, interspersed with red granular areas and covered with filiform papillae that are longer than those noted in early lesions. Lesions are circumscribed by a discrete line of hyperkeratotic skin (Radostits et al., 2000; Read & Walker, 1998a; Holzhauer et al., 2008).

There is some uncertainty about aetiology of BDD and the contributing factors. Recent studies have associated it with various Treponema spp. phylogroups identified in the deeper epidermal layer of affected tissues (Nordhoff et al., 2008; Evans et al., 2009; Logue, 2011). Seasonal differences are noted in some affected countries and may be due to differences in climate, housing and management (Radostits et al., 2000).

Histologically an active BDD lesion is often characterised by extensive loss of the stratum corneum, a thick dense mat of mainly spirochaete bacteria invading the stratum spinosum and papillary dermis, and a dermal inflammatory response consisting predominantly of neutrophils and plasma cells. However, relatively inactive or treated lesions may be very difficult to differentiate from other warty digital lesions (Deryck Read, pers. comm., 2011).
Recent cases
The following summary describes five cases of suspected bovine BDD reported to the exotic pest and disease hotline over the past year. The first report of this disease in New Zealand was in 2004 (Vermunt & Hill, 2004) and affected a single three-year-old Holstein-Friesian bull in a 500-head North Island dairy herd. This case was considered positive for BDD owing to the lesion’s histopathological similarity to those seen in overseas reports, including the presence of small numbers of Warthin-Starry silver stain-positive bacteria in the epidermis. Since then, only a single case of BDD, from the South Island in 2006, appears to have been reported (Varney & Gibson, 2006). In 2011 a number of cases were reported, prompting the referral of material for specialist testing and histopathological assessment by Dr Deryck Read, an overseas pathologist with extensive BDD experience.

Our investigations focused on confirming the additional cases of BDD in New Zealand in light of a current case definition, and undertaking Treponema-specific testing by immunohistochemistry (IHC) to assess the distribution of treponemes in the lesions. Results are summarised in Table 1. The IHC was carried out at the California Animal Health and Food Safety Laboratory, San Bernardino, USA. The sensitivity of IHC testing is not high, given that the assay can detect a number of Treponema species; but the location of the spirochaetes, interpreted along with histological lesions, can help confirm a diagnosis of BDD.

Photomicrographs of case material are shown in Figures 2 and 3. Papilloma virus testing was completed either by polymerase chain reaction (PCR) at MPI’s Animal Health Laboratory Wallaceville, or by IHC at the California Animal Health and Food Safety Laboratory.

Table 1: Table 1: Case details for each of the described investigations carried out into bovine digital dermatitis during 2011

<table>
<thead>
<tr>
<th>CASE</th>
<th>REGION</th>
<th>ANIMALS</th>
<th>LAMENESS NOTED</th>
<th>HISTOLOGICAL CRITERIA (SEE TEXT)</th>
<th>TREPONEMA IHC</th>
<th>PAPILLOMA VIRUS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>LOSS OF THE STRATUM CORNEUM</td>
<td>SPIROCHAETE MAT</td>
<td>DERMAL INFLAMMATORY RESPONSE</td>
</tr>
<tr>
<td>1</td>
<td>Waikato</td>
<td>1</td>
<td>300 Dairy</td>
<td>No</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>2</td>
<td>Waikato</td>
<td>1</td>
<td>150 Dairy</td>
<td>No</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>3</td>
<td>Bay of Plenty</td>
<td>7</td>
<td>42 Beef</td>
<td>Yes</td>
<td>X</td>
<td>√</td>
</tr>
<tr>
<td>4</td>
<td>Canterbury</td>
<td>1</td>
<td>600 Dairy</td>
<td>Yes</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>5</td>
<td>Waikato</td>
<td>1</td>
<td>167 Dairy</td>
<td>No</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Figure 2: Photomicrograph of case material from one of the sampled lesions, showing the stratum corneum (SC) and stratum spinosum (SS). The epithelium is hyperplastic with ballooning degeneration of epidermal cells in the stratum spinosum and extensive infiltration of degenerate neutrophils in the stratum corneum and superficial stratum spinosum.
CASE 1
A single adult Holstein-Friesian from a 300-cow dairy herd in the Waikato was reported to have a unilateral raised wart-like 2 x 3-cm mass on a hind limb at the level of the heel bulbs. Lameness was not reported. The lesion was amputated and submitted for histology, which showed epidermal hyperplasia, orthokeratotic hyperkeratosis, degeneration of cells in the stratum spinosum and infiltration of the stratum spinosum with neutrophils. Silver staining revealed the presence of large rod-shaped bacteria in the surface layers of keratin and sporadically in the deeper epidermis. IHC was positive for BDD Treponema spp. in focal areas of the stratum spinosum, and the case was considered to have the required histological features for a diagnosis of BDD (Deryck Read, pers. comm., 2011).

CASE 2
An ulcerated raised 2 x 5-cm mass was removed from the hind limb of an adult Holstein-Friesian dairy cow. Lameness was not seen and only a single animal was reported to be affected in the herd of about 150 cows. Histological examination of the amputated tissue revealed changes similar to those seen in Case 1, with epidermal hyperplasia, orthokeratotic hyperkeratosis, and the stratum spinosum showing degenerative changes and neutrophil infiltration. Large colonies of bacteria among the surface layers of keratin also extended into the deeper epidermis. Silver staining revealed large pure colonies of long rod-shaped bacteria with features of spirochaetes, extending from the superficial layers of the epidermis to the areas of parakeratosis at the level of the papillary dermis. IHC was positive for BDD Treponema spp. in focal areas of the deeper epidermis. Histological findings were consistent with a diagnosis of BDD (Deryck Read, pers. comm., 2011).

