Access and Impact: The Spatial Effects of Off-Road Vehicles on a Saltmarsh Wetland in Canterbury, New Zealand

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Abstract

Saltmarsh wetlands are highly productive environments that provide a wide range of ecosystem services, yet many of them have been lost globally and continue to be degraded. Significant impacts can occur when wetlands are used by off-road vehicles. However, little is known about the extent or significance of their impacts on saltmarsh wetlands, and how to mitigate them through planning, design and management. Using a saltmarsh wetland at Greenpark Sands Conservation Area, along the shore of Te Waihora/Lake Ellesmere, as a case study, this research uses GIS spatial analysis to measure the areal extent and intensity of off-road vehicle damage. The wetland is co-managed by Te Rūnanga o Ngāi Tahu and the Department of Conservation, according to a management plan which seeks to protect mahinga kai, restore and protect indigenous wetland biodiversity and improve the mauri of the lake. Results demonstrated that the total impact of off-road vehicles on the saltmarsh wetland was substantial, being both extensive and intensive. Damage measured in transects stretching from the park's inland edge to the water's edge showed that the entire park width had been damaged. Of the 7403 quadrats sampled, impacts were present in 66%, of the samples. Proximity to access increased the intensity of impacts, with an average 19% of off-road vehicle track cover in transects adjacent to roads; compared with 8% cover of damage in transects not adjacent to access gates. With an average vehicle impact cover of 28.3%, glasswort *(Sarcocornia quinqueflora)*-grass herbfields had the highest concentration of vehicle track cover of any vegetation community, demonstrating a low resistance to off-road vehicle use. Across the park were pockets of very high (50-75%) and extreme (75-100%) cover of off-road vehicle tracks, indicating a high frequency of vehicle use in those locations. The results of this study strongly suggest that the objectives of Te Waihora's Joint Management Plan are not being met under the current management strategy of Greenpark Sands Conservation Area and that actions must be taken to prevent further off-road vehicle use impacts. Recommended planning, design and management strategies include: limiting the area of ORV use to specified zones with well-defined and hardened routes, protecting areas of ecological importance through permanent or seasonal closure, and altering behaviour of use through site design that both filters the type of use and enhances visitor's perceptions of the site.

Keywords: Recreation ecology, recreation management, saltmarsh wetlands, off-road vehicle impacts, GIS image analysis.

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Chapter 1

Introduction

1.1 Problem statement: Off-road vehicles on saltmarsh wetlands

Wetlands have been identified as one of the world's most valuable ecosystems (de Groot et al., 2012; Myers, Clarkson, Reeves, & Clarkson, 2013) due to their range of production, habitat, cultural and regulatory services (Aber, 2012; de Groot et al., 2012; Myers et al., 2013; Wilson, 2018). The ecosystem services provided by coastal wetlands, including saltmarshes, are of especially high value because of their outstanding regulatory and habitat services (de Groot et al., 2012). In spite of these values, global wetland loss averages between 50% (Aber, 2012; Myers et al., 2013) and up to 57% (Davidson, 2014). In New Zealand the loss of wetlands stands at 90% (Aber, 2012; Johnson & Gerbeaux, 2004; Myers et al., 2013). Although saltmarshes are a distinctive ecosystem within the broader wetland classification, there is no global inventory of their area or distribution, so it is impossible to estimate their global loss (Adam, 2002). However, saltmarshes have been subject to modification or destruction resulting from human activities for centuries (Adam, 2002; Doody, 2008; Weis & Butler, 2009), and recently, saltmarshes have been negatively impacted by off-road vehicle (ORV) use (Kelleway, 2006). As an activity, ORV use has seen a dramatic growth in participation numbers over the past few decades (Huddart & Stott, 2019; Hughes & Paveglio, 2019). Off-road vehicles have been shown to cause modification, fragmentation and destruction of many fragile landscapes (Hughes & Paveglio, 2019; Kobryn, Beckley, Cramer, & Newsome, 2017; Trip & Wiersma, 2015), and are damaging to both vegetation and wildlife (Kelleway, 2006; Thompson & Schlacher, 2008). Despite the impacts of ORVs being more severe where soil moisture is high (Kelleway, 2006; Trip & Wiersma, 2015), there have been few studies on the impacts of ORVs on saltmarshes.

1.2 Research questions and objectives

Using Greenpark Sands Conservation Area near Christchurch, New Zealand, as a case study, this thesis addresses two research questions by meeting six research objectives:

1.2.1 Research questions

1. What is the total impact of ORV tracks on the saltmarsh wetland?
    a. What is the areal extent of ORV track impacts across the saltmarsh?
    b. What is the intensity of ORV impacts across the saltmarsh?

i. Does the intensity of ORV track impacts change across different vegetation communities?

2. How can ORV track impacts be reduced through improved recreation management strategies?

1.2.2 Research objectives

i. To describe the theory of ORV impacts on conservation areas, including saltmarshes, and to research best practice planning, design and management theories and strategies for reducing ORV track impacts.

ii. To calculate the areal extent of ORV track impacts through GIS image analysis.

iii. To analyse the intensity of impact based on an unobtrusive measure of human activity.

iv. To overlay maps of ORV track impacts and of vegetation communities in order to calculate cover of ORV track damage across different vegetation types.

v. To evaluate whether the design of the saltmarsh conservation area is effective in limiting ORV track impacts and therefore in protecting the park's values.

vi. To critically evaluate strategies for reducing ORV track impacts within saltmarsh wetlands.

1.3 Organisation of the thesis

In this thesis there are six chapters. Chapter two is a literature review containing sections that address the value of wetlands, the impacts of ORV use and the Māori cultural framework of kaitiakitanga for resource management. Additionally, it discusses recreation management theories and strategies for protecting natural areas, including wetlands, from the impacts of human activities and ORV use. Chapter three moves on to describe the research methodology, the case study site, and data and analysis methods. In chapter four, the first two sections communicate the findings on the areal extent and intensity of ORV use at Greenpark Sands Conservation Area, along with an interwoven discussion. The following section goes on to discuss the total impact of ORV use at Greenpark Sands. Finally, the implications of the results are addressed. Chapter five makes recommendations for how to increase the protection of saltmarshes through improved management strategies, based on best practice strategies within the literature. Chapter six concludes by summing up the research and identifying its limitations, along with areas for future research.

Table 1.1 shows where each of the research objectives are addressed within this thesis.

Table 1.1 Research objectives by research step and thesis chapter

Research objective		Research step	Chapter in thesis
i.	To describe the theory of ORV impacts on conservation areas, including saltmarshes, and to research best practice planning, design and management theories and strategies for reducing ORV track impacts.	Literature review	Chapter 2
ii.	To calculate the areal extent of ORV track impacts through GIS image analysis.	Methodology, Results and Discussion	Chapters 3 & 4
iii.	To analyse the intensity of impact based on an unobtrusive measure of human activity.	Methodology, Results and Discussion	Chapters 3 & 4
iv.	To overlay maps of ORV track impacts and of vegetation communities in order to calculate cover of ORV track damage across different vegetation types	Methodology, Results and Discussion	Chapters 3 & 4
v.	To evaluate whether the design of the saltmarsh conservation area is effective in limiting ORV track impacts and therefore in protecting the park's values.	Implications	Chapter 4
vi.	To critically evaluate strategies for reducing ORV track impacts within saltmarsh wetlands.	Recommendations	Chapter 5

Chapter 2

Wetlands, Off-Road Vehicles and Recreation Management Strategies

In this chapter, an overview is provided of the ecosystem services and values of wetlands, particularly of saltmarsh wetlands, and their rates of loss and degradation globally. Following this section is a review of the impacts of off-road vehicles. Next, the concept of kaitiakitanga is discussed, a Māori framework for resource management. To conclude the chapter is an overview of design and management strategies for reducing the area and intensity off-road vehicle impacts.

2.1 Saltmarsh wetlands

The International Ramsar Convention on Wetlands 1971 defines wetlands as “areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water to the depth of which at low tide does not exceed six metres.” (Ramsar Convention, 1971, article 1.1). Within a New Zealand context, the Resource Management Act 1991, that legislates the national management of natural resources, defines wetlands as “permanently or intermittently wet areas, shallow water, and land water margins that support a natural ecosystem of plants and animals that are adapted to wet conditions” (New Zealand Government, 1991, section 2.1).

As a wetland sub-type, coastal wetlands are generally composed of mangroves in tropical and sub-tropical climates, and in temperate regions of the northern and southern hemispheres, they are characterised by saltmarshes (Chapman, 1977). Saltmarshes depend on the interaction of the land with the sea (Doody, 2008) and are characterised by low herbaceous plants, or small woody species (Adam, 2002), creating an open and expansive habitat. Although many saltmarsh wetlands are located in estuarine ecosystems, they can also be found in lagoons with unpredictable tidal inflow, where water level is determined by rainfall and intermittent lagoon openings (Adam, 2002). Because of their low elevation, saltmarshes are generally tidally influenced and have high water tables, resulting in a high soil moisture content. An example of a saltmarsh wetland is shown in Figure 2.1.

Figure 2.1 Saltmarsh wetland bordering Te Waihora/Lake Ellesmere (Johanna Blakely, 2019)

2.1.1 Ecosystem services of saltmarsh wetlands

Coastal wetlands are highly productive environments that provide a wide range of ecosystem services. Saltmarshes provide vital supporting services as habitat for a range of plant and wildlife species, especially wader birds, waterfowl and juvenile fish (Doody, 2008; Weis & Butler, 2009). In particular, they are an important spawning site for many fish species (Doody, 2008; Weis & Butler, 2009). They provide many products to human communities, including fish and shellfish (Doody, 2008; Queen, 1977; Weis & Butler, 2009), game birds (Doody, 2008; Weis & Butler, 2009), and plant materials for grazing (Doody, 2008; Queen, 1977; Weis & Butler, 2009), hay making (Queen, 1977; Weis & Butler, 2009), roof thatching and packing material (Queen, 1977). The large numbers of game birds supported by saltmarshes are demonstrated in Figure 2.2. In addition, saltmarshes offer many cultural services, including spiritual and aesthetic experiences and educational and recreational opportunities (Doody, 2008; Weis & Butler, 2009).

Figure 2.2 An abundance of waterfowl adjacent to the saltmarsh at Te Waihora (Johanna Blakely, 2019)

Less obvious, but of great importance are the regulatory services provided by saltmarsh wetlands. They cleanse water by filtering sediments and pollutants (Weis & Butler, 2009), and by taking up excess nutrients (Doody, 2008; Queen, 1977; Weis & Butler, 2009). Being highly productive ecosystems (Queen, 1977; Weis & Butler, 2009) that cycle nutrients efficiently (Weis & Butler, 2009), saltmarshes sequester carbon both above and below ground (Doody, 2008). With a dynamic ability to respond to change (Doody, 2008), saltmarsh wetlands also protect terrestrial land from storm surges (Doody, 2008; Weis & Butler, 2009) and prevent coastal erosion (Queen, 1977; Weis & Butler, 2009).

Coastal wetlands, including saltmarshes, are of especially high economic value to humans, mostly due to their outstanding supporting and regulatory services (de Groot et al., 2012). In 2007, a global study that was based on 320 academic publications compared the value of the ecosystem services provided by the earth’s ten main biomes. Of all the biomes, coastal wetlands had the highest monetary value for habitat supporting services, especially nursery services, and the highest value for regulating services, in particular waste treatment and protection from floods and storm surges (de Groot et al., 2012). However, the monetary values of some coastal wetland services, such as their cultural and provisioning services, are difficult to quantify, because they are outside of the market and are a non-tradeable public benefit (de Groot et al., 2012).

2.1.2 Human associations with wetlands

Because saltmarsh wetlands are such productive and valuable ecosystems, various cultures have had a long history of association with them and saltmarshes have often been favourable locations for early human settlement (Doody, 2008). Across the world, archaeologists have discovered evidence of human settlements in and alongside of wetlands that date back thousands of years (Wilson, 2018). These settlements have been uncovered in Japan and England, and across Africa, Asia and the Americas (Wilson, 2018). In New Zealand, archaeological evidence has found that wetland areas were occupied or in continuous use since early indigenous Māori settlement (Barr, 1998). Where necessary, Māori adapted their pā (fortified settlements) to swamp conditions that could only be reached by boat (Barr, 1998; Wilson, 2018). Although limited archaeological work has been carried out in New Zealand’s wetland sites, those that have been studied highlight the intentional selection and modification of wetland environments for habitation and resource gathering (Barr, 1998). Wetlands continue to be of significant cultural value to Māori as a source of food and traditional resources, known as mahinga kai (Myers et al., 2013).

Wilson (2018) notes that as people groups have developed and adopted technology, there has been a tendency for them to leave their wetland settlements or to drain and clear them. A shift occurs from that of being in harmony with the environment to a mentality of dominance over the land.

2.1.3 Wetland loss and degradation

International loss and degradation

As a result of primarily agricultural and urban development, studies indicate that between 50% (Aber, 2012; Myers et al., 2013), and up to 57% (Davidson, 2014) of all wetlands have been destroyed internationally, and this loss is both continuing and increasing (Davidson, 2014; Wilson, 2018). Key threats to wetlands include: urban expansion, resource demands, poverty that leads to overuse of resources, the impacts of climate change on a wetland's adaptive capacity, governmental failures of management, challenges of cross-boundary wetland management, and wetland degradation (Aber, 2012). When wetlands are destroyed, their ecosystem services are lost, and the people most likely to suffer as a consequence are low-income groups and future generations (de Groot et al., 2012).

