UNGULATE-PROOF FENCES IN THE MARLBOROUGH SOUNDS

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October 2015

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INTRODUCTION

In the Marlborough Sounds, there is considerable enthusiasm from land owners and land managers to protect and enhance the Sounds environment.

This report aims to provide Marlborough Sounds' landowners with information on the potential of deploying fences that keep large browsing mammals (feral goats, deer, pigs and sheep) out of natural areas.

Feral goats, deer, pigs and sheep (collectively known as 'ungulates') can undermine the integrity of remnant and regenerating forests in the Sounds through selective browsing and pig-rooting. Feral pigs can also prey on native seabirds, reptiles, native snails and invertebrates.

Several successful ungulate-proof fences have been built in the Sounds and elsewhere in New Zealand, and have been widely deployed overseas.

The Sounds is particularly suited for ungulate-proof fencing for the following reasons:

- As much of the Sounds was previously cleared and is now regenerating into native forest, a priority step in ecological restoration is to protect these sites from extensive browsing and rooting, to allow the natural forest regeneration process to continue. Without a healthy and diverse forest, these sites will never be able to harbour a full representation of native fauna - even with intensive pest control.
- The Sounds is a national stronghold for native *Powelliphanta* landsnails and for breeding seabirds. Both could substantially benefit from effective ungulate-proof fences.
- While fully predator-proof fences are an exciting breakthrough for conservation management in New Zealand, and a preferred option in 'mainland' areas, the Sounds peninsula geography undermines this advantage. Two of the key target species, rats and stoats, are good swimmers and able to get around such fences, or reach fenced areas from adjoining land as far as 1km away.
- The Sounds is a popular recreational hunting area, and both feral deer and pigs are valued species. Ungulate-proof fences are likely to receive wider community acceptance than targeted hunting, if the impacts of these species are to be managed.

This report reviews the impact of ungulates in the Sounds, highlights some existing ungulate-proof fences in the area, and provides recommendations for the design of such fences in the future. It aims to provide Sounds landowners and land managers with inspiration and knowledge about a conservation management option that complements other techniques, such as predator-proof fences and intensive pest and weed control programmes.

THE MARLBOROUGH SOUNDS CONTEXT

Before people arrived, the Marlborough Sounds were clad in a rich mantle of forest, from the shores to the highest peaks. This primeval forest was highly diverse, reflecting the Sounds' location in the centre of New Zealand, complex geology, a multiplicity of landforms and aspects, predominantly fertile soils and a relatively benign climate. Added to that was the complete absence of mammals (other than bats and seals). The forest was alive with birds and other unique creatures. The whole ecosystem was sustained by complex and subtle relationships between the vegetation, flora and fauna. With the arrival of people, the primeval patterns and processes were disrupted.

When Cook arrived at Ship Cove, the Marlborough Sounds was still largely forested, apart from some areas of low-stature vegetation on ultramafic soils around Mt McLaren and on D'Urville Island, around the summit of Mt Stokes, and areas of Maori settlement. Cook's description was that Queen Charlotte Sound "consists wholly of high hills and deep valleys well stored with a variety of excellent Timber fit for all purposes."

During the late nineteenth century, there was a rapid change in land use over a substantial area of the Sounds, from mixed hardwood, podocarp and beech forests to pasture, through widespread burning and, to a lesser degree, the logging of native forest. Cattle, sheep, pigs and goats were introduced and farmed throughout the Sounds. Many of these animals became feral, living within the remaining native forests. They were joined by deer, which were introduced as a hunting resource.

The areas that retained their indigenous forest cover were generally either gullies or south-facing slopes, which did not easily burn, or upland sites which were unsuitable for farming and not targeted for burning in the first place. These areas today form the bulk of the public conservation estate in the Sounds.

With the gradual cessation of farming since the early 1900s, many of the areas of coastal lowland that had been burnt for farming have progressively begun to revert to native forest, of which kanuka (*Kunzea ericoides*) and to a lesser degree, manuka (*Leptospermum scoparium)*, are the dominant pioneer forest species. Entire faces, such as the south side of Kenepuru Sound and the south side of Grove Arm, represent six decades or more of native forest regeneration following the removal of stock and absence of fire.

With the Sounds' mild climate and abundant rainfall, these areas represent a potential powerhouse of native forest recovery if they are allowed to naturally transition to broadleaved, beech and podocarp species (such as rimu, totara and matai). And, only if they are allowed to recover, will they be able to provide habitat to the diverse range of native fauna that they previously contained.

In the North Marlborough Significant Natural Areas Report (MDC, 2009), the authors summarised this recent history:

"kanuka forests, tree fern communities and early successional shrublands have greatly increased in extent due to clearance of the primeval forest cover and prolific regeneration following the waning of pastoral farming. If not unduly disturbed, the kanuka forests and tree fern communities will in time be overtaken by larger native trees and become diverse forests resembling the primeval forest cover."

THE ROLE OF FERAL UNGULATES

'Ungulates' is the collective term applied to hoofed mammals, and includes a wide range of animals, including horses, sheep, camels and hippopotami. In New Zealand, 'feral ungulates' refers to that smaller subset of ungulates that maintain populations in the wild and which are often of conservation concern.

Feral ungulates in the Marlborough Sounds are primarily represented by red deer (*Cervus elaphus scoticus*), feral pigs (*Sus scrofa*) and feral goats (*Capra hircus*), all of which are widespread throughout the area. Fallow deer (*Dama dama*) are present on D'Urville Island, and feral sheep (*Ovis aries*) and cattle (*Bos taurus*) are also occasionally encountered throughout the Sounds.

While some ungulates, particularly deer and pigs, are valued for recreational hunting and a source of wild meat, all ungulates are also recognised as threats to biodiversity conservation. They pose a particular threat to the early stages of native forest regeneration so widely distributed through the Sounds, to the integrity of remnant native forest stands, and a direct threat to New Zealand's distinctive native snails and seabird colonies.

STALLED SUCCESSION

The impacts that sheep, deer and goats can have in stalling the native forest regeneration process has been well-documented in New Zealand.