CASE 3
A veterinarian treating a 42-head Hereford cross beef herd with a number of footrot (interdigital necrobacillosis) cases identified some animals with heel-bulb lesions grossly compatible with BDD. Parenteral antibiotic and topical copper sulphate treatment had been administered and many of the lesions had resolved, apart from those in two cows, which were biopsied. Before treatment it was estimated that a further five cattle (including calves and adults) had proliferative heel lesions generally affecting the hindlimbs, although some had forelimb lesions. This herd had also experienced an outbreak of footrot 12 months prior to the report. Lesions ranged in size from 1 x 3 cm to 2 x 5 cm and were proliferative and wart-like. They occurred on the heel bulbs of a single hind limb in one cow and on both hind limbs in the other. Histological analysis of these lesions showed marked epidermal hyperplasia with ballooning degeneration and neutrophilic infiltration of cells in the stratum spinosum. Long rod-shaped bacteria consistent with spirochetes were visible after silver staining. Spirochaete colonisation ranged from the superficial layers into the stratum spinosum. The lesions had many of the histological features of BDD. Although histopathology was consistent with the features of BDD, no definitive diagnosis could be reached in this case.

CASE 4
An adult Holstein-Friesian cow in a large Canterbury dairy herd was found with a non-painful unilateral ulcerated raised 2 x 2-cm lesion on one hind limb. The whole herd was examined by an experienced foot-trimmer and one other animal was reported to have a possibly similar lesion but this was significantly smaller than the biopsied lesion and the similarity could not be confirmed. Histopathological examination of a biopsy of the larger lesion identified a chronic hyperplastic interdigital dermatitis characterised by epidermal hyperplasia and orthokeratotic hyperkeratosis. Ballooning
and degeneration of cells and infiltration of neutrophils were noted in the stratum spinosum. Silver staining revealed numerous large rod-shaped bacteria with some resemblance to spirochaetes in the surface layers of keratin. These findings lacked the characteristic histological features of an active BDD lesion but could have represented an older lesion. IHC was not requested.

CASE 5
A single crossbred Friesian/Jersey cow from a 167-cow milking herd in the Waikato region was reported to have proliferative wart-like lesions measuring 5 x 2 cm on the heel bulbs of both hind limbs. The right side was less severely affected than the left. The entire herd was examined but no further lesions were seen. Lesion biopsies were collected after a period of treatment with various topical agents including dermisol, copper chelates and aloe vera. Histology revealed a marked epidermal hyperplasia and excessive thickening of the stratum corneum, orthokeratotic hyperkeratosis, ballooning degeneration of the cells in the stratum spinosum, and intraepithelial pustules filled with neutrophils. No spirochaetes were seen after silver staining, and the *Treponema* IHC was negative. These lesions were considered to be non-specific protuberant papillomatous dermatoses, which were likely to be mature inactive BDD lesions (Deryck Read, pers. comm., 2011).

**Discussion**

All reported cases were in herds running on pasture-based systems, and dairy farm tracks were reportedly in good condition. None of the affected animals were housed or managed under intensive conditions.

Diagnosis and reporting of BDD may be complicated by concurrent foot conditions, including footrot and/or the presence of bovine papilloma virus (Brandt et al., 2011). For example, in Case 3 (the beef herd) lesions were associated with an outbreak of footrot. Specific factors in this case (overweight cattle, grazing on hill paddocks and excessive heel erosion) are likely to have predisposed the interdigital skin to trauma, resulting in footrot, which could have contributed to the development of the heel lesions (Holzhauer et al., 2008). In the USA, muddy conditions and the purchasing-in of replacement heifers were positively associated with disease occurrence (Radostits et al., 2000), and maceration of the skin has been identified as a prerequisite for establishment (Read & Walker, 1998b). In summary, BDD is a multifactorial disease whereby treponemes interact with environmental conditions that promote colonisation of the keratinised skin of the heel.

These investigations have provided additional information about the occurrence and characteristics of spirochaete-associated foot lesions in New Zealand. When the histopathological features of the recent cases are assessed in conjunction with their epidemiological and clinical presentation, it can be concluded that although spirochaetes are present in lesions that fulfil the criteria for the diagnosis of BDD in individual animals, the syndrome as it is recognised in other countries (epidemic spread with high intra-herd prevalences) does not appear to be present here.

Dairy NZ’s Healthy Hoof Programme (HHP) teaches early recognition of lameness, and systematic approaches to minimising and managing lameness by understanding the reasons behind it. This successful programme will become increasingly more important as intensive management approaches are adopted (Cleeve, 2012). Coverage could very easily be expanded to help farmers, livestock advisers and veterinarians identify, understand and track new or novel conditions such as BDD.

Further study of the clinical presentation of the BDD-like lesions seen in New Zealand conditions is needed – their effect on production, and management factors associated with their development. Further bacteriological assessment could focus on typing the *Treponema* spp. associated with these lesions and comparing with those associated with the condition in other countries. This could provide useful information regarding the role of certain *Treponema* spp. in causing BDD. It is important to monitor the prevalence of this condition in New Zealand, given the projected shift from pasture-based systems to management of larger herds under more intensive conditions.

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Francisco Uzal of the California Animal Health and Food Safety Laboratory, and Dr Read also provided further interpretation of the histopathology.

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