Coastal wetlands have also experienced a significant reduction in area. For example, Canada has lost 53% of its Atlantic tidal and salt marshes and 80% of its Pacific coastal estuaries, while Australia has experienced a 75% loss of wetlands along the Swan Coastal Plain and coastal New South Wales (Aber, 2012). Because there is no global inventory of saltmarsh wetlands, it is difficult to determine their total extent of loss (Adam, 2002; Doody, 2008). Until recently saltmarshes were regarded as wastelands (Queen, 1977; Weis & Butler, 2009), and consequently they have been subject to modification and destruction for centuries (Adam, 2002; Doody, 2008; Queen, 1977; Weis & Butler, 2009). Key threats to saltmarshes include: continued degradation, invasion of exotic species, poor management practices, expanding development of urban and suburban areas (Weis & Butler, 2009), and coastal squeeze from sea level rise (Doody, 2008; Weis & Butler, 2009). Recreational activities have also been observed to have significant adverse impacts on saltmarsh wetlands (Kelleway, 2006).

Wetland loss and degradation in New Zealand

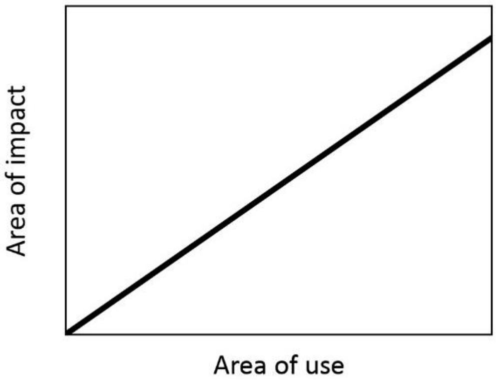
New Zealand has lost 90% of its wetlands (Aber, 2012; Johnson & Gerbeaux, 2004; Myers et al., 2013) and most of this loss has occurred in the past 150 years (Myers et al., 2013). Because most studies in New Zealand have focused on freshwater wetlands, it is difficult to assess the loss of saltmarsh wetlands. However, it is assumed that they follow similar trends to those of freshwater wetland loss. Between 1954 and 1976 alone, 263,999 ha of wetlands were drained; more than the entire area of freshwater wetlands remaining (249,484 ha) (Myers et al., 2013). The fertile lowlands have seen the greatest loss, with many wetlands in these environments reduced to small remnants that are surrounded by developed land (Myers et al., 2013; Pompei & Grove, 2010). As a result, wetlands have become one of New Zealand's most threatened ecosystems (Myers et al., 2013). Although wetland loss in New Zealand has slowed, it still occurs, with several wetlands listed as nationally important for biodiversity having recently been reduced in size (Pompei & Grove, 2010).

In addition to a reduction in size, the quality of many wetlands across the country have been assessed as low, with moderate to severe degradation, and wetlands are under continued pressures from human activities (Myers et al., 2013). These pressures occur both directly, for example through drainage for agricultural expansion, and indirectly, through impacts such as heavy metal runoff from nearby vehicle use. This has been happening despite the increasing awareness of the importance of wetlands (Myers et al., 2013). Myers et al. (2013) states that as a signatory of the Ramsar Convention on Wetlands, New Zealand's responsibility and objective to prevent further wetland loss has not been met.

2.2 Recreation impacts in conservation areas

The pursuit of development and productivity is not the only cause of environmental loss and degradation. Studies show that recreational use of protected areas inevitably causes ecological impacts (Cole, 1994; Cole & Landres, 1996; D'Antonio & Monz, 2016; Priskin, 2003; Tomczyk, 2011) and recreational use and its management has been identified as "[one] of the most significant threats to wilderness ecosystems" (Cole & Landres, 1996, p. 168).

In recreation ecology, total impacts of recreation on conservation areas are determined by the area of use and the intensity of use (Cole, 1994). There is a positive linear relationship between area of use and the area of impact (Cole, 1994; Hammitt, Cole, & Monz, 2015), as shown in Figure 2.3. By contrast, there is a curvilinear relationship between frequency of use and intensity of impact (Cole, 1994), as shown in Figure 2.4. Therefore, recreation in conservation areas is associated with biophysical impacts even at low levels of use (Priskin, 2003). Damage is more severe where soils are fine textured or organic, and where soils are poorly drained or have high water tables (Cole, 1994), such as in saltmarshes (Kelleway, 2006). In some places, even when recreational users are removed, the impacts can be irreversible or the recovery slow (Cole & Landres, 1996).



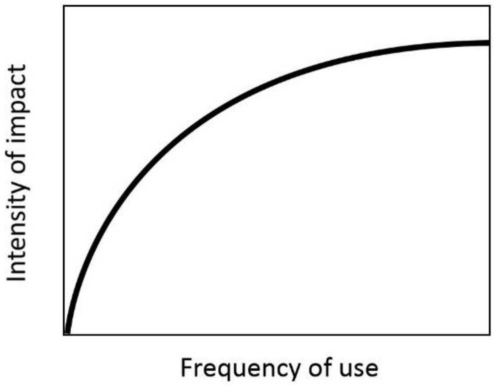


Figure 2.3 Generalised model of the linear relationship between the area of use and area of impact

Figure 2.4 Model of the curvilinear relationship between frequency of use and impact (both adapted from Cole (1994))

Many recreational activities have been shown to have detrimental ecological impacts. These activities include: swimming (Huddart & Stott, 2019; Priskin, 2003), boating (Huddart & Stott, 2019; Priskin, 2003; Wuerthner, 2007), recreational fishing (Huddart & Stott, 2019; Priskin, 2003), bird watching (Aikins, Gbogbo, & Owusu, 2018), game bird hunting (Belanger & Bedard, 1995), camping (Cole & Monz, 2004; Huddart & Stott, 2019; Priskin, 2003), hiking (Ballantyne & Pickering, 2015; Huddart & Stott, 2019; Priskin, 2003), cycling (Milton & Harding, 2011), horse riding (Huddart & Stott, 2019; Taylor, Marsden, & Hart, 2012) and off-road vehicle (ORV) use (Arp & Simmons, 2012; Kelleway, 2006; Nortjé, Hoven, & Laker, 2012). Table 2.1 lists the impacts associated with several of these activities.

Table 2.1. Impacts associated with recreational activities. (Adapted from Priskin (2003))

Recreational Activities	Impacts
Bush walking	Littering, soil compaction, reduced nutrient flows and vegetation cover, spread of noxious weeds
Camping	Soil compaction, loss of organic material, trampling, erosion, lighting of fires, littering, waste disposal, reduced visual amenity, spread of exotic species
Horse riding	Loss of vegetation and biodiversity, spread of noxious weeds and diseases, destabilisation, erosion
Off-road vehicle use	Noise and air pollution, fuel leakage, damage to vegetation, destabilisation, erosion, spread of noxious weeds, wildlife disturbance
Power boating	Noise, fumes, vibrations, oil spills, paint leakage, sediment turbulence

Recreational fishing	Decline of fish stocks, contributes to littering, when fishing from boats see above impacts also
Sightseeing	Disturbance to wildlife, littering, trampling

Recreational impacts affect not only the ecological environment, but also degrade the experience of other users. In a Canadian forest area, a survey by Lynn and Brown (2003) identified a strong negative relationship between recreational impacts and the experience of hikers. Rubbish, vegetation damage and fire pits had the most effect on walking experience (Lynn & Brown, 2003). However, Lynn and Brown (2003) noted that recreational users are less likely to contribute to impacts that would degrade their own experience. A similar study by Priskin (2003) in a West Australian coastal area found that for some recreational activities, people who participated in them were less likely to perceive the ecological harm of their actions. This perspective applied to off-road vehicle users (Priskin, 2003).

2.2.1 The culture of off-road driving

"An off-road vehicle (ORV) is any vehicle intended to be ridden off road," (Hughes & Paveglio, 2019, p. 57) including dirt bikes, quad bikes and four-wheel-drive (4WD) vehicles. Off-road driving often creates an experience of freedom and adventure (Jones, Newsome, & Macbeth, 2016) and for many users, ORVs become a way of experiencing nature (Hughes & Paveglio, 2019). Sub-cultural identities and social cohesion have been observed to form between ORV user groups (Hughes & Paveglio, 2019). Demographically, studies in the USA show that ORV users are predominantly male, earn above average incomes and spend thousands of dollars on their hobby annually (Havlick, 2007). As a recreational activity on public land in the USA, ORV use has seen a significant increase in recent years and this growth is expected to continue (Groom, McKinney, Ball, & Winchell, 2007; Huddart & Stott, 2019; Hughes & Paveglio, 2019).

In New Zealand, vehicles are common on sand beaches (Stephenson, 1999; Taylor et al., 2012) and the frequency of ORV use is especially high between the months of August and April (Taylor et al., 2012), when the days are longer and the weather is warmer.

2.2.2 The impacts of off-road vehicles

Off-road vehicle use has been shown to cause modification, fragmentation and destruction of fragile landscapes (Hughes & Paveglio, 2019; Kobryn et al., 2017; Trip & Wiersma, 2015). In coastal ecosystems, ORVs are highly destructive to both flora and fauna (Kelleway, 2006; Stephenson, 1999; Thompson & Schlacher, 2008).

Although damage increases with the number of vehicle passes (Onyeanusi, 1986), the most damage occurs from the first pass of a vehicle's tyres (Nortjé et al., 2012; Stephenson, 1999). Therefore, even where usage of vehicles is low, there can be substantial environmental impacts such as erosion and loss of vegetation (Trip & Wiersma, 2015). Schlacher and Morrison (2008) found a curvilinear relationship between the frequency of vehicle passes and the percentage of area disturbed, as shown in Figure 2.5. After ten vehicle passes, 15% of their continuous quadrat samples were disturbed by ORV tyre tracks, while after 100 passes, 85% of the quadrats were impacted (Schlacher & Morrison, 2008). Thus, the percentage of an area impacted by ORVs can act as an indicator of the frequency of use.

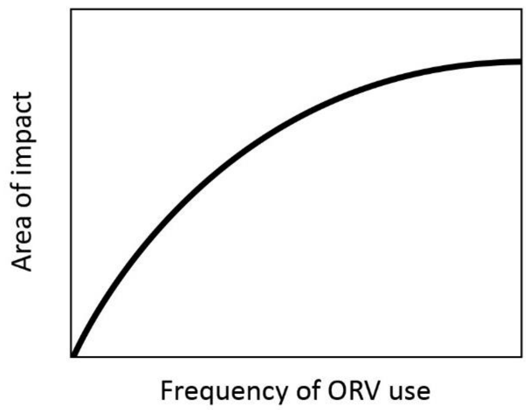


Figure 2.5 The curvilinear relationship between frequency of ORV use and percentage of area disturbed (adapted from Schlacher and Morrison (2008))

In sensitive areas such as organic wetland soils and at stream crossings, Arp and Simmons (2012) observed a continued widening and braiding of trail networks over time as the tracks erode and degrade. While Nortjé et al. (2012) demonstrated that ORVs have strong negative impacts on soil compaction and crusting in both wet and dry conditions, Kelleway (2006) and Trip and Wiersma (2015) found that the greater the soil moisture, the more severe the impacts were. In wet soils, ruts were more likely to form and were deeper, and these ruts were observed to modify local drainage networks and hydrology within a saltmarsh (Kelleway, 2006). Because of their fine textures, saltmarsh soils are especially susceptible to compaction from ORV use (Kelleway, 2006).

Where ORVs are present, vegetation cover is adversely affected (Groom et al., 2007; Kelleway, 2006; Stephenson, 1999; Thompson & Schlacher, 2008) and ORVs have been shown to reduce height, biomass and total cover of vegetation in coastal areas (Stephenson, 1999). Loss of vegetation is more significant where vehicles have turned than on straight stretches of a track (Onyeanusi, 1986). In a study of an Australian saltmarsh wetland, the total vegetation cover of both *Sarcocornia* and *Juncus* plant communities were found to significantly reduce with disturbance from ORVs (Kelleway, 2006), indicating a low resistance to vehicle use. While areas with a high density of ORV tracks were usually completely devoid of vegetation, even sites with a single vehicle track showed a significant reduction in plant cover. *Sarcocornia quinqueflora* is especially vulnerable to vehicles and can likely be killed with a single pass of an ORV (Kelleway, 2006). Bare areas of ground (Kelleway, 2006) or areas of low-stature vegetation (Smith, 2014) have been found to attract initial use from recreational ORV drivers.

In places where there has been long-term ORV use, studies across a range of bog, saltmarsh and coastal dune ecosystems have shown a reduced number of plant species and a change in community composition (Charman & Pollard, 1995; Kelleway, 2006; Stephenson, 1999). Recovery is determined by an individual plant's growth and reproduction habits (Stephenson, 1999). Due to their high resilience, *Astragalus magdalenae* var. *peirsonii* plants in the Algodones Dunes, California recovered quickly when ORV access was restricted (Groom et al., 2007). However, while grassland communities recovered quickly from ORV impacts in Dartmoor, UK, blanket bog communities showed poor recovery and may never return to their former state (Charman & Pollard, 1995). Over 24 years after vehicle tracks were abandoned in the blanket bog areas, vegetation remained patchy and the species composition had changed (Charman & Pollard, 1995). Similarly, ORV tracks in the wind tidal flats of the Laguna Madre, Texas showed no sign of recovery after 38 years (Martin, Onuf, & Dunton, 2008). These studies indicate that vegetation communities in wetland environments have a low resilience to ORV use, and may never fully recover from their impacts.

Long distance transport of seeds by ORVs is the rule rather than the exception and by scarifying the soil and providing seeds attached to the tyre tread, ORVs create ideal germination conditions for weed species (Rew et al., 2018). The rate of seed accrual is affected by surface conditions and season, with the highest accrual rates in off-road, autumnal and wet conditions (Rew et al., 2018). However, Kelleway (2006) found no evidence of weed species being introduced into an Australian saltmarsh as a result of vehicle use. This may be due to high soil salinity.