One report (Smale et al, 1995), from Kaipara Heads in Northland, concluded that two markedly different succession pathways are evident in a kanuka forest, inside and outside a deer-proof fenced exclosure .

"Within the exclosure (i.e., in the absence of deer), kanuka and its associated subcanopy species are being replaced by mahoe and another generation of houpara, and outside by another generation of both kanuka and houpara - an example of a partially "stalled succession" (Connell and Slatyer, 1977). Mapou seems likely to be but a minor component of any future canopy. Successions similarly stalled by red deer have been reported in secondary kanuka forest in the northern Urewera country by Payton, Allen and Knowlton (1984)."

The authors note that the current and immediate future canopy species (ie: primarily kanuka) are all relatively short-lived, implying frequent canopy turnover and hence susceptibility to invasion by weeds.

Similarly, a longitudinal study of native forest succession in a kanuka forest at Te Urewera, in the North Island, concluded that, in the presence of browsing mammals:

"the minimal compositional change over 30 years in these communities and paucity of recruitment of trees of canopy species point to arrested succession. Without management intervention to increase tree recruitment rates of canopy species, forest successions in this region will be characterised by high tree fern abundance, low biomass at local scales, and limited transitions to tall forest communities". (Richardson et al, 2014).

The authors subsequently note that such future forest successions will be "vulnerable to exotic tree invasion".

While no such formal studies have been done in the Sounds, a 2012 survey of the Momorangi Bay Scenic Reserve by the Department of Conservation found that, following repeated burning:

"natural recruitment is either very slow or not evident … due to the paucity of seed sources and by suppression of forest succession due to browsing impacts by ungulates and possums." (Shannel Courtney, pers. comm).

Species that were identified as "very rare or locally extinct" under the intact kanuka canopy of the reserve, and which would be expected to be present, included kahikatea, matai, miro, black and hard beech, hinau, nikau, pukatea, swamp maire, tawa, titoki and tree fuchsia.

In summary, there is abundant evidence that, following burning, a pioneer forest of manuka and kanuka may not necessarily give way to the diverse podocarp forests that previously cloaked the Sounds, if feral ungulates are allowed to subvert the natural succession process. In time they may only be succeeded by more pioneer species, species unpalatable to ungulates, and opportunistic weeds. In the Marlborough Sounds, the most likely adventive weeds are wilding pines, old man's beard and banana passionfruit.

ERODING FOREST REMNANTS

Feral ungulates also have a negative impact on otherwise intact native forest remnants. This process has also been well-documented in New Zealand.

Deer and goats, in particular, have extensively modified native forest understories (Wardle 1984, McKelvey 1995), favouring certain plant species over others as food and therefore considerably modifying the composition of the vegetation. One recent report, using a 'seedling ratio index' across multiple sites, including the Marlborough Sounds, found that the following were highly-preferred species:

- *Asplenium bulbiferum* (hen & chicken fern/mother spleenwort)
- *Astelia* spp.
- *Freycinetia baueriana* (kiekie)
- *Coprosma grandifolia* (kanono)
- *Coprosma lucida* (karamu)
- *Griselinia littoralis* (kapuka/NZ broadleaf)
- *Melicytus ramiflorus* (mahoe)
- *Myrsine australis* (red matipo)
- *Olearia rani* (heketara)
- *Schefflera digitata* (pate/seven-finger)
- *Weinmannia racemosa* (kamahi)

(Sweetapple & Nugent, 2004).

In 1978, three ungulate exclosures, approximately 30m x 20m in size, were constructed within the forest in Arapawa Island Scenic Reserve, to gauge the impact of ungulates, the effectiveness of controlling them and the forest undergrowth recovery process in the absence of ungulates. Within a few years, a deep layer of leaf litter had accumulated within the exclosures, soil was beginning to be rebuilt from the litter and the ground was covered in masses of ferns and tree seedlings. Many of the trees had produced new shoots from their bases. Now, what was completely devoid of undergrowth has become a dense thicket, with canopy species well on the way to taking their place alongside the old trees.

Prolonged impacts can be devastating, leaving the forest with a "hollowed out" structure, lacking undergrowth and ultimately threatening canopy regeneration.

In the Sounds, this phenomenon can be readily observed in many native forest remnants, such as those within the D'Urville Island Scenic Reserve, which has high deer and pig numbers.

"It should not be possible to see far or walk easily within a healthy temperate rain forest. In the forests of the reserve though, the lower tiers of ferns, shrubs, seedlings and saplings are depleted or missing. From the outside they look great - healthy canopies and diverse vegetation on the edges - but the hollow interior tells a different story. Many of the smaller trees have their bark stripped by deer and are dead or wounded. And in the upland forests, where the giant land snails are, the ground is extensively bared and ploughed up. It's not just the direct damage that ungulates do that is the problem; once the damage is done, it only takes a few animals to prevent recovery." (Geoff Walls, pers. comm).

PREDATION ON NATIVE LAND SNAILS & SEABIRD COLONIES

The Department of Conservation (DOC) has described feral pigs as “particularly effective snail predators and habitat modifiers”, capable of both eating the native land snails, and modifying their habitat sufficiently to make it unsuitable for snails (Walker, 2000). Coleman *et al*. (2001) found that pigs were the main cause of mortality of snails on D’Urville Island (73% of 33 shells).

As a local example, the large land snail, *Powelliphanta hochstetteri obscura,* is now restricted to isolated colonies on D’Urville Island and the western Marlborough Sounds, but is facing gradual decline through predation by pigs, possums, thrushes and rats, and degradation of their forest habitat, of which pigs play a key role. DOC has estimated that the extinction of these *P. hochstetteri obscura* colonies within 50 years seems possible given the present rate of decline (Walker, 2000).

Feral pigs are also capable of eating the eggs and young chicks of seabirds, where colonies exist, with multiple observations of seabird predation (e.g.: Challies, 1975). In Kaikoura, the feral pig is considered the primary threat to the two residual colonies of Hutton’s shearwater (*Puffinus huttoni*) left in the world, through predation and trampling.

In the Sounds, two gannet colonies have recently established – at Waimaru Bay, Pelorus Sound and at East Bay, Queen Charlotte Sound – both of which are considered susceptible to feral pig damage. DOC has erected a short fence across the peninsula at East Bay, to protect the small colony there – which numbered just 45 nests in 2002.