Based on his international literature review, Stephenson (1999) claimed that the impacts of ORVs on intertidal biota were minimal, but less studied. In keeping with this claim, Macleod, Forbes, Shepherd, and Crawford (2009) found that intertidal fauna at Pipeclay Lagoon, Tasmania were very resilient, with species numbers only being significantly reduced where there were approximately 40 vehicle trips a day across a specific area. However, other studies have found that shellfish and crab populations are sensitive to ORVs and are adversely impacted by them (Kelleway, 2006; Taylor et al., 2012; Thompson & Schlacher, 2008). In a study at Pegasus Bay, New Zealand, Taylor (2013) demonstrated a positive linear relationship between surf clam mortality and vehicle passes, with an average mortality rate of 4.56% after five vehicle passes and increasing at a rate of 0.27% per additional vehicle pass. Therefore, extended periods of high-frequency vehicle use are likely to cause long-term impacts on shellfish populations (Taylor, 2013).

Additionally, beach driving had been shown to cause displacement and disturbance of shorebird species (Forgues, 2010; Megnak, Dayer, Longenecker, & Spiegel, 2019; Wallace, 2016). In a study by Meager, Schlacher, and Nielsen (2012), the presence of ORVs had the strongest influence on a bird's habitat selection than any other recreational activity. When ORVs are present, migratory birds spend less time foraging (Forgues, 2010).

2.2.3 Location of off-road vehicle impact studies

Despite the intensity of ORV impacts increasing in wet conditions (Kelleway, 2006; Trip & Wiersma, 2015), most studies of vehicle impacts have been in well drained, terrestrial environments such as arid grass or shrubland areas (Nortjé et al., 2012; Onyeanusi, 1986; Smith, 2014), coastal dunes and beaches (Kobryn et al., 2017; Schlacher & Morrison, 2008; Taylor, 2013; Thompson & Schlacher, 2008) and landlocked dunes (Groom et al., 2007; Hughes & Paveglio, 2019). Few studies have looked at the impacts of ORVs on wetland environments, with only three studies of ORV impacts on bog environments (Charman & Pollard, 1995; Mize, Evans, MacRoberts, MacRoberts, & Rudolph, 2005; Trip & Wiersma, 2015), one assessment in a boreal wetland (Arp & Simmons, 2012), one study of a wind tidal flat (Martin et al., 2008) and one investigation in a saltmarsh ecosystem (Kelleway, 2006). Of these studies, only Kelleway (2006) and Martin et al. (2008) measured the areal extent of ORV impacts on wetlands.

Although the use of ORVs is common in New Zealand for both work and recreation, the study of their ecological impacts is rare. In New Zealand, studies of ORV impacts have been limited to one analysis of vehicle damage to the vegetation of the Rangipo Desert in the Tongariro National Park (Smith, 2014), and one assessment of vehicle and horse impacts on intertidal shellfish populations at sandy beaches along Pegasus Bay (Taylor, 2013). There is a clear knowledge gap on the extent and intensity of ORV impacts on saltmarsh wetlands in New Zealand. International literature on this topic is also very limited.

2.3 Management of recreation impacts in conservation areas

The tension that exists between the objectives of conservation and recreation is a recurring issue for the management of conservation areas (Arp & Simmons, 2012; Charman & Pollard, 1995; Cole & Landres, 1996; D'Antonio & Monz, 2016; Hammitt et al., 2015; Jones et al., 2016; Lynn & Brown, 2003; Tomczyk, 2011). In some places the mandate for public access incorporates not only allowance for recreation, but also for cultural subsistence harvest and resource gathering, which adds an additional layer of complexity to the issue (Arp & Simmons, 2012; Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005). In New Zealand, some conservation areas, such as at Te Waihora/Lake Ellesmere, are governed by joint management between local government and local iwi (Māori tribes) (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005). Therefore it is important that management practices in these areas reflect not only a Western framework, but also a Māori worldview.

2.3.1 Kaitiakitanga: An indigenous Māori framework for conservation management

"Te toto o te tangata, he kai; te oranga o te tangata, he whenua.

Food supplies the blood of man; his welfare depends of the land." (Hayes, 1998, p. 899)

Prior to European settlement in New Zealand, Māori had developed a strong ethic of conservation and of sustaining the land and its resources for future generations (Wheen, 2013). This concept is known as kaitiakitanga. In the Resource Management Act 1991 kaitiakitanga is defined as, "the exercise of guardianship by the tangata whenua of an area in accordance with tikanga Māori in relation to natural and physical resources; and includes the ethic of stewardship" (New Zealand Government, 1991, s2(1), ammended 1997). Commonly translated simply as 'guardianship' or 'stewardship', many Māori argue that the term kaitiakitanga has been forced into a Western framework and has become severed from its cultural and spiritual contexts and thus its fullness of meaning (Harmsworth & Awatere, 2013; Kawharu, 2000).

Within a Māori worldview, all natural elements, including humans, descend from Ranginui (sky father) and Papatūānuku (earth mother) (Hayes, 1998). This gives Māori a genealogical connection to all of earth's flora, fauna and natural resources and instils within Māori an holistic and interconnected relationship with the natural environment (Awatere & Harmsworth, 2014; Harmsworth & Awatere, 2013; Hayes, 1998). "Maori see themselves as a part of ecosystems rather than separated from ecosystems" (Harmsworth & Awatere, 2013, p. 276). Because of their whakapapa (genealogical) connections to both humans and the gods, everything in the natural world is tapu (sacred) and should be respected (Hayes, 1998). Therefore, it is essential to preserve the mauri (life essence) of all natural elements (Hayes, 1998). The Māori environmental concept of kaitiakitanga is entwined with the concepts of whakapapa (genealogy/connection), mana (authority), ki utu ki tai (mountains to the sea/holistic landscape approach), taonga tuku iho (heritage/intergenerational protection of taonga (treasures)), te ao turoa (intergenerational concept of resource sustainability), mauri (life essence of all living and non-living entities), ritenga (customs, protocols and regulations) and wairua (the spiritual dimension) (Harmsworth & Awatere, 2013). Kaitiakitanga involves not only managing environmental resources, but also managing human relationships between the past, the present and the future (Kawharu, 2000). Kaitiaki (guardians) of an area must be mana whenua (those with authority over the land) or ahi kaa (those with intergenerational occupation rights) (Matunga, 2015).

A key aspect of kaitiakitanga is reciprocity, in which "humans provid[e] benefit to the ecosystem and natural resource, through for example guardianship and sustainability, and means that the ecosystem or resource is sustained, if cared for, and can then provide benefit back to humans" (Harmsworth & Awatere, 2013, p. 281).

Within the framework of kaitiakitanga, environmental regulation is implemented through means of tapu (sacred status which can imply complete prohibition) and rāhui (temporary prohibition such as seasonal closure) (Hayes, 1998; Wheen, 2013). Rāhui can be applied over a polluted or unproductive area with the aim of restoring the mauri of the resource base (Kawharu, 2000). Another form of rāhui is a conservation prohibition to protect a specific depleted resource (Kawharu, 2000), as is demonstrated in Figure 2.6.

Figure 2.6 Rāhui implemented by Ngāti Wheke at Rāpaki to protect and manage resources (Johanna Blakely, 2020)

Based on the Treaty of Waitangi 1840, in which partnership between Māori and the Crown is a key principle, Māori see engagement in resource management as a right (Harmsworth & Awatere, 2013; Kawharu, 2000). Through legal requirements to develop kaitiakitanga policies, kaitiakitanga has become a key connection point between Māori and non-Māori in New Zealand and helps to maintain Māori status as tangata whenua (the people of the land) (Kawharu, 2000).

Due to the unique climate and resources of Te Waipounamu (the South Island), Ngāi Tahu[1] have developed a distinctive culture based around mahinga kai (food and resource gathering) (O'Regan, 2019). Unable to grow kumara crops because of the cold, Ngāi Tahu instead seasonally hunted and gathered resources from around Te Waipounamu (Lenihan, 2013). In this way mahinga kai enabled successive generations of Ngāi Tahu to learn and practice kaitiakitanga (Lenihan, 2013), as it was necessary to manage and conserve these resources (Dick, Stephenson, Kirikiri, Moller, & Turner, 2012).

The decline in area and quality of natural resources along with an increased difficulty in accessing them through the loss of traditional areas of whenua (land) is viewed by Māori as "significant and challenging" (Harmsworth & Awatere, 2013, p. 274). It is not just the ecological loss that is of concern, but also the consequential cultural loss (Dick et al., 2012). These losses include a severed connection from the land and resources, loss of cultural knowledge and tribal development and reduced points of family and social connections (Dick et al., 2012). Resource loss affects indigenous identity (Dick et al., 2012).

> *"We'll just become like anyone else. If we don't have that connection with our whenua or be able to go up our mountain, be cleansed by the winds of Tāwhirimātea. If we aren't able to go in and do the practices of what we used to do, that removes our uniqueness."* (Dick et al., 2012, pp. 123, Interviewee, Ngāti Kahungunu)

2.3.2 Recreation management: problem solving

The quality of management of protected areas is essential for meeting global environmental challenges and stopping the earth's loss of biodiversity (Jones et al., 2016). Because "impact is inevitable with use" (Cole, 1994, p. 12), Cole argues that managers should aim for prevention rather than mitigation of recreational impacts. It is necessary to choose effective strategies for recreation management and to implement them as soon as possible (Hammitt et al., 2015). With change being

[1] The tribe who hold mana whenua over most of Te Waipounamu

an inevitable pattern in nature, managers should not attempt to halt change, but to set limits to acceptable levels of impact (Hammitt et al., 2015).

Before a recreation management issue can be dealt with, it is necessary to first define the problem, to understand the factors that contribute to the problem and to decide on achievable steps for addressing the issue (McWilliam, 2007; Megnak et al., 2019). Megnak et al. (2019) outlines a step by step approach for this decision-making stage, which can be abbreviated to the acronym 'PrOACT' and is shown in Figure 2.7.

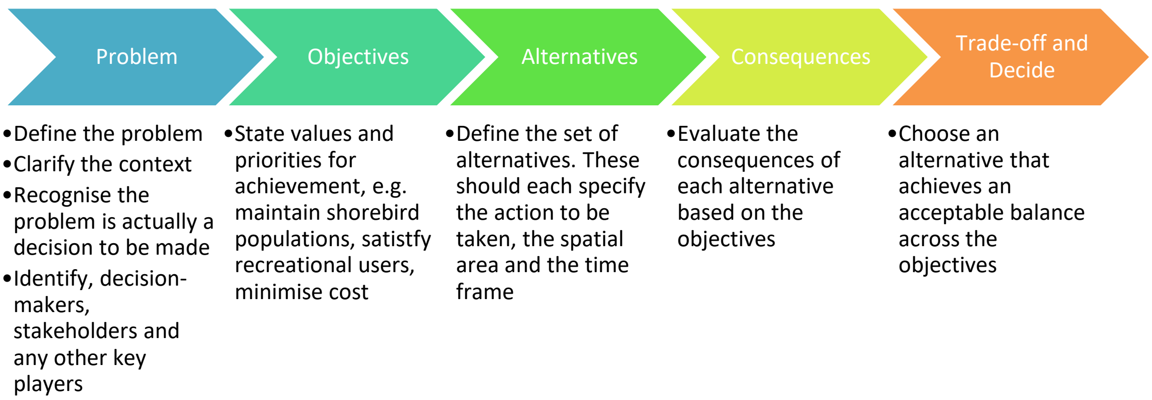


Figure 2.7 PrOACT method of decision making within a recreation management context (adapted from Megnak et al. (2019, p. 35))

When making recreation management decisions, it is necessary to consider the implications of those actions on both the natural environment and on recreational users (Cole, 1994; Hammitt et al., 2015). If an area is being closed to public recreation, the cost of denied access must be taken into consideration (Cole, 1994). A likely result of this action is that recreational impacts will increase in other conservation areas, or that the public will simply stay at home and lose their experience of the natural environment (Cole, 1994). Because it is challenging to make decisions for both quality of recreational experience and for conservation of ecological integrity (Lynn & Brown, 2003), compromise is always required (Hammitt et al., 2015). It is necessary to weigh up factors such as effectiveness, cost to visitors, likely side effects and costs of implementation and maintenance (Hammitt et al., 2015).

2.3.3 Recreation management strategies

Due to the linear relationship between area of use and impacts, controlling the area of use is the most effective way to reduce the total impact of recreation activities (Cole, 1994; Hammitt et al., 2015; McWilliam, 2007). Where recreational activities are not controlled, there is a tendency for impacts to spread across the landscape (Cole, 1994). Recreation impacts tend to be concentrated around attractions, facilities and along travel routes, therefore this natural concentration can be reinforced through planning and site design (Hammitt et al., 2015). Similarly, careful planning and site design can be used to counteract the tendency for continual expansion in area of use (Hammitt et al., 2015).

By contrast, frequency of use and impacts have a curvilinear relationship (Cole, 1994; McWilliam, 2007). Therefore, reducing the frequency of use does not result in a significant reduction in intensity of impacts (McWilliam, 2007). Closure and restoration strategies are likely to be the most effective in low-resistance and high-resilience environments (Hammitt et al., 2015).

A range of recreation management strategies are listed in Tables 2.2 and 2.3. These strategies are separated into two broad categories: strategies for limiting spatial extent (Table 2.2) and strategies for limiting intensity of use (Table 2.3).

Table 2.2. Strategies to limit the spatial extent of recreational use (adapted from Hammitt et al. (2015) and McWilliam (2007))

Strategies to limit spatial extent of use:	
Concentration strategies	• Clustering of recreational use • Surface hardening to delineate areas of use • Physical or natural barriers such as fences, waterways, or bushy vegetation • Provision of hardened trails and authorised points of access
Segregation strategies	• Buffers that provide room to accommodate impacts without damaging sensitive areas or disturbing wildlife • Permanent or seasonal closure where resistance and/or resilience is low

Table 2.3 Strategies to limit intensity of recreational use. (Adapted from Hammitt et al. (2015) and McWilliam (2007))

Strategies to limit intensity of use:	
Frequency reduction strategies	• Provide alternative recreation areas (these could be at the edge of the conservation area)

Dispersion strategies	• Spread the activities so that impact occurs at an acceptable intensity (only effective with low impact recreation types)
Strategies that alter the type of effect	• Barriers that allow certain activities but prevent others, such as bollards
Strategies that alter the behaviour of effect	• Education to influence behaviour so that recreationists can be aware of ecosystem sensitivities and act on that knowledge • Site design to improve perception of an area (see section 2.3.7) • CPTED: design of spaces to maximise surveillance and minimise crime or fear of crime • Gain stakeholder support by fulfilling cultural, recreational, and adjacent landowner needs
Strategies that alter the season of effect	• Seasonal closure e.g. to reduce impacts when soils are wet or to remove disturbance when migratory birds are feeding
Strategies that alter the ecosystem of effect	• Zoning so that recreation occurs in areas with high resistance and resilience
Integrated strategies at multiple scales	• An integration of strategies for large conservation areas that occur at different spatial scales and across different time frames to maximise reduction of recreation impacts

2.3.4 Strategies to reduce off-road vehicle impact

Because ORVs have heavy impacts on vulnerable environments, segregation strategies involving complete closure to motorised vehicles is the most commonly recommended management strategy for ORVs across a range of both wetland and beach ecosystems (Charman & Pollard, 1995; Mize et al., 2005; Stephenson, 1999; Taylor et al., 2012). In a western USA dune ecosystem with high resilience and fast recovery of vegetation, it has been shown that seasonal or periodic closure may allow ORV use to continue if a dune-wide rotational strategy is implemented (Groom et al., 2007). However, observation by Charman and Pollard (1995) of a blanket bog in the UK and by Kelleway (2006) of a saltmarsh wetland in Australia indicates that even with permanent closure, full recovery of the wetland may never be possible without restoration interventions. The same conclusion is reached by Mize et al. (2005), who note that where contours are not re-established in damaged bogs in Texas, USA, the soil surface will remain lower and vegetation composition is likely to be affected. Therefore, although restoration of bogs following heavy vehicle damage is possible, prevention by closure of an area is more effective, both ecologically and economically (Charman & Pollard, 1995; Mize et al., 2005). Kelleway (2006) suggests that this may require appropriate, heavy-duty gates and fences to deter dedicated ORV enthusiasts.

Where full closure to ORVs is not possible, studies recommend concentrating the area of vehicle use through zoning (Taylor, 2013; Taylor et al., 2012). Another method of concentration is to require ORV users to follow hardened and clearly defined tracks (Stephenson, 1999; Taylor, 2013) and to manage unauthorised route creation (Whitbeck & Fehmi, 2016).

However, because there is demand for ORV recreational areas, Jones et al. (2016) recommends development of a regional park network on brownfield lands; to cater for 4WD use and simultaneously to reduce the frequency of high impact activities on vulnerable conservation areas.

In order to influence behaviour changes, it is important to understand a recreationist's underlying beliefs and attitudes, as recreational ORV users may well have different environmental values to other user groups (Megnak et al., 2019). Off-road vehicle users are often unaware of the ecological impacts of their activities (Jones et al., 2016) or are less likely to perceive its harm (Priskin, 2003). There appears to be a misconception among ORV users that areas of ecological value are simply unused wastelands (Huddart & Stott, 2019). Megnak et al. (2019) recommends a combination of education and of user involvement in the decision-making process in order to gain ORV user support of any new management strategies.

2.3.5 Strategies to reduce ORV disturbance to wader birds and waterfowl

Because ORVs cause disturbance to birdlife, it is recommended that important wader bird and waterfowl habitat is segregated from and closed to ORV use (Megnak et al., 2019; Wallace, 2016). If full closure is not possible, places where driving is allowed should be concentrated by reducing the area or restricting use to sites of lesser habitat value (Megnak et al., 2019). In parts of the northeast USA, it has been found that shorebirds spend more time on wider beaches (Megnak et al., 2019). Thus, it is recommended that where partial closure is possible, wide sections of beaches or coastal areas should be set aside for birdlife (Megnak et al., 2019).

Buffers are also an effective segregation strategy for reducing disturbance from ORVs (Megnak et al., 2019). They rely on the finding that wildlife disturbances reduce with distance from the disruption (Glover, Weston, Maguire, Miller, & Christie, 2011). However, buffers rely on high compliance levels to be effective (Glover et al., 2011; Megnak et al., 2019). Although a survey of coastal residents and recreationists in Australia showed overall support for use of set-back distances to protect shorebirds, respondents were less supportive of buffers for walkers, who were the most common recreation user group (Glover et al., 2011). This is in keeping with findings by other studies, which show that recreationists often blame other user groups and do not take responsibility for their own impacts (Megnak et al., 2019).

Strategies to limit intensity of recreational impacts for protection of birdlife include seasonal closures (Glover et al., 2011) and reduction of speed where vehicles are present (Megnak et al., 2019).

2.3.6 Strategies and challenges for altering visitor behaviour

Education is often cited as an important means of altering the behaviour of recreational use to reduce environmental impacts (Hammitt et al., 2015; Jones et al., 2016; McWilliam, 2007; Priskin, 2003). Without education, management remains reactionary (Priskin, 2003). However, although public ecological awareness is essential for protecting the integrity of natural areas (Jones et al., 2016), knowledge does not always translate into changes in behaviour (Megnak et al., 2019). Visitors are less likely to rank their own recreational interest as harmful (Glover et al., 2011; Priskin, 2003) and there is a tendency for recreationists to blame other user groups for any negative impacts (Megnak et al., 2019).

People are more likely to adopt new behaviours that are easy and rewarding (Megnak et al., 2019). Therefore, specific action-related information is more likely to motivate changes in behaviour than broad, background information because "a person must recognise the problem, be aware of a solution to the problem and feel capable to enact that solution" (Megnak et al., 2019, p. 11). Having an understanding of recreational user's values, beliefs and attitudes is essential for effectively communicating with that user group (Megnak et al., 2019).

When making changes to the management of a conservation area it is important to communicate clearly to visitors what changes are being make and why (Hammitt et al., 2015). Any signage should be colourful and relevant and should clearly define the issue and the desired behaviour from visitors (Megnak et al., 2019). Visitors need to know how they are expected to behave, and these new regulations must be enforced (Hammitt et al., 2015). In many situations simply the presence of an official looking volunteer causes a significant reduction in negative behaviour (Megnak et al., 2019). It is preferable that any new management strategies are regulated at the minimum level and that the majority of behaviour is already altered through site design and through cues to care (Hammitt et al., 2015; Nassauer, 1995).

2.3.7 Altering human behaviour through site design

Because humans dominate earth's environment (Nassauer, 2011), it is important to protect what remains of natural, rare and vulnerable ecosystems. The concept of nature however, has become entangled with the idea of the picturesque; of large trees and impressive mountains (Nassauer, 1995). This is a Eurocentric cultural concept rather than an ecological one (Nassauer, 1995). Protection of mountain areas can draw conservation efforts away from less scenic but often highly important lowland ecosystems (Gobster, Nassauer, Daniel, & Fry, 2007), such as saltmarsh wetlands. Many ecologically valuable remnant environments are at risk because they appear to be messy and do not meet cultural aesthetic of orderliness and attractiveness (Gobster et al., 2007; Nassauer, 1995). For example, a study in Minnesota, USA found that owners of rare ecosystems were likely to care for oak woodlands but were less inclined to appreciate prairies or wetlands (Nassauer, 1995).

Expressing care of the environment through simple design interventions can be a powerful way of aligning ecological and aesthetic goals (Gobster et al., 2007; Nassauer, 1995), because people value landscapes that show traces of care (Nassauer, 2011). Unfamiliar or messy ecosystems can be protected by using commonly recognised stewardship techniques that display human care and intention for a landscape (Nassauer, 1995). These cues to care indicate that the ecosystem is part of a larger, intended pattern (Nassauer, 1995). Although cues to care differ between cultural and landscape contexts, commonly recognised stewardship interventions include: neatness and order, structures in good repair, mown borders, low fences, signs identifying ownership, carefully placed boardwalks, removal of rubbish and entrance plantings (Gobster et al., 2007; Nassauer, 2011; Nassauer & Raskin, 2014). These are strategies for altering the behaviour of effect and may help to reduce the intensity of ORV impacts. Mowing, landscaping, low wooden fences and removal of rubbish are also associated with an increased sense of safety, along with lower actual crime rates and vandalism (Nassauer & Raskin, 2014). Gobster et al. (2007) add that knowledge interventions such as signage, media, and experiential activities[2] can help to alter the cognitive perception of an environmental experience.

[2] For example, participation in a community restoration planting event

Chapter 3

Methodology

This chapter discusses the framework used for the research design before describing the case study site, the data collection and the analysis methods.

3.1 Research design

The research within this thesis is designed according to Cole's (1994) framework of total impact, which argues that several factors overlap to influence the intensity and area of impact, thus combining to form the total impact. Figure 3.1 shows the framework and how each factor is addressed within this thesis.

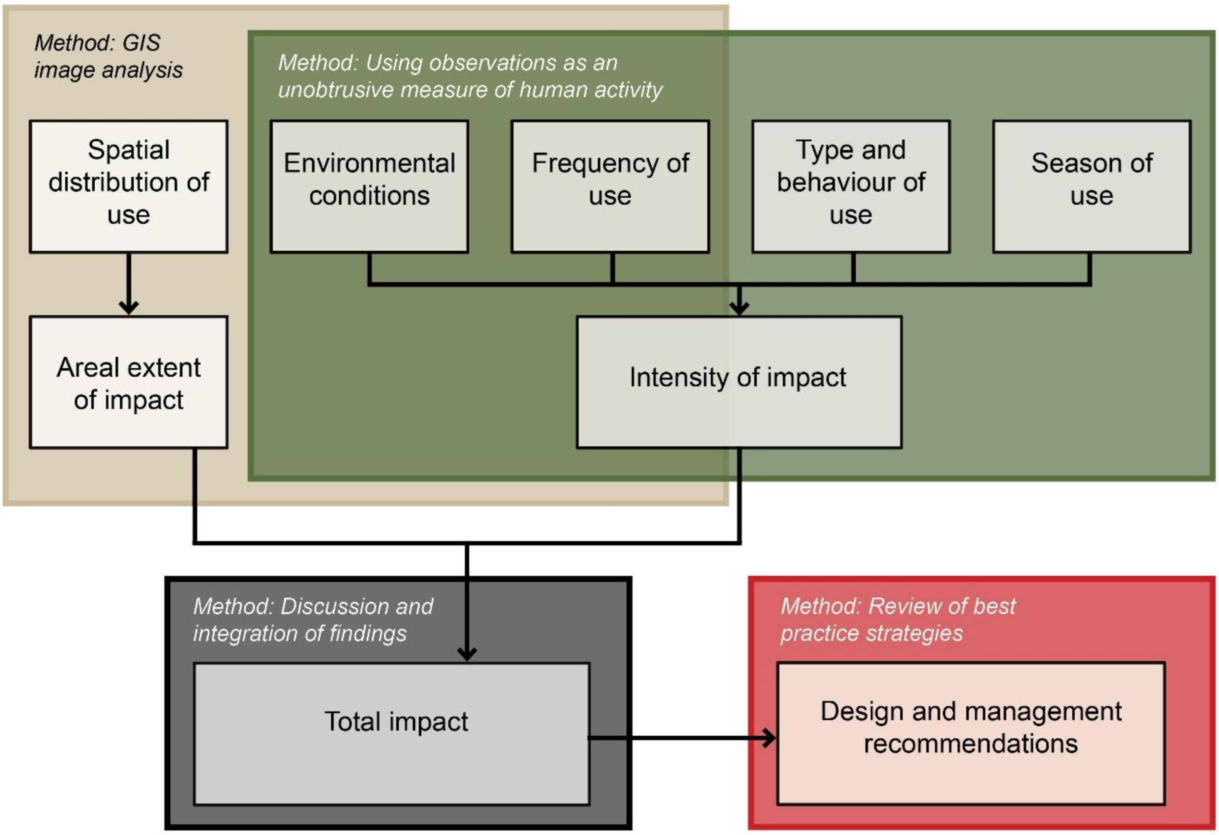


Figure 3.1 Thesis framework (adapted from Cole (1994)

Because this research primarily measures the area of saltmarsh impacted by ORV tracks, the focus of the results is on the areal extent of the impacts. Where the variation in areal extent of ORV tracks across different vegetation types was calculated, the findings also overlap with the factor of environmental conditions. Because there is a relationship between area of impact and amount of use (Schlacher & Morrison, 2008), the concentration of ORV tracks was also used to indicate frequency of use. The intensity of impact factors are addressed within the literature review, and observations of these factors are detailed in the results and discussion. In the final section of the results and discussion chapter, the research fingings on the areal extent of impacts are brought together with observations on the intensity of impacts and commentary from the literature review to give an overview of total impact. Based on the implications of the findings and informed by a literature review of theories and strategies to restrict vehicle damage, recommendations are made in chapter five for the future planning, design and management of the saltmarsh conservation area.

This study measured the impacts ORV use through observation and analysis of physical traces of tyre tracks. This method is defined by Del Balso and Lewis (2001) as an unobtrusive measurement of human activity. Because traces of impact are measured after the activity has occurred, this method does not influence user behaviour.

3.2 Study site: Greenpark Sands Conservation Area, Te Waihora

The study site for this research has been selected both for its ecological importance as a significant saltmarsh wetland and for the presence of ORV track damage.