OPTIONS FOR MANAGEMENT

For landowners and land managers wanting to prevent any of these three processes described – stalled succession, the erosion of forest remnants, and snail/seabird predation – the most common response is to undertake or allow hunting of ungulate species.

In this regard, where hunting is permitted, recreational hunters play an important role in managing populations of deer and pigs and can be seen as a potential ally of conservation. However, the extensive hinterland and the wide-ranging habits of the ungulate species means that continual re-invasion is an issue. The recreational hunting practice of not targeting breeding females, in order to protect a hunting resource, also undermines the conservation value of recreational hunting.

For landowners or land managers that want increased protection, the recourse is either targeted hunting for conservation purposes, or the creation of ungulate-proof fences.

Targeted conservation hunting is particularly suited for feral goats, as they are not generally targeted by recreational hunting, and has been extensively practiced by DOC in the Sounds. Extending the scope of targeting hunting to include deer and pigs is problematic, as it is likely to incur resistance from the recreational hunting community.

Furthermore, targeted hunting is expensive, preferably requires the use of appropriately-trained dogs and a skilled handler, and will need to be maintained into perpetuity. DOC experience has shown that for native vegetation to show significant recovery, the animal population needs to be reduced to a level where one experienced hunter and dog will encounter only one animal per hunting day. Control that does not achieve this level will still reduce the pressure on the native habitat but not to the extent that full recovery will be able to occur.

Therefore, in sites with existing feral ungulate populations and with high connectivity to adjacent feral ungulate populations, ungulate-proof fences may be a viable alternative in conjunction to hunting. The creation of ungulate-proof fences has been trialled in several locations in the Sounds, and elsewhere in New Zealand, but may have more widespread potential.

An interesting parallel is the State of Hawai'i, in the United States. Like New Zealand, the islands of Hawai'i evolved in the absence of large grazing animals and, like New Zealand, the presence of feral ungulates has had a devastating impact on native forests and ecosystems – in their case, feral goats, feral pigs, axis deer (*Axis axis*) and Mouflon sheep are considered the main problem species.

A recent forest restoration guide (Sailer, 2006) considers that "fencing is the most successful and cheapest long-term solution to ungulate problems" in their context, and accordingly ungulate-proof fences have been widely deployed (Figure 4, Photo Selection). The Hawai'i Association for Watershed Partnerships (www.hawp.org), for example, has erected more than 65kms of 'protective forest fences' as part of a programme of forest protection and restoration.

PEST-PROOF OR UNGULATE-PROOF?

Pest-proof fences are an exciting development in New Zealand, with many ambitious projects underway nationally, such as Zealandia (www.visitzealandia.com), Maungatautari (www.sanctuarymountain.co.nz) and the Brook Waimarama (www.brooksanctuary.org), that aim to maintain pest-free sanctuaries. It may be considered that pest-proof fences are a preferable alternative to ungulate-proof fences, as they will keep out a wider range of species, including stoats, possums and rodents, as well as ungulates.

However, while the Marlborough Sounds geography lends itself to fencing projects, with its many peninsulas allowing large or significant natural areas to be protected behind a relatively short fence, pest-proof fences also have significant disadvantages in the Sounds context.

Pest-proof fences, such as Xcluder® (www.xcluder.co.nz) and Pest Proof Fencing (www.meshindustries.co.nz), are very expensive, costing approximately $250/m and require intensive maintenance, particularly in the Sounds coastal environment. In addition, while the Sounds geography is well-suited for such fencing, this natural advantage is eroded by the strong swimming ability of rats and stoats, both of which are key targets for exclusion by pest-proof fences. Rats and stoats are able to swim around fences or across up to a kilometre of open water from adjoining mainland. There is thus a natural limitation to the implementation of fully pest-proof fencing projects in the Sounds.

By contrast, ungulate-proof fences are cheaper and easier to maintain and, of the excluded species, only deer are likely to swim around a fence or across open water from adjoining mainland. Based on their presence on a number of Fiordland islands, it has been identified that deer can easily swim distances of a kilometre or more (Brown 2005). By comparison with rats and stoats, however, deer are relatively easily detected and controlled.

In an ecological context, as noted earlier, ungulate fencing is also appropriate as much of the Sounds is in early stages of native forest regeneration, and a key ecological objective must be to protect and foster the natural process of native forest regeneration. In these sites, ungulate control should be regarded as the first step in any forest restoration programme, and can be complemented in the future by a bait station or trap network targeting possums, stoats and rodents.

LOCAL FENCING INITIATIVES

The desire to facilitate the process of native forest succession has seen several landowners and land managers undertake their own fencing projects in the Marlborough Sounds.

KENEPURU SOUND

Location: Kenepuru Road, Kenepuru Sound

Land Tenure: Private land in a QE2 National Trust covenant.

Site Description: The site is composed of moderate to steep hill slopes, rising from the shore to the main dividing ridge between Kenepuru and Queen Charlotte Sound, and is drained by a series of small streams in eroded gullies.

The slopes have mostly been cleared in the past, except in gullies, and are now regenerating with a continuous manuka/kanuka canopy, and seral-broadleaf species beneath.

Objective: The objective of the fence is to protect the 12ha QE2 covenant on the site, by keeping out pigs and deer.

Construction: The fence was constructed in 2004. To the west, a standard deer mesh was used, which is 1800mm high. Posts are varying distances apart, with a mixture of steel and wooden warratahs in between – in some cases existing trees are used as posts. To the west and at the top of the site, an existing sheep fence was in place, and top-up fencing was added to increase the height of standard fencing to 1800mm high. The bottom of the site, which is bounded by Kenepuru Road, is unfenced.

The fence follows ridgelines and an old benched track through the forest (Figure 5, Photo Selection).

Maintenance: The fence has less corrosion issues than exposed sites in the Sounds. The key maintenance task has been to add and replace tie-downs at the bottom of the fence to prevent pig access.