3.2.1 Te Waihora context and significance

Wetland type and landscape context

Te Waihora/Lake Ellesmere is located within the Canterbury Plains Ecological Region (McEwen, 1987). To the north and west it is surrounded by low alluvial plains, while to the east it is bordered by the volcanic Port Hills and Banks Peninsula. The lake is bounded to the south by Kaitorete Spit and the Pacific Ocean. A location map is shown in Figure 3.2. Being distinctive in size, ecology and landscape characteristics, Te Waihora forms its own ecological district within the New Zealand Ecological Regions and Districts classification (McEwen, 1987). Characterised by its shallow and brackish water, the lake is surrounded by extensive saltmarshes and swamplands and is separated from the ocean by the stony beach ridge of Kaitorete Spit (McEwen, 1987). Stephenson describes Te Waihora/Lake Ellesmere as, “more a collection of habitats surrounding a lagoon that a single wetland” (Stephenson, 1986, p. 29). Because of its shallow form and relatively flat shorelines, the area of Te Waihora varies greatly depending on lake level.

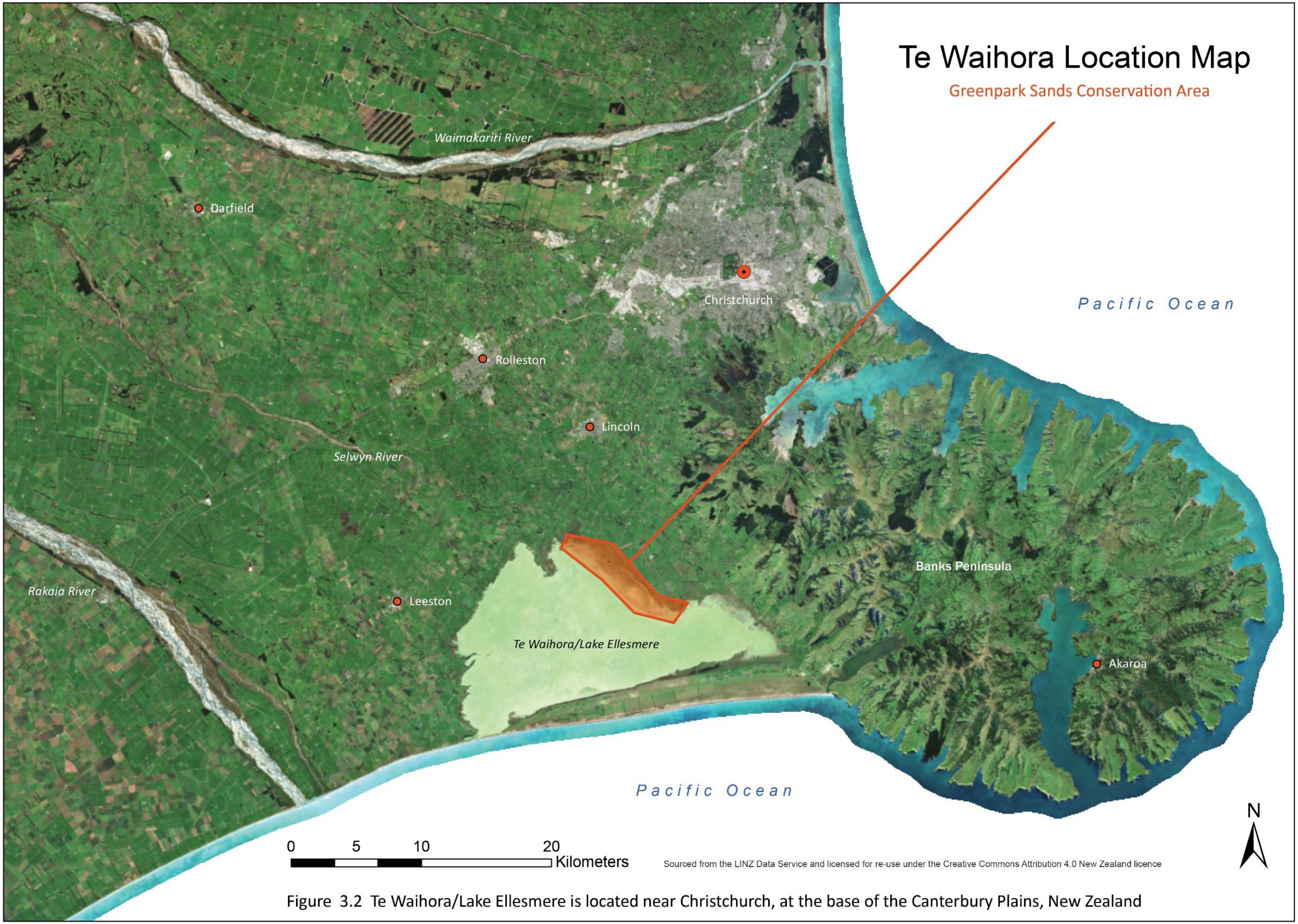


Figure 3.2 Te Waihora/Lake Ellesmere is located near Christchurch, at the base of the Canterbury Plains, New Zealand

Based on the wetland classification system developed by Johnson and Gerbeaux (2004), Te Waihora would be described as an estuarine hydrosystem, in which there is a mixing of freshwater and seawater. In form, the lake is a 'Waituna' type coastal lagoon because it has small inputs of river inflow and is more often closed to the sea than open to it (Johnson & Gerbeaux, 2004). Of the habitats surrounding Te Waihora, 83% are composed of brackish wetlands, and saltmarsh herbfields are the most extensive vegetation type (Grove & Pompei, 2019). While native plant species are generally predominant in the saltmarsh communities, most vegetation units mapped in Environment Canterbury's 2017 vegetation survey of Te Waihora contained a combination of native and exotic species (Grove & Pompei, 2019).

Because the Canterbury Region has already lost 90% of its wetlands, those surrounding Te Waihora are of especial significance (Pompei & Grove, 2010). The Selwyn/Waihora Water Management Zone, which is the catchment that drains into Te Waihora/Lake Ellesmere, has seen a 93.4% loss of wetlands to the year 2000 (Pompei & Grove, 2010).

Ngāi Tahu Values

Having sustained Ngāi Tahu[3] for generations, Te Waihora is of outstanding value to tangata whenua (the people of the land) (Boffa Miskell, 2010; Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005) and is imbedded in the iwi's history (Ford, Hughey, & Taylor, 2017). Also known as Te Kete Ika o Rākaihautū (The Fish Basket of Rākaihautū) (Environment Canterbury, 2019), Te Waihora is of great importance as a place of provision and a source of mahinga kai (food and resources*)* (Boffa Miskell, 2010; Ford et al., 2017; Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005). The lake is a tribal taonga (treasure) and is a provider of great mana (authority, power) for Te Rūnanga o Ngāi Tahu (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005).

The outstanding cultural significance of Te Waihora was recognised by the Ngāi Tahu Claims Settlement Act 1998 (Environment Canterbury, 2019). As part of the Ngāi Tahu Settlement, ownership of Te Waihora's lakebed was returned to Ngāi Tahu as a fee-simple estate (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005). The Ngāi Tahu Settlement also resulted in the Te Waihora Joint Management Plan (Te Waihora JMP), the "first statutory joint land management plan between the Crown and Iwi" (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005, Preface), which aims for integrated management of the Te Waihora area. Multiple levels of the lake's governance and management are now vested in Te Rūnanga o Ngāi Tahu (Ford et al., 2017).

[3] Ngāi Tahu is the indigenous tribe/iwi with mana whenua (jurisdiction over the land) within the Canterbury Region.

International Significance

The wetlands surrounding Te Waihora are of international importance for migratory wader birds (Department of Conservation, 2016; Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005) and provide habitat for a globally significant abundance and diversity of wildlife (Ford et al., 2017). Under the Ramsar Convention on Wetlands 1971, which was ratified by the New Zealand Government in 1976, a wetland is eligible to be recognised as a Wetland of International Importance if it meets one or more of the criteria (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005). Although Te Waihora meets every one of the criterion for a Wetland of International Importance, it has not yet been nominated for this international status (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005). According to the Department of Conservation (2016), the Te Waihora JMP aims for improved management of the lake before a nomination for Wetland of International Importance is made.

National Significance

Te Waihora has been described in the previous version of the Canterbury Conservation Management Strategy (CMS) as "the most important wetland habitat of its type in New Zealand" (Department of Conservation, 2000, p. 71) and the lake is recognised as one of the country's most important wetland systems (Ford et al., 2017). The lake, its shoreline and Kaitorete Spit have been identified as an Outstanding Natural Feature and Landscape (ONFL) due to their exceptional natural science and tangata whenua values and very high landscape values (Boffa Miskell, 2010).

With a size of approximately 20,000ha depending on lake level, Te Waihora/Lake Ellesmere is the largest lake in Canterbury and the fifth largest in New Zealand (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005). It is an important link in the chain of coastal lagoons and estuaries along the eastern South Island (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005). Collectively these coastal wetlands contain some of Canterbury's most threatened habitats and species, and create an ecological corridor for movement of wildlife (Department of Conservation, 2016).

Te Waihora is of national significance for wildlife (Environment Canterbury, 2019). Supporting many threatened indigenous species as well as international migratory birds, the lake provides habitat for a large diversity of wildlife, including high proportions of bird populations and many indigenous fish species (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005). The lake's outstanding value to wildlife is enabled by its unique characteristics and water fluctuations; at any one time up to 98,000 birds may be present at Te Waihora. The lake hosts the most diverse bird population in New

Zealand, with over half of the country's total number of bird species represented there (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005).

Recreation Values

As an important recreational resource that is of value to many people (Environment Canterbury, 2019), Te Waihora supports a range of human recreational activities including fishing, cycling along the Rail Trail, waterfowl hunting, boating, birdwatching, walking, four-wheel-driving and picnicking (Ford et al., 2017). Regularly supporting over 30,000 waterfowl, the lake is the most popular location in both Canterbury and New Zealand for game bird hunting (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005). Consequently, maimai (hides, shown in Figures 3.3) have become a distinctive feature of the Te Waihora landscape (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005) as they are the only vertical element in an otherwise flat and expansive environment.

Figures 3.3 Maimai at Greenpark Sands (Johanna Blakely, 17th April 2019)

3.2.2 Current management goals of the Te Waihora Joint Management Plan

The Te Waihora Joint Management Plan (JMP) aims to uphold and respect the rangatiratanga (self-governance) and kaitiakitanga of Ngāi Tahu. Te Waihora's management must be in accordance with Ngāi Tahu tikanga (protocol), with the aim of Te Waihora being recognised and supported as mahinga kai. Additionally, Ngāi Tahu must have access to this mahinga kai (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005).

The JMP seeks to conserve landscape integrity through high standards of environmental design, to protect and enhance scenic, landform and natural features and to maintain cultural landscapes and historic values. The plan aims to maintain and improve indigenous wetland biodiversity through restoration and protection of native plant and animal communities and the ecological processes that sustain them. It seeks to increase public awareness and participation in protecting wetland biodiversity, and to improve the mauri (life force) of Te Waihora (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005).

Where there are no likely adverse effects on mahinga kai, cultural or conservation values, the Te Waihora JMP seeks to provide public access and recreational use (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005).

For the full list of the JMP's objectives, refer to section 8 of the Te Waihora JMP (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005).

3.2.3 Greenpark Sands Conservation Area

Located along a 13km stretch of lakeshore between the mouths of the Huritini/Halswell River and the Ararira/LII River, Greenpark Sands contains a range of nationally significant saline to freshwater wetland vegetation (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005). While the whole of Te Waihora/Lake Ellesmere has been recognised for its notable plants (Boffa Miskell, 2010), Greenpark Sands Conservation Area and Yarrs Flat Wildlife Reserve[4] have been especially highlighted for their high botanical value (Hughey & Taylor, 2008). The lower mud and sand flats contain only native plant species (Hughey & Taylor, 2008), a few of which are shown in Figures 3.4 . Since the 1980s, the vegetation at Greenpark Sands has consistently been rated as outstanding (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005).

Figures 3.4. Specialised halophyte species, Greenpark Sands (Johanna Blakely, 17th April 2019)

At Greenpark Sands, the wetland class is saltmarsh due to its high soil salinity and the mixing of groundwater with adjacent brackish lake water. Being composed of predominantly saltmarsh herbfields (Grove & Pompei, 2019), the Greenpark Sands Conservation Area is an open, flat and expansive environment. The area is of outstanding importance for wader birds, especially migrant species, and is of high importance for waterfowl (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005).

[4] Greenpark Sands Conservation Area and Yarrs Flat Wildlife Reserve are collectively known as Greenpark Sands from here on.

Design of Greenpark Sands Conservation Area

Greenpark Sands Conservation Area is bordered by Te Waihora to the southwest and by privately owned farmland to the northeast. While its northwest border abuts Yarrs Flat Wildlife Reserve, the eastern edge is bounded by the Huritini/Halswell River. The small Greenpark Huts community is located on the northeast edge of the park, near the Huritini/Halswell River. A map of Greenpark Sands Conservation Area is shown in Figure 3.7.

There are five public access gates to Greenpark Sands Conservation Area. Of these entrance points, the two located at Greenpark Huts are gated but not locked (Figure 3.5), while the access at Clarks Rd has two closed gates to navigate, with a grazed paddock between. By contrast, the gates at Jarvis Rd and Embankment Rd are permanently open (Figure 3.6). Except at Embankment Rd, all the access points have Department of Conservation signs, which stipulate access requirements. Under section 6.2 of the Te Waihora JMP, vehicles are allowed on the conservation area if they stick to the prescribed routes, do not exceed 10km/hr and use the access routes only when ground conditions are dry and the lakebed is firm (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005). Although the prescribed routes are supposed to be marked, many of the markers have fallen over or have disappeared. The access route from Greenpark Huts to the river, and from this route to the lake edge, was hardened with gravel but has since subsided and deteriorated.