Efficacy: Deer are occasionally detected inside the fence. It is thought that they have either come off the road or jumped over the upper section of the fence, where the hillslope is steep enough that deer on the upper slope are sufficiently high that they can reach the top of the fence with ease. This is exacerbated by the upper section of the fence line following a benched track, with a high cut bank on the uphill side of the fence. It is estimated the fence would need to be 2200mm high here to prevent deer access. The fence has been very successful at keeping pigs out.

Native forest regeneration: The site was inspected with Tom Stein, of the Queen Elizabeth 2 National Trust, in August 2014. A notable contrast in vegetation was evident on either side of the fence, despite occasional deer incursions. Common broadleaf species were more abundant and in better condition inside the fenced area, including mahoe (*Melicytus ramiflorus*), five finger (*Pseudopanax arboreus*), karamu (*Coprosma lucida*), kanono (*Coprosma grandifolia*), makomako (*Aristotelia serrata*), and various bush ferns.

ARAPAWA ISLAND

Location: Arapawa Island, Queen Charlotte Sound

Land Tenure: Arapawa Island Scenic Reserve

Site Description: An unusual mix of subtropical kohekohe, warm temperate tawa and montane beech-podocarp-broadleaved forests.

Objective: The objective of the fence is to protect this important forest remnant by keeping out pigs, sheep and goats.

Construction: The whole fence is approximately 5 km long and was constructed in about 1994 (Figure 6, Photo Selection).

The fence is made of standard 8-wire 150 mm boundary netting, which is 900mm high. Posts are 10 m apart, with a mixture of steel and wooden warratahs in between, spaced at approximately 2m intervals and tie-downs are used as required. The mesh is protected at the bottom by a row of barbed wire to minimise pigs gaining access underneath the mesh, and a barbed wire stay above the mesh, to create a total fence height of approximately 950 - 1100mm.

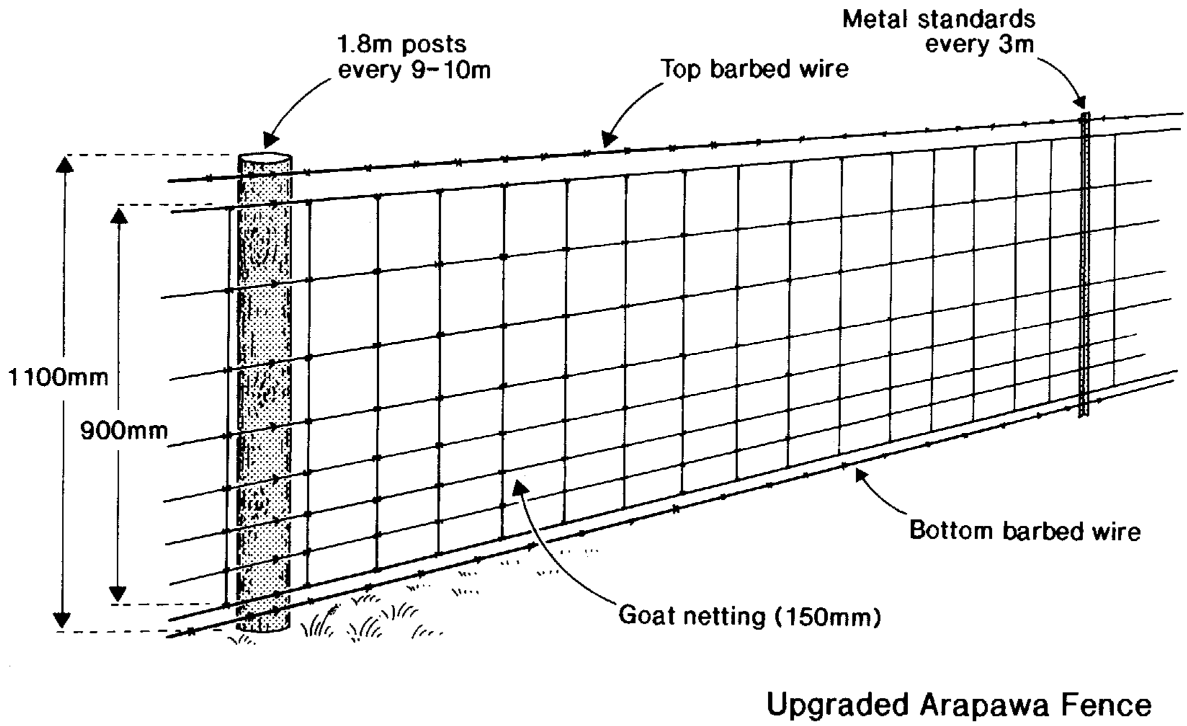

Figure 1: A representation of the Arapawa Island fence (reproduced from Aviss & Roberts 1994)

Maintenance: Corrosion is a major issue at the site, and several steel warratahs were heavily rusted, with one broken at ground level. These also create rust points where the mesh touches the warratahs.

Efficacy: DOC reports the 150 mm netting used excludes all but very young animals from passing through, with young piglets observed getting through the mesh. The fence is complemented by targeted hunting inside the reserve.

Native forest regeneration: In the part of the reserve that is fenced and protected from goats, sheep and pigs there is impressive re-growth of understory shrubs and trees transforming it into more natural, healthy forest. Seedlings are now abundant whereas before the forest floor was almost bare of new growth due to grazing by goats and pig rooting (Figure 7, Photo Selection).

CAPE LAMBERT

Location: Cape Lambert, Outer Sounds

Land Tenure: Cape Lambert Scenic Reserve

Site Description: The Reserve (181ha**)** occupies most of a long narrow, rugged peninsula extending into Cook Strait and comprises areas of coastal kohekohe forest, tall scrub dominated by kanuka or broadleaved species, low scrub, rough grassland and coastal cliff communities (Walls 1984).

Objective: The objective of the fence is to protect this forest remnant by keeping out possums and goats.

Construction: The fence is approximately 2 km long and was constructed in about 1994.

The fence is made of chain-link netting, which is 900mm high and with a small mesh size. Wooden posts are 2-3 m apart, with battens between each post.

The mesh was protected at the bottom by a 150mmx50mm board, partially buried, and with electrified outriggers to prevent possums climbing the fence.

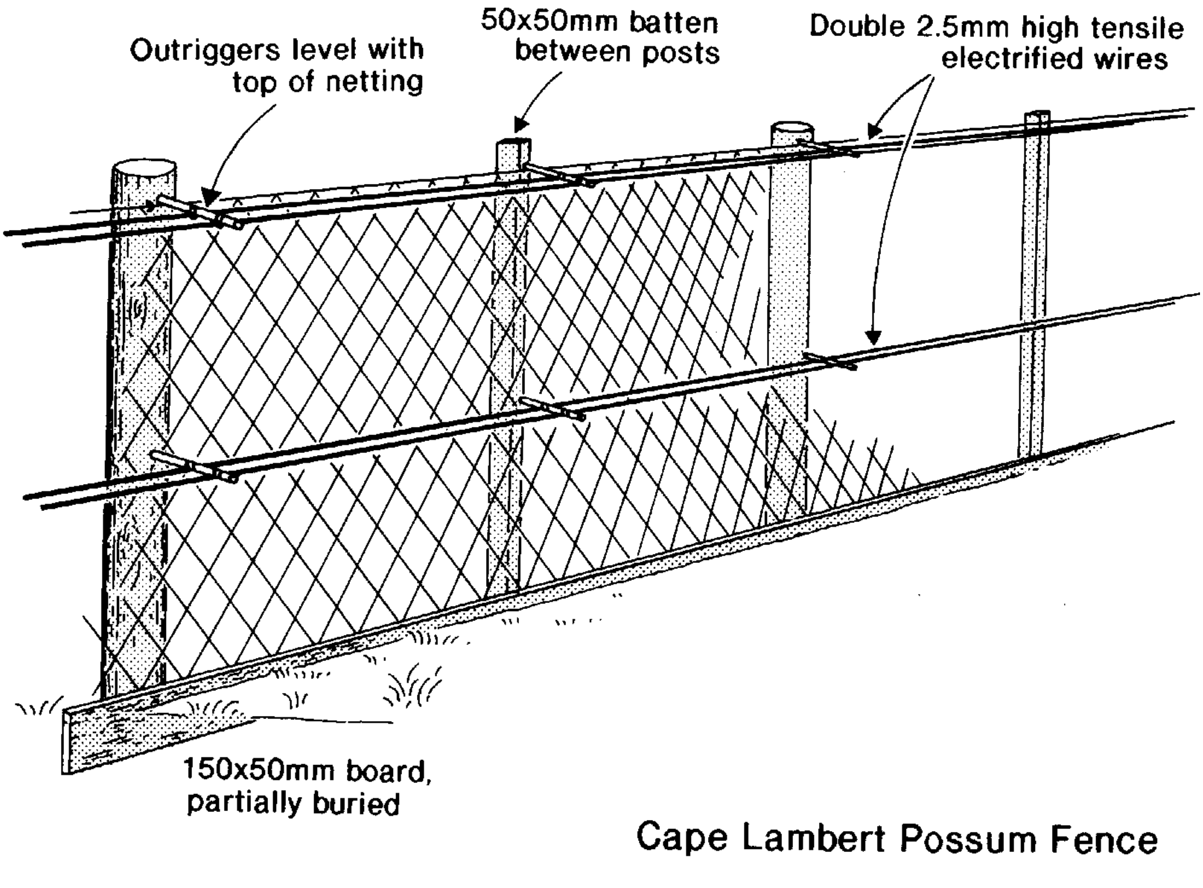

Figure 2: A representation of the Cape Lambert fence (reproduced from Aviss & Roberts 1994

Maintenance: Maintaining the electrified outriggers proved to be problematic, with power often lost through vegetation growth and storm damage. There will also problems with the electrification unity and holding the outriggers in place. The electrification has now been discontinued. Corrosion at the site is also an issue.

Efficacy: The fence has proved reliable in preventing goat access, but was not successful against possums.

Native forest regeneration: While no formal monitoring has taken place, informal observations suggest healthy native forest condition within the fence.

TUI NATURE RESERVE

Location: Otohutu Peninsula in the Waitata Reach, Outer Pelorus Sound

Land Tenure: Private.

Site Description: The Tui Nature Reserve (42ha) occupies the southern side of the peninsula consisting of mature and regenerating native bush.

Objective: The objective of the fence is to exclude goats and pigs while trapping stoats, rats, and possums within the fenced area.

Construction: The fence is still under construction, to be completed by the end of 2015, and will be c3km long. The fence is made of 150x150mm sheep netting, which is 900mm high. Wooden H4 posts are 4m apart, with galvanised warratahs in between at 1m spacings. The fence will be complemented by two electrified outriggers, powered by solar panels.

On flatter sections of the route along the ridge line a digger was used to clear a c3m swath to even the ground and facilitate construction. Steep sections required clearing of vegetation by hand and helicopter support for construction. The cost has averaged out at about $30/metre for materials, with labour provided largely by volunteers.

A noticeable increase in deer numbers recently has led to plans to extend the height of the posts and to string electrified tape between these to discourage these animals.