Figures 3.5 and 3.6 Other than entrance signage, the access gates at Greenpark Huts and Jarvis Rd shown no indication that a person is entering an area of significant cultural and ecological importance (Johanna Blakely, April 2019).

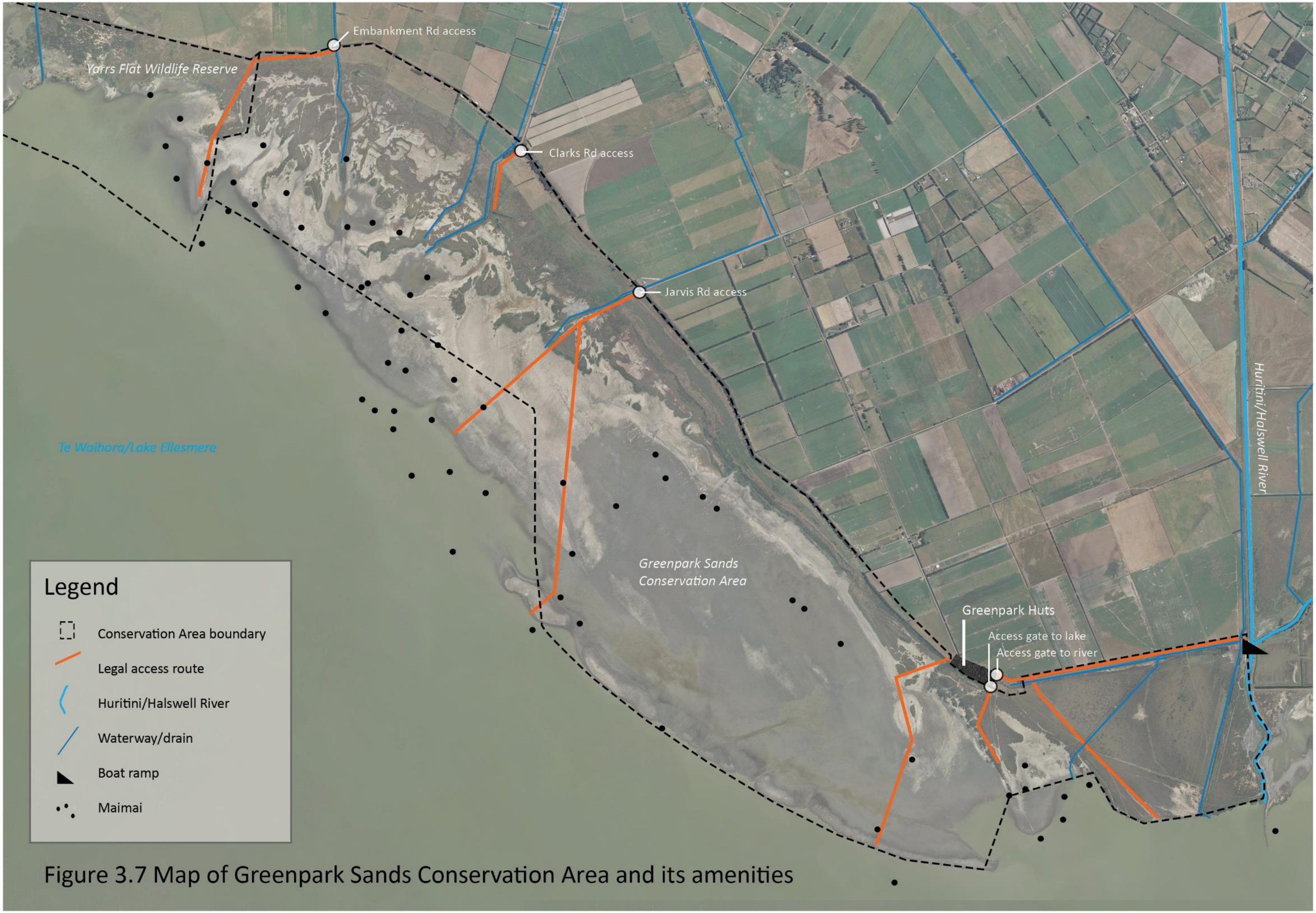


Figure 3.7 Map of Greenpark Sands Conservation Area and its amenities

Due to the Maimai Agreement 1997 between Te Rūnanga o Ngāi Tahu, the Department of Conservation and the North Canterbury Fish and Game Council, game bird hunters who hold Fish and Game permits have the right to use maimai located around Te Waihora, provided they comply with access regulations (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005). Because Greenpark Sands is popular for game bird hunting, maimai are spread liberally across the area.

There are several highly modified waterways and drains across Greenpark Sands Conservation Area. These do not extend all the way to the lake edge and carry varying amounts of water seasonally.

Off-road vehicle impacts at Greenpark Sands

Recent Te Waihora/Lake Ellesmere State of the Lake reports have highlighted the impacts of off-road vehicle (ORV) use on saltmarsh vegetation communities at Greenpark Sands, describing the damage as “extensive” (Ford et al., 2017, p. 23) and “heavy” (Lomax, Johnston, Hughey, & Taylor, 2015 p. 20). This follows from an unpublished report prepared for the Department of Conservation by Jensen (2014) and available from them on request, which assessed the impacts of grazing and vehicle use on the ecological values of Greenpark Sands. Jensen concludes that ORV access is leading to severe impacts, with parts of the saltmarsh communities being “very damaged by vehicles” (Jensen, 2014, p. 2) and it is obvious that ORVs are not keeping to the official tracks nor using the area only when dry (Jensen, 2014). Vehicle tracks have broken through the delicate saltmarsh vegetation and there are multiple ORV routes with deep ruts and overlapping routes (Jensen, 2014). The Greenpark Sands saltmarsh vegetation is vulnerable to vehicle use and it is clear that conservation values at this site are being negatively impacted by ORV damage (Jensen, 2014)

3.3 Methods for measuring off-road vehicle impacts

The methods by which off-road vehicle (ORV) impacts have been measured depend on the type of impacts being assessed. Trip and Wiersma (2015) observe that there are three types of ORV impacts: 1. Direct effects (within the tracks), 2. Indirect effects (immediately adjacent to the tracks) and 3. Landscape effects (such as habitat fragmentation). Because most studies have focused on either direct or indirect effects, there is an expanding knowledge of ORV impacts on soils, vegetation and wildlife. These studies have primarily involved transect and quadrat sampling, with some use of penetrometers and soil sampling.

Of the different types of impact, the least studied are the landscape effects caused by ORVs. In order to inform ORV management strategies, it is necessary to develop an understanding of the scale and distribution of ORV tracks across different environments. Studies that looked at landscape effects have primarily used historic aerial images to analyse ORV track networks and their changes in location and extent over time (Arp & Simmons, 2012; Charman & Pollard, 1995; Kelleway, 2006; Martin et al., 2008).

By using GIS image analysis to quantify the area and concentration of ORV track networks across a landscape, studies by Kobryn et al. (2017), Martin et al. (2008) and Whitbeck and Fehmi (2016) have provided both a quantified percentage of area impacted and a spatial assessment of the damage. As a result of mapping the ORV damage in this way, these studies have "established a quantitative baseline of track networks" (Kobryn et al., 2017, p. 102) against which further studies of the location can be assessed.

This study focuses on measuring the spatial extent (landscape effects) of ORV impacts based on the procedures outlined by Kobryn et al. (2017) and Martin et al. (2008). While their method of GIS image analysis provides a spatial assessment of ORV track damage, it does not assess the intensity of the damage on supporting, provisioning, regulatory or cultural ecosystem services.

3.4 Data Collection

3.4.1 Location of study transects

Because the Greenpark Sands site is held in three land parcels that cover a combined area of 1,513.6ha[5] (Land Information New Zealand), it was not practical to carry out an analysis of the entire area for this research due to equipment limits such as UAV battery life, budget and time constraints. Although Kobryn et al. (2017) studied the entire coastline adjacent to the Ningaloo Marine Park, covering an area of 988km/sq., detail was compromised. Their assessment was only able to determine ORV tracks through vegetated areas and could not distinguish vehicle tracks across the sand (Kobryn et al., 2017). By comparison, Martin et al. (2008) selected six smaller (2km/sq.) study sites that were chosen for their existing damage, proximity to access points and high recreational usage. Due to having a smaller study area and a correspondingly higher aerial image resolution, Martin et al. (2008) were able to locate and digitise individual tyre tracks through the wind tidal flats. Because much of the Greenpark Sands study site is composed of saltmarsh herbfields and mud flats, it was important to have image resolution for this study at a sufficient level of quality to be able to locate vehicle tracks through sparsely vegetated areas. Therefore, rather than mapping the entire site, 10 aerial image transects were chosen as samples across the area, which allowed for more detailed aerial images. With a combined area of 404.60ha, each of the transects run from the site's north-western boundary with adjacent farmland to the lake edge. Based on field observations

[5] The western land parcel being Yarrs Flat Wildlife Reserve, while the middle and eastern parcels form Greenpark Sands Conservation Area

and analysis undertaken on the 16th of April 2019 to identify suitable study sites, six transects were placed at road access points with an additional four transects evenly spaced between the access routes. Although not mapping the whole area, the transects show changes in patterns of use and impacts across the site. A map of the transect sites is shown below in Figure 3.8.

Figure 3.8 Greenpark Sands Conservation Area transect sample locations

3.4.2 Capturing of aerial images

To map the impacts of ORV tracks and boat propeller scars in a wind tidal flat, Martin et al. (2008) used standard RGB images with a pixel size of 0.192m. Assessing the coastline at a much coarser scale, Kobryn et al. (2017) had an RGB pixel size 0.5m and a hyperspectral pixel size of 3.5m. Although Kobryn et al. (2017) could not determine vehicle tracks to such a high level of detail, the hyperspectral images allowed them to identify vegetation and soil types.

For this study, a DJI Phantom 4 Pro drone was used to fly the ten transect sites. Operated by Dronescapes Ltd., the drone was flown at a height of 90m for transects 1-3 and at 100m for transects 4-10 with a corresponding pixel size of 2.50cm and 2.75cm respectively. The RGB aerial images were pre-processed by Dronescapes Ltd. They were stitched into a single orthomosaic for each transect and georeferenced.

The flights were initially undertaken in June, which is early winter in New Zealand and is mid-way through the game bird hunting season. When the pilot study was flown at transect 2 on the 10th of June, the average lake level sat at 1.08masl. The exposed lake margins were soft from recent rain. By the 20th of June, when transects 1 and 3 were flown, the water level had risen to 1.16masl. Unfortunately, at this height the lake water had already covered much of the vehicle damage and the remainder of the data collection had to be postponed until the lake was opened to the sea and allowed to drain.

Te Waihora was not successfully opened to the sea for a suitable length of time to allow sufficient drainage to occur until October 2019, and then a period of unstable weather postponed drone flights for another month, so it was not until November 2019 that the study sites were able to be re-flown. When Dronescapes Ltd. flew transects 1-10 on the 21st and 22nd of November, the lake level was at an average of 0.78masl, the groundcover vegetation was lush and vigorous, and the lakeshore was relatively firm.

3.5 Analysis

Vehicle tracks were analysed using an established method of GIS image analysis, which involves a two-step process of digitisation and ground truthing (Martin et al., 2008).

3.5.1 Digitisation

While Kobryn et al. (2017) used both image classification and digitisation to identify the ORV tracks in GIS software, Martin et al. (2008) relied fully on digitisation for this process. Although it had been hoped to use machine learning for this study, the variation in soil colour, directional changes and complex patterns of the vehicle tracks made image classification inconsistent and inaccurate. Instead, the tracks were digitised in ArcMap 10.6 using the polygon tool to create shapes covering the areas of damage. Due to the high resolution of the aerial images, which allowed clear zooming to a scale of 1:80, the polygon tool could be used to outline the vehicle tracks to a level of high detail and accuracy. Although Martin et al. (2008) measured each tyre track individually, for this study, ORV impacts were defined as the tyre tracks, and for four-wheel vehicles also included the axel space between these treads. This was because the high intensity of criss-crossing tracks in pockets of the conservation area made measuring individual tyre treads time consuming and impractical. Kobryn et al. (2017) also quantified the area of vehicle tracks to include the axel space, although their study applied an additional buffer to this measurement to account for indirect effects beyond the tracks.

In this study, the tracks were identified manually using visual observations of combinations of pattern, texture and contrast of soil and vegetation colours, with the following questions being used to help determine if an area was impacted by ORVs: Can I see that it is impacted? If yes, is it clearly identifiable as ORV impacts?