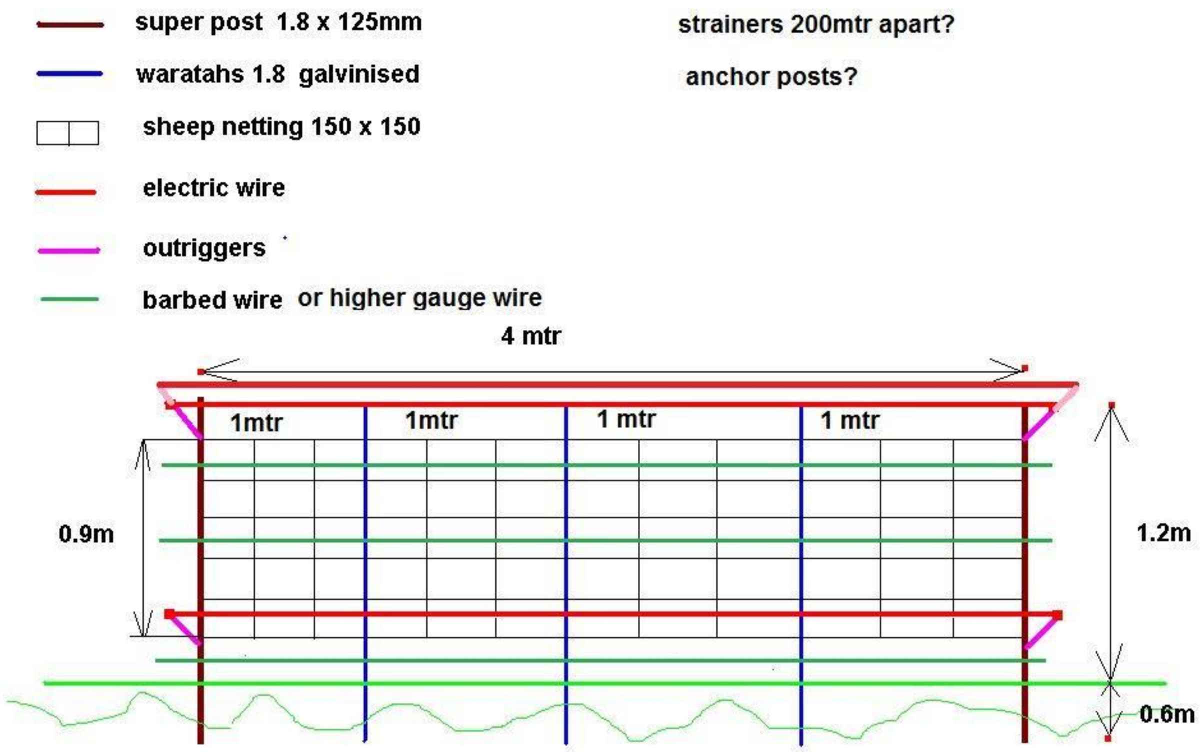

Figure 3: Diagrammatic representation of Tui Reserve Fence

Maintenance, efficacy and native forest regeneration: It is too early to have any information on these issues, as the fence is not yet complete.

GENERAL FENCING PRINCIPLES

In considering an ungulate-proof fence, there are some basic principles to consider:

- The best fences are carefully designed, recognising the particularities of the target species.
- The best fences are carefully sited, making use of natural features such as ridgelines, and utilising formed tracks where possible.
- Even the best fence is not likely to be 100% effective 100% of the time.
- A fence must be complemented by the effective removal of all ungulates from within the fenced area, or at least control to very low levels.
- If invasive weeds are present, weed control should be planned in conjunction with ungulate control efforts as the removal of ungulates, particularly goats, can lead to a large increase in weed growth, particularly if the native forest canopy is not continuous.
- The fenced area must be subject to regular surveillance to detect any ungulate incursions or the growth of any residual population following control.
- For a fence to be effective, it must be regularly inspected and maintained.
- Community support for fencing and ungulate control is vital to deter vandalism of fences and to ensure ungulates are not illegally liberated back into a fenced area after control.

FENCE DESIGN & CONSTRUCTION

As the range of fence designs already deployed in the Marlborough Sounds, and elsewhere, shows, there is no single design that will work for all situations.

Considerations that may affect design include:

- Budget
- Topography and soil type
- The suite of feral ungulates present (e.g. D'Urville Island has high red deer numbers, moderate fallow deer and pigs, and no goats compared to the southern faces of Queen Charlotte Sound, which has high goat numbers, moderate red deer and pigs, and no fallow deer.)
- Landowner/community concerns (e.g. some sites may choose not to target deer, recognising their value for recreational hunting).

However, any fence must be fit for purpose, and in this regard, must meet basic design and construction considerations that address the abilities and behaviours of the target species.

DEER

In order to exclude deer, the key design parameter is height, in recognition of the jumping ability of deer.

In Scotland, where land managers have considerable experience fencing deer, a minimum height of 1.8 - 2.0m is recommended for red deer, and a height of 1.5m for the smaller fallow deer (Trout & Pepper, 2006). In Hawai'i, where the target deer species is Axis deer, a minimum height of 1.98 – 2.13m is recommended (Sailer, 2006). In Kenepuru Sound, the 1.8m fence has been shown to be generally effective against red deer, but the landowner believes an increased height of 2.2m would be preferential in places (Ian Hamlin, pers. comm).

A maximum mesh size of 300x200mm is recommended for red deer, and 200x200m for fallow deer (Trout & Pepper 2006). Standard graduated deer mesh has been successfully deployed in Kenepuru Sound.

Locked joint mesh is recommended over the cheaper hinged joint mesh, as the latter but may be opened by deer (Trout & Pepper 2006).

FERAL GOATS

Feral goats may try to pass over, through or under fences.

In Hawai'i, where there has been considerable experience in fencing goats, a height of 1.22 – 1.32m is recommended (Sailer, 2006). In the Marlborough Sounds, at Arapawa Island and Tui Nature Reserve, a fence height of 1.1 – 1.2m is considered adequate.

An additional consideration is that goats are very adept at climbing, so external wooden diagonal bracing posts should be avoided (Parkes et al. 1996).

A mesh size of 150x150mm is considered adequate to keep goats from passing through fences, and has been used at Arapawa Island and Tui Nature Reserve.

Goats are also very capable at squeezing under fences. The gap between the fence and the ground should not exceed 80mm, and with tie-downs used. Running a strand of barbed wire on the bottom wire is also used to prevent goats trying to get under a fence, with this method deployed at Arapawa Island.

In Hawai'i, ground skirt fencing is deployed to prevent goat access in preference to barbed wire. This involves joining the upper section of a 0.9m wide roll of fine mesh to the bottom of the fence, and laying the lower section of the mesh along the ground, anchored with tiedowns. Wire coated in Bezinal® is used as this considerably improves resistance against rusting.

FERAL PIGS

Pigs preferentially pass through or under fences.

As pigs can dig effectively under fences, considerable attention has been given to preventing this. In Hawaii, ground skirt fencing, as used against goats, has been successfully deployed, while in New Zealand, a strand of barbed wire has also been used.

In Australia, a study of pig-proof fences (Hone & Atkinson, 1983) showed that electric outriggers increased the effectiveness of a range of fence designs, as pigs quickly learned to avoid electrified fences. The authors considered that electrifying an existing fence, such as a deer fence, with an electric outrigger is likely to be the cheapest and simplest way to pig-proof it.