Categories of ORV impacts are listed below with examples:

1. A clear, single track from a two-wheeler (Figure 3.9).

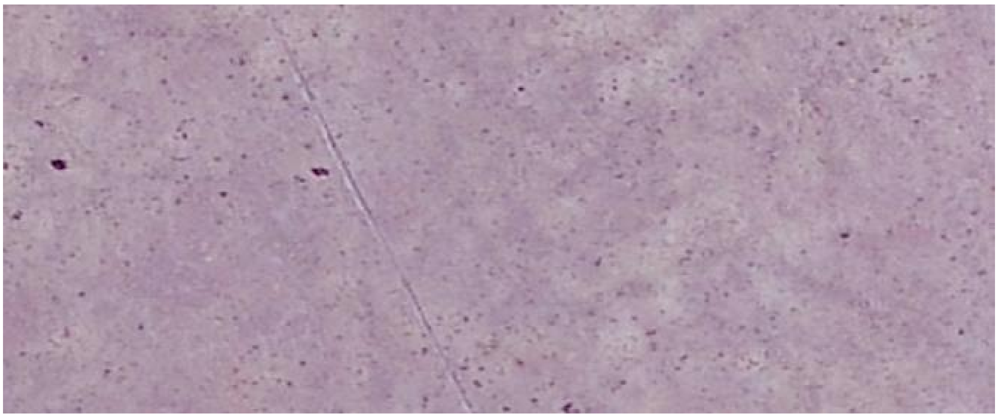


Figure 3.9 A two-wheeler track (scale at 1:150 in ArcMap)

2. Parallel tracks from a four-wheel vehicle that have broken through the soil (Figure 3.10).

Figure 3.10 Parallel tracks from a four-wheel vehicle that have broken through the soil (scale at 1:150 in ArcMap)

3. Parallel tracks from a four-wheel vehicle that have compressed the vegetation (Figure 3.11).

Figure 3.11 Parallel tracks from a four-wheel vehicle that have compressed the vegetation (scale at 1:150 in ArcMap)

4. An area of ground broken up by parallel or crossing vehicle tracks less than an axel width apart (Figure 3.12).

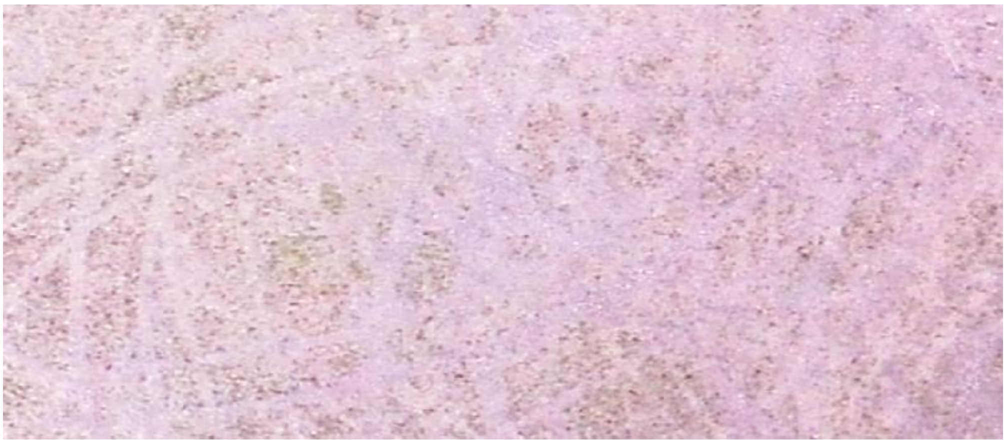


Figure 3.12 An area of ground broken up by parallel or crossing vehicle tracks less than an axel width apart (scale at 1:150 in ArcMap)

5. Very faint or ambiguous tracks (Figure 3.13).

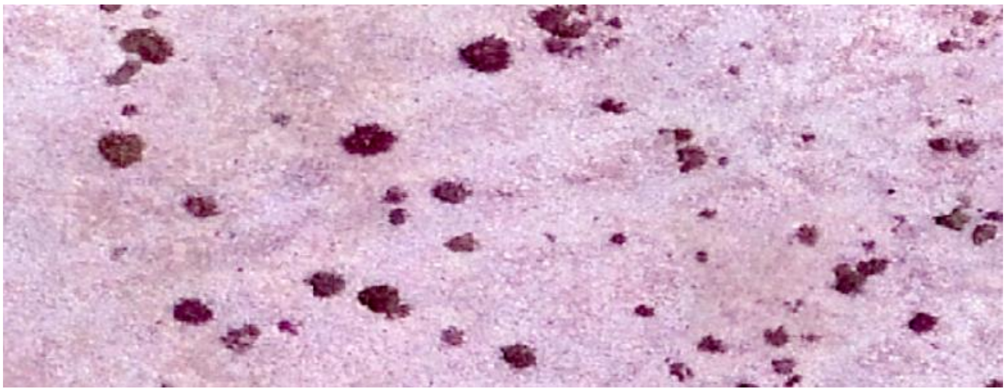


Figure 3.13 Very faint or ambiguous tracks running from left to right diagonally (scale at 1:150 in ArcMap). These particular tracks are more obvious at a larger scale.

6. Evidence of impact but not clearly definable as ORV tracks so therefore not included in the analysis (Figure 3.14). Possibly there has been ORV impact but it has since been covered by water or vegetation, or the lighting is overexposed.

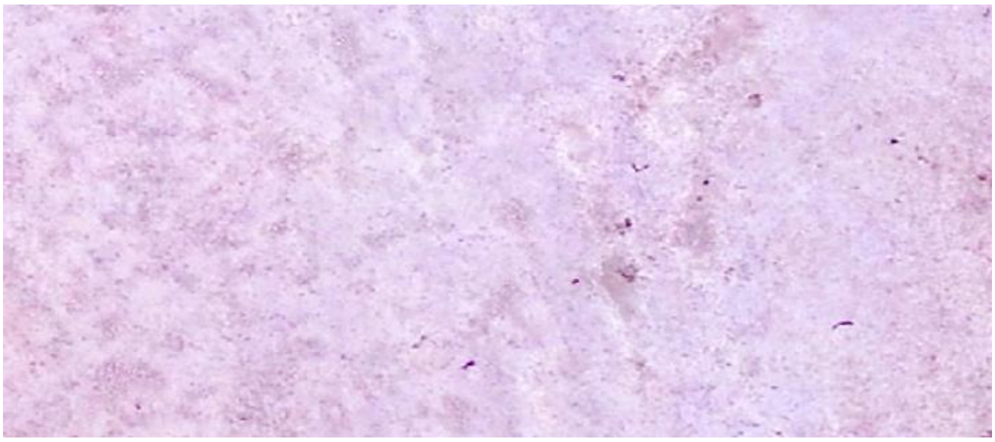


Figure 3.14 Evidence of impact but not clearly definable as ORV tracks (scale at 1:150 in ArcMap)

A limitation of the digitisation method is that it is subjective and relies on the accuracy of the person who is identifying and placing polygons over the areas of track damage, and individual GIS operators are likely to each trace the vehicle track impacts differently. However, the high resolution of aerial image data makes these inconsistencies minor.

3.5.2 Ground truthing

After digitising the ORV tracks, examples of each category of impact that had been identified in the digitisation process were selected and GPS located. The ground truthing took place on the 25th of January 2020, in mid-summer, when the lake edge was firm. This ground truthing confirmed a high level of confidence in the digitisation method, with only one of the 44 sites that were ground truthed not showing any sign of ORV damage. Because the soil was very soft in this location however, it appeared that the water from the nearby lake edge had risen and receded at some point since the aerial images were taken, covering the two-wheeler track. At a couple of other sites, the ORV tracks were difficult to discern due to vegetation growth, yet the tyre ruts could be felt underfoot. Overall, a significant majority of the sites were consistent on ground with what could be seen in the aerial images. Figures 3.15-3.20 show examples of each category of ORV track damage as seen from the ground.

1. A clear, single track from a two-wheeler (Figure 3.15).

Figure 3.15 A two-wheeler track (Johanna Blakely, 25th January 2020, 50mm lens)

2. Parallel tracks from a four-wheel vehicle that have broken through the soil (Figure 3.16).

Figure 3.16 Parallel tracks from a four-wheel vehicle that have broken through the soil (Johanna Blakely, 25th January 2020, 50mm lens)

3. Parallel tracks from a four-wheel vehicle that have compressed the vegetation (Figure 3.17).

Figure 3.17 Parallel tracks from a four-wheel vehicle that have compressed the vegetation (Johanna Blakely, 25th January 2020, 50mm lens)

4. An area of ground broken up by parallel or crossing vehicle tracks less than an axel width apart (Figure 3.18).

Figure 3.18 An area of ground broken up by parallel or crossing vehicle tracks less than an axel width apart (Johanna Blakely, 25th January 2020, 50mm lens)

5. Very faint or ambiguous tracks (Figure 3.19).

Figure 3.19 Very faint or ambiguous tracks (Johanna Blakely, 25th January 2020, 50mm lens)

6. Evidence of impact but not clearly definable as ORV tracks so therefore not included in the analysis (Figure 3.20). Possibly there has been ORV impact but it has since been covered by water or vegetation, or the lighting is overexposed.

Figure 3.20 Evidence of impact in the foreground but not clearly definable as ORV tracks (Johanna Blakely, 25th January 2020, 50mm lens)

3.5.3 Mapping the intensity of ORV tracks by quadrats

To calculate the cover of ORV tracks within quadrats, a 25mx25m grid was placed over the ArcMap file using the create fishnet tool and with the transect areas used as the template extent. This method has been used by Martin et al. (2008) to calculate the cover of ORV and boat propeller scars within a sea grass meadow. Kobryn et al. (2017) and Whitbeck and Fehmi (2016) used grids to calculate the density of lengths of ORV tracks within a coastal environment and a desert respectively. Although both Martin et al. (2008) and Kobryn et al. (2017) used 100mx100m grids and Whitbeck and Fehmi (2016) used a 20mx20m grid, for this study a 25mx25m (625m2) grid was selected as the most appropriate scale based on the resolution of the aerial images and the size of the transects.

The ORV track impact layer was intersected with the fishnet layer so that within each 25mx25m grid, the area of vehicle damage could be calculated individually. This showed the intensity of ORV track impacts across the grid samples.

Next, ORV track damage was selected through the ArcMap attributes table and colour coded based on the cover of damage within each square. To categorise percentages of cover, the DAFOR scale was used (Wheater, Bell, & Cook, 2011) and is shown in Table 3.1 below. Because this scale is normally used within an ecology context for assessing vegetation cover, its descriptors for each percentage bracket were not the best fit for describing cover of ORV tracks. In this study, the terminology of the DAFOR scale was adapted by taking landscape assessment terms from Best Practice Note: Landscape Assessment and Sustainable Management 10.1 (New Zealand Institute of Landscape Architects Education Foundation, 2010) and assigning them to each percentage bracket to better reflect the level of impact occurring; see Table 3.2 below. By calculating the cover of ORV tracks in this way, it was possible to create a map showing the density of vehicle impacts across Greenpark Sands Conservation Area.

Table 3.1 The DAFOR scale, from Wheater et al. (2011). Table 3.2 The adapted DAFOR scale, using terminology from New Zealand Institute of Landscape Architects Education Foundation (2010)

DAFOR scale	
Dominant	>75% cover
Abundant	50-75% cover
Frequent	25-50% cover
Occasional	10-25% cover
Rare	<10% cover

Adapted DAFOR scale	
Extreme	>75% cover
Very high	50-75% cover
High	25-50% cover
Moderate	10-25% cover
Low	<10% cover

3.5.4 Calculating the percent area of impact

Average cover of impact

Once the ORV track impacts had been digitised, the vehicle impact polygons for each transect were combined using the Merge tool, allowing the area of identified ORV impact within each transect to be calculated in the attributes table. The areas of ORV track damage were divided by each transect area and multiplied by 100 to calculate the percentage of all transects damaged. Thus, the average cover of ORV tracks across each transect and across the site as a while could be calculated.

Cover of impact around the maimais

To calculate the percentage of ORV impacts around the maimai, a 100m buffer was placed around the maimai using the geoprocessing buffer tool. The buffer area was intersected with the transects and again with the digitised ORV track impacts using the Intersect tool to separate the overlapping areas as an individual layer. From these new layers, the percentage of area of ORV damage within the 100m buffer was able to be calculated.

Cover of impact with distance from access gates

By placing a multiple ring buffer around the access points and following the steps carried out for the maimai buffer, the percentage of ORV track impact was able to be calculated for each 200m of distance from the access point, up to 1000m; giving a change in percentage of impact with distance from access.

Cover of impact across vegetation types

Using the shapefile from Environment Canterbury's 2017 vegetation survey of Te Waihora, the main vegetation types within the sample transects were intersected with the transect areas and then with the vehicle impact areas to calculate percentage of ORV track impacts within each vegetation type.

3.5.5 Observations of intensity of ORV use

Observations from aerial images and on-site photographs at Greenpark Sands were used to show evidence of human activity and to reveal information about ORV use and behaviours. This method of analysis is known as an unobtrusive measurement of behaviour (Del Balso & Lewis, 2001) and was used in this research to inform findings on intensity of ORV use.

Chapter 4

Off-Road Vehicle Impacts at Greenpark Sands Conservation Area: Results and Discussion

In this chapter, key findings of the research are described, with a discussion concluding each section. Firstly, the spatial distribution of ORV tracks at Greenpark Sands Conservation Area are described, beginning with the extent of tracks, before moving on to describe the average cover of vehicle tracks across the park, the average cover of tracks around maimai, and the change in vehicle track density with distance from access points. Next, the intensity of ORV tracks is described. The relationship between cover of ORV tracks and vegetation types is analysed and discussed before looking at frequency of use, type and behaviour of use, and season of use. The chapter concludes by discussing the total impact of these results on the conservation area, and implications for planning, design and management.

4.1 Spatial distribution of off-road vehicle tracks

4.1.1 Extent of off-road vehicle tracks

The results indicate that the entire park width has been impacted by ORV tracks, from Greenpark Sands' inland boundary to the lake edge; a distance of up to 2.03km. Vehicle tracks were present in each of the ten transects, and therefore, were also spread across the length of the park; a distance of 8.45km between the outside edges of the furthest transects. In every transect vehicle tracks were present at the water's edge. Figure 4.1 shows the extent of ORV track impacts across Greenpark Sands Conservation Area.