In Hawai'i, a height of 1.06 – 1.22m is recommended (Sailer, 2006), and in Scotland a height of 0.9 – 1.2m in considered adequate. The Australian study (Hone & Atkinson) recommended a height of 0.9m.

Pigs will also exert considerable force trying to get through a fence. For this reason, locked joint mesh is recommended over the cheaper hinged joint mesh.

Putting these considerations together, Hone & Atkinson (1983) recommended the following design as being pig-proof: steel posts 5m apart, 900mm high, 800m high hinge joint mesh (8 horizontal wires, verticals 15cm apart), two top barbed wires at 900 and 850mm, electrified 'stand-off' wire 15cm on pig side of fence.

MULTI-SPECIES

In the Sounds, it is likely most land managers will specify a fence that addresses two or more species. In this regard, the fence must include a mesh size to exclude the smallest species, a fence height to exclude the most agile jumper or climber, and have the material strength to withstand the most powerful species.

In this regard, the specifications used by the Hawai'i Association for Watershed Partnerships have been developed to prevent access by goats, pigs and Axis deer, and as such are similar to the likely requirements in the Sounds. They recommend galvanized steel posts no more than 3m apart, 2100mm high, 1200mm high Bezinal®-coated graduated mesh (13-48), two Bezinal®-coated barbed wires at the top and bottom of the mesh, and 1000m Bezinal®-coated woven wire ground skirting (Melora Purell, Kohala Watershed Partnership, pers. comm.)

ELECTRIFICATION

Electric fences may be cheaper to build than a wire mesh fence, but are considered less effective in most situations and require more maintenance.

By contrast, electric wires are commonly used to improve the effectiveness of a fixed fence. Animals often investigate objects with their noses, which are particularly sensitive to shocks, so electric wires can be offset from the base of the fence at the appropriate height. Making these electric outriggers more obvious, such as with plastic strips, can also be helpful in order to encourage investigation.

In Australia 70% of feral goat, pig, rabbit and dingo fence designs in Australia incorporate some electric wires (Long & Robley, 2004). Similarly, as noted above, a study found that electrification significantly reduced the number of pigs getting through fences (Hone & Atkinson 1983).

While electrification is widely used in Australia, using electrified fences in forested areas is more problematic, as windfalls, vegetation growth and storm events can lead to regular failure of the system. For this reason, while desirable, electrification may have limited applicability in the Sounds context.

Similarly, electrification supported by mains power is preferable, which may also not be possible in the Sounds, as voltages must be maintained as high as possible and automated monitoring systems are desirable to provide alerts on voltage drops.

Compliance with Australia/NZ Standard 'Electrical Installations-Electric fencing' (AS/NZ 3014:2003) is required.

CORROSION

Corrosion is a major potential issue that will shorten the lifespan of any fence. In the Sounds, this is likely to occur where the fence is in an exposed coastal situation, or where fencing materials are in contact with the ground.

In the Sounds, steel warratahs has proven to rust out quickly and create corrosion points for the fencing material. Similarly, warratahs, wire and mesh in contact with the ground will also rust out more rapidly. In order to prevent this, the fence at Tui Nature Reserve uses galvanized warratahs and H4 wooden posts.

In Hawaii, standard fencing specifications now include Bezinal® coating for all fencing materials, fasteners and barbed wire, as this considerably prolongs the life of fencing materials. Bezinal® (Bekaert Zinc Aluminium) is claimed to have superior corrosion resistance, outperforming galvanized products by at least 3 to 1 in many applications (www.bekaert.com).

SITING A FENCE

In considering where to site a fence, the ratio of fence length to the area enclosed will have an important influence on the feasibility of a fencing project.

With the Sounds geography, there are ample opportunities to fence relatively large areas behind a short fence, and clearly the shorter the fence to the area protected, the higher cost/benefit ratio. The area protected, however, should not be so large that it becomes impractical or unrealistic to remove all the feral ungulates within the fenced area in the first place or to maintain it at either very low densities or ungulate-free. Similarly, there needs to be landowner or land manager support for the removal of feral ungulates within the fenced area, and a willingness to accommodate on-going activities in that area.

Once a general site has been determined, the best route on which to run a fence should be dictated by the terrain. Experience has shown that a weak spot will be created wherever a fence crosses a waterway, as it is difficult to fence these effectively. In order to avoid this, fences that follow ridgelines are strongly preferred. Furthermore, the route should follow straight lines where possible, as this will be more easily constructed, more effective and more easily maintained than a fenceline with many corners.

In most cases, it will be worth clearing a corridor using a digger before construction to create a level base to build on, with a general guideline being to create a corridor as wide as the fence is tall (Sailer, 2006). During the course of fence construction, cleared routes will allow additional fencing material to be strategically placed in anticipation of fenceline failures in the future.

If a fence must cross a waterway, a hinged gate or apron is required that lifts and falls according to water flow. There are two common strategies employed in Hawai'i. In intermittent and low flow streams, a hinged apron can be built in the stream bed. The apron is weighted with rocks or logs to prevent ingress in dry periods. During heavy flows, the apron lifts and is held by the hinge. The apron is again weighted down after the flow recedes. In perennial, high flow streams, and in more remote areas with seasonal stream flow, a variation of the hinge technique is used using a heavy rubber mat instead of a fence apron. The rubber mat lifts during high flows and hopefully sits tight enough across the stream during low flow periods to prevent ungulates from moving upstream. Barbed wire can also be stapled to the rubber mat as additional deterrence (Sailer, 2006). In Scotland, similar pivoted gates are widely used, although generally of timber construction (Trout & Pepper 2006).

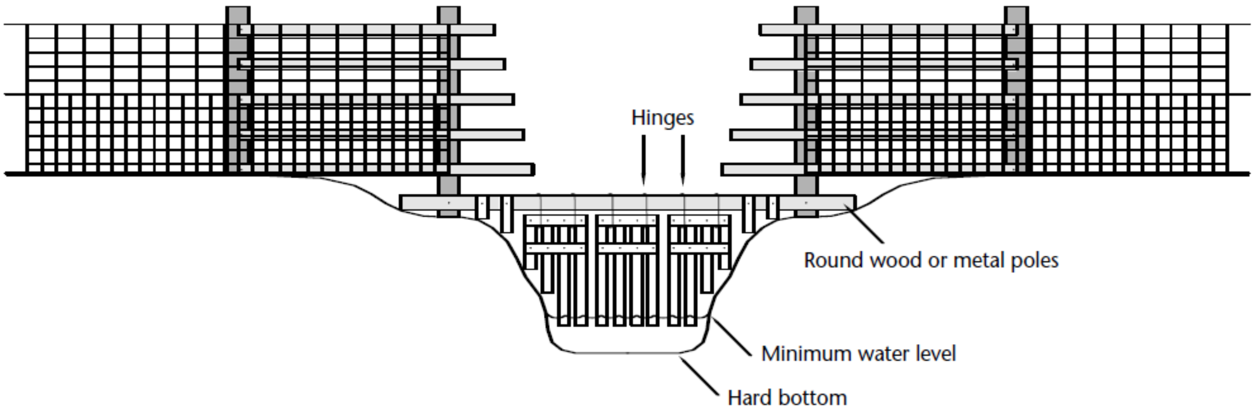

Figure 4 (from Trout & Pepper, 2006): Fencing across waterways is not recommended, as fences can trap debris and lead to the fence being washed away. In Hawai'i and Scotland, hinged wooden or rubber aprons are deployed.

The termination of fences on the coastline can also be problematic. Trout & Pepper (2006) recommend that wings be constructed at right angles to the fence, and parallel to the water's edge, for at least 50m, to deflect the animals away from the coastline. In the Sounds, where a coastal escarpment exists, an option developed in Hawai'i is to deploy 'slinky' type fences. This type of lightweight fencing consists of coiled stainless steel wire similar to military concertina wire, but without the razors or barbs (Sailer, 2006).

The existence of roads and public tracks within the site also needs to be taken into consideration. It is not feasible to run a fence across these, unless gates or cattle stops are deployed, which will be weak points in the fenceline. Trout

& Pepper (2006) recommend that a cattle stop needs to be at least four metres wide to prevent deer leaping across it.

However, roads and public tracks can provide an ideal line along which to run a fence. For fence construction and maintenance, roads and tracks provide a clear and level working platform, and allow easier maintenance into the future.

COSTS

There is likely to be a high level of variation in the cost of erecting an ungulate-proof fence in the Sounds, determined in large part by the target species for exclusion, the location and geography of the site, and whether volunteer or paid labour is used.

Ultimately, for any fence proposal, the cost will only be determined by obtaining multiple quotations from fencing providers.

As a general guideline, however, it is estimated that an ungulate-proof fence is likely to cost between $40 to $80 per metre, compared to the approximate cost of at least $250 per metre for a fully predator-proof fence and $17-25 per metre for a standard stock fence, and $30-35 per metre for a standard deer fence.

Of the local fencing initiatives, the Arapawa Island fence, built in 1994, cost $8.10 per metre in materials. The Cape Lambert fence, also built around 1994, cost about $10 per metre in materials, and a contract labour cost of $8,400 to get it to stock-proof condition, making a materials and part-labour cost of $14.20 per metre.

Of more recent examples, the Tui Nature Reserve fence, currently under construction, costs around $30 per metre in materials, and with volunteer labour being used. A 2015 DOC cost assessment of erecting a pig-proof fence at Canaan Downs Scenic Reserve, within Abel Tasman National Park, using specifications very similar to that proposed by Hone & Atkinson (1983), estimated a total cost of $53 per metre, including labour.

ADDITIONAL RESOURCES

A very detailed technical resource on fence construction and materials, and information on registered local contractors, is available from the Fencing Contractors Association NZ (www.fencingcontractors.co.nz).

A high level review on fencing options in Australia, Cost Effective Feral Animal Exclusion Fencing for Areas of High Conservation Value in Australia (2004), provides comprehensive design suggestions from both New Zealand and Australia (www.environment.gov.au/biodiversity/invasive-species/publications/cost-effective-feral-animal-exclusion-fencing).

An earlier review of fencing options in New Zealand, Pest Fences: Notes and Comments (1994), also provides a range of design suggestions (www.doc.govt.nz/documents/science-and-technical/tsop05.pdf).

The considerable experience in fencing in Hawaii is summarised in *I Ho'ola I Ka Nahele: To heal a forest*. A Mesic Forest Restoration Guide for Hawaii (2006) (http://manoa.hawaii.edu/hpicesu/DPW/SAILER_2006/01.pdf).

A review of fencing in Scotland to protect forestry areas, with particular relevance for managing deer, is provided in Forest Fencing (Trout & Pepper, 2006) (http://www.forestry.gov.uk/pdf/fctg002.pdf/$FILE/fctg002.pdf),.

Local knowledge and technical advice can be provided by the Marlborough District Council, Department of Conservation and Queen Elizabeth 2 National Trust.

Funding support of landowner or community-led fencing initiatives may be available from a range of sources, including the Marlborough District Council, the Department of Conservation's Community Fund, Queen Elizabeth 2 National Trust, the New Zealand Lottery Grants Board and a range of other smaller funding agencies.

PHOTO SELECTION

Figure 5: Ungulate-proof fences have been widely deployed in Hawai'i (*above & below*). Note the use of the ground skirt (*below*) as extra protection against feral pigs. (Photos: Maui Now)

Figure 6: Kenepuru - a deer fence running through mature kanuka forest (*above & below*).(Photos: Andrew Macalister)

Figure 7: Arapawa - a stark contrast in vegetation on either side of the fence is evident in these views (*above & below*). (Photos: DOC)

Figure 8: The native forest recovery on Arapawa Island is evident in these photos taken at the time of fence construction in 1993 (*above*) and 15 years later, in 2008 (*below*). (Photos: DOC)

Figure 6: The contrast between fenced (above) and unfenced (below) areas at Anakoha Bay, in the Outer Sounds, is dramatic. The presence of ungulates leads to the removal of the native understorey and a 'hollowed out' effect. (Photos: Geoff Walls)

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