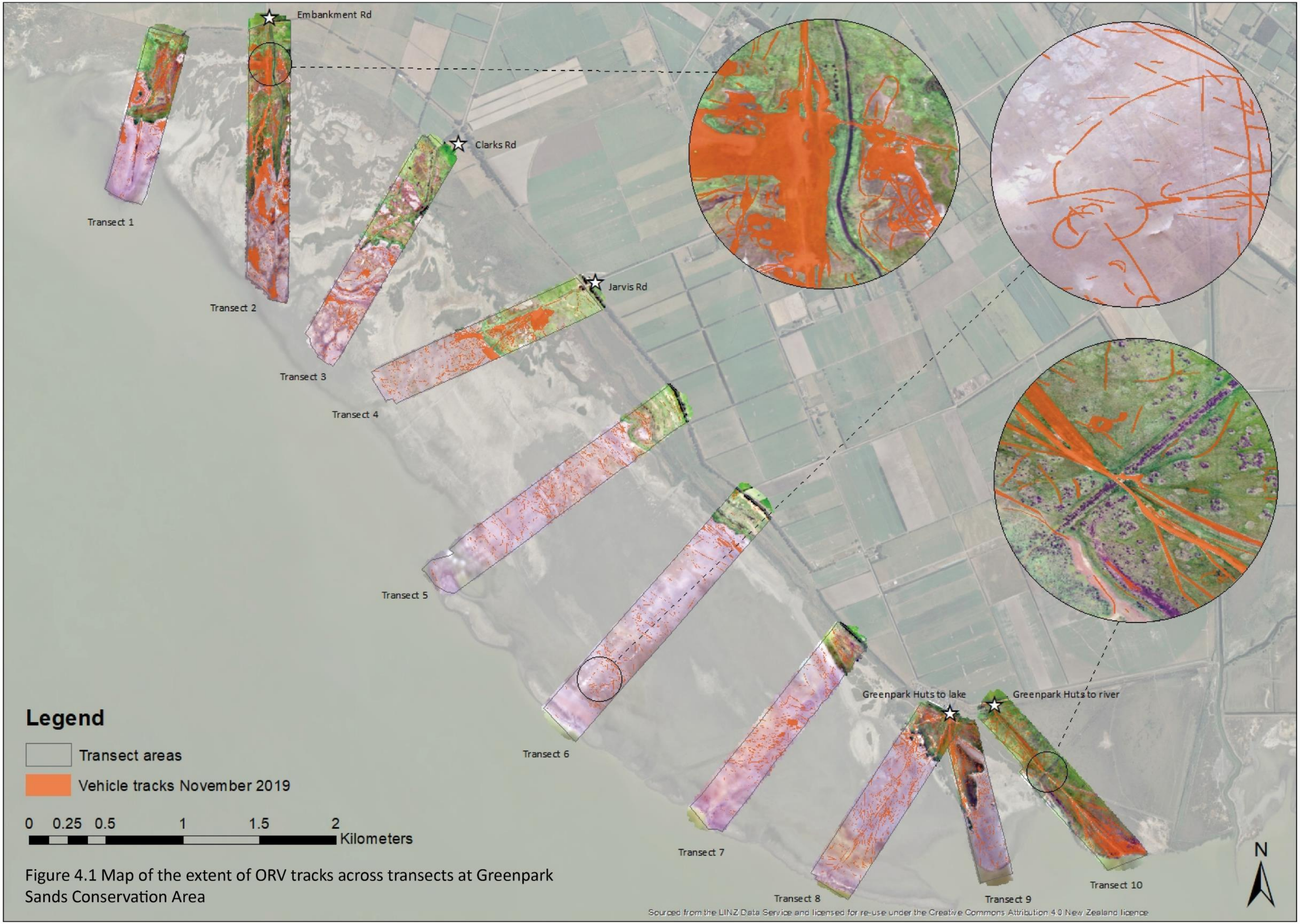


Figure 4.1 Map of the extent of ORV tracks across transects at Greenpark Sands Conservation Area

4.1.2 Presence of ORV tracks within quadrats

When mapped in 25mx25m grids, ORV tracks were present in 65.92% of the 7403 sampled grids at Greenpark Sands, as shown in Figure 4.2. These results are similar to the findings from a study by Martin et al. (2008), who found a range of 42.2%-79.4% of 100mx100m grids in wind-tidal flats in the USA to be impacted by ORV tracks.

In an Australian saltmarsh wetland, Kelleway (2006) measured 23.2% cover of ORV tracks. However, it is difficult to determine how this result compares with the findings here, as Kelleway may have used a different method to measure cover, and it is uncertain if the grid count method used in his study was a presence/absence count, or an estimated percentage of vehicle track cover.

There are no previous studies of cover of ORV tracks in a New Zealand saltmarsh wetland; although in New Zealand's Rangipo Desert, Smith (2014) found ORV tyre marks to be present in 5.8% of the 50mx50m grids across her study area.

According to Hammitt et al. (2015) and Huddart and Stott (2019), increasing the area available for recreational use will increase the area of associated impacts. Because Greenpark Sands is an open and flat habitat, with predominantly low-stature vegetation and limited surveillance, there are few barriers to hinder the dispersion of ORV tracks. In the Rangipo Desert, New Zealand, Smith (2014) noted that ORV drivers predominantly chose to drive on flat environments, with sparsely placed or short-stature vegetation. Due to the large number of maimai and the length of the lake edge at Greenpark Sands, the high level of track dispersion is likely also to be influenced by drivers accessing maimai or the lake edge for hunting, fishing or sightseeing.

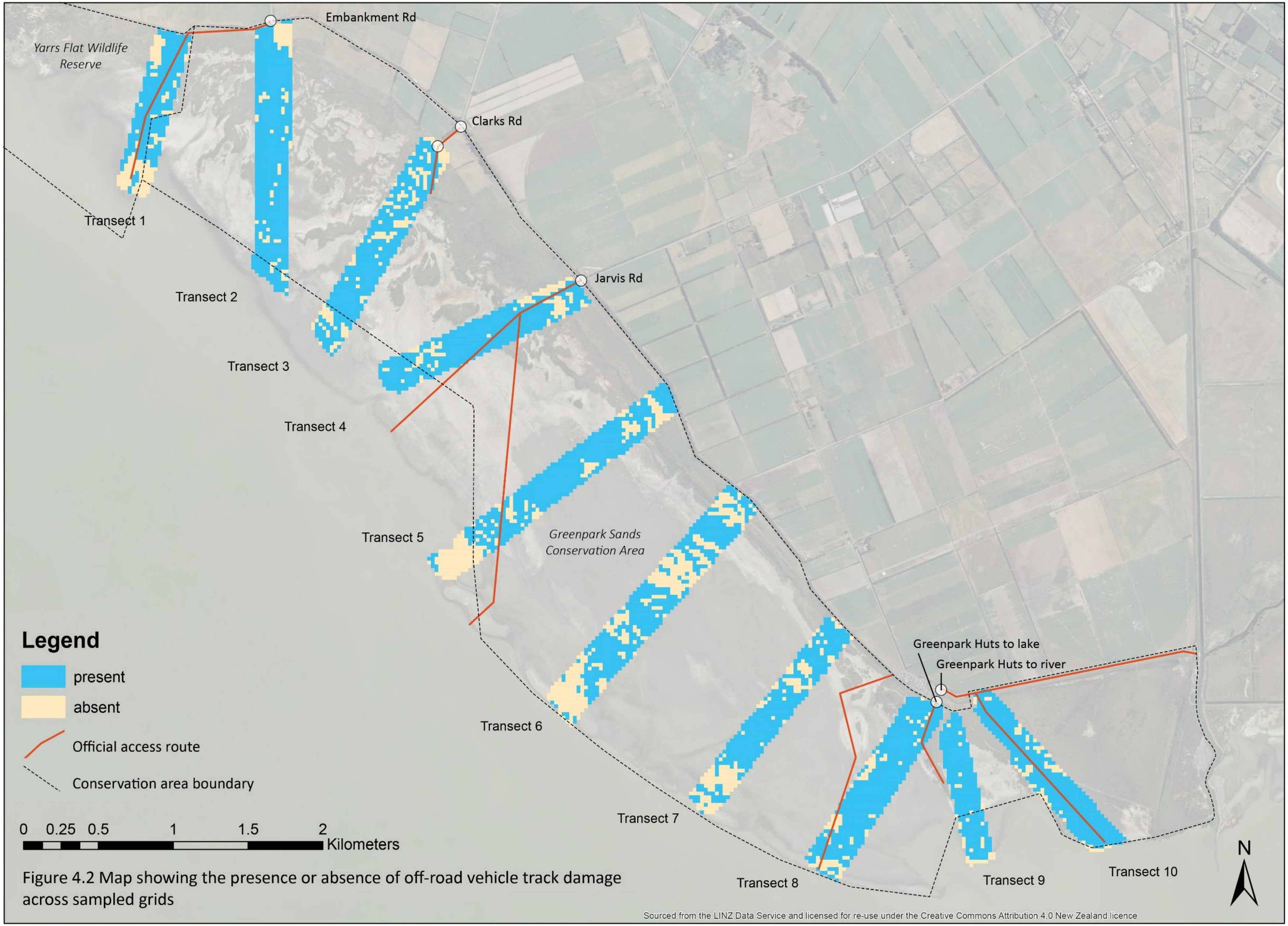


Figure 4.2 Map showing the presence or absence of off-road vehicle track damage across sampled grids

4.1.3 Average cover of off-road vehicle tracks across Greenpark Sands

While the previous section looked at the presence of ORV tracks within quadrats across Greenpark Sands, this section discusses the average cover of vehicle tracks across each transect and across the site as a whole.

Not all areas of the park have the same levels of ORV impacts. The average cover of ORV tracks varied by 22% between transects, with Transect 2 having an average 27.33% cover of ORV track damage, while Transect 6 had an average 5.29% cover of ORV track damage (Figure 4.3 and Table 4.1).

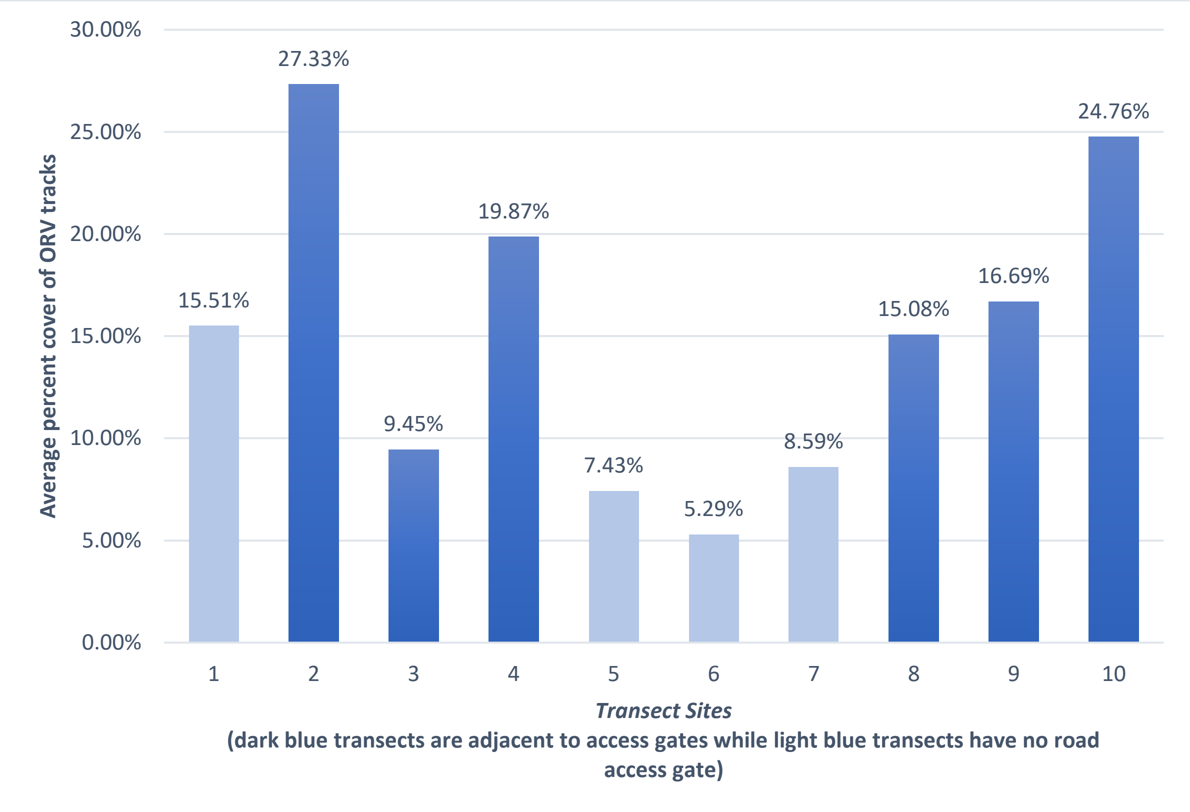


Figure 4.3 Average cover of ORV tracks varied by 22% between transects

Table 4.1 Average cover of ORV tracks by transect

Transect number	Area of transect (ha)	Area of ORV tracks (ha)	Average cover of ORV tracks
1	29.87518579	4.634315666	**15.51%**
2	47.13486881	12.88286024	**27.33%**
3	42.2503052	3.991391068	**9.45%**
4	39.63177953	7.873174591	**19.87%**

5	51.12991726	3.797154328	**7.43%**
6	58.20137858	3.07693646	**5.29%**
7	39.01365568	3.351969161	**8.59%**
8	41.54134539	6.265096858	**15.08%**
9	21.67495121	3.617232149	**16.69%**
10	34.14420436	8.454299358	**24.76%**

Across the whole site the ORV track damage averaged 14.32% and covered a total area of 57.94ha (Figure 4.4 and Table 4.2).

Proximity to access points was a strong indicator of vehicle track cover, with transects adjacent to access gates (shown in dark blue) having an average ORV track cover of 19.03%, while transects not adjacent to access gates (shown in light blue) had an average ORV track cover of 8.34% (Figure 4.4 and Table 4.3).

By multiplying the approximate length of the managed vehicle access routes outlined in the Te Waihora JMP (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005) by a width of 5m to allow for passing vehicles and some track expansion, it was estimated that if vehicles stayed on the prescribed routes, only 0.39% of Greenpark Sands would be impacted by ORV tracks (Figure 4.2 and Table 4.4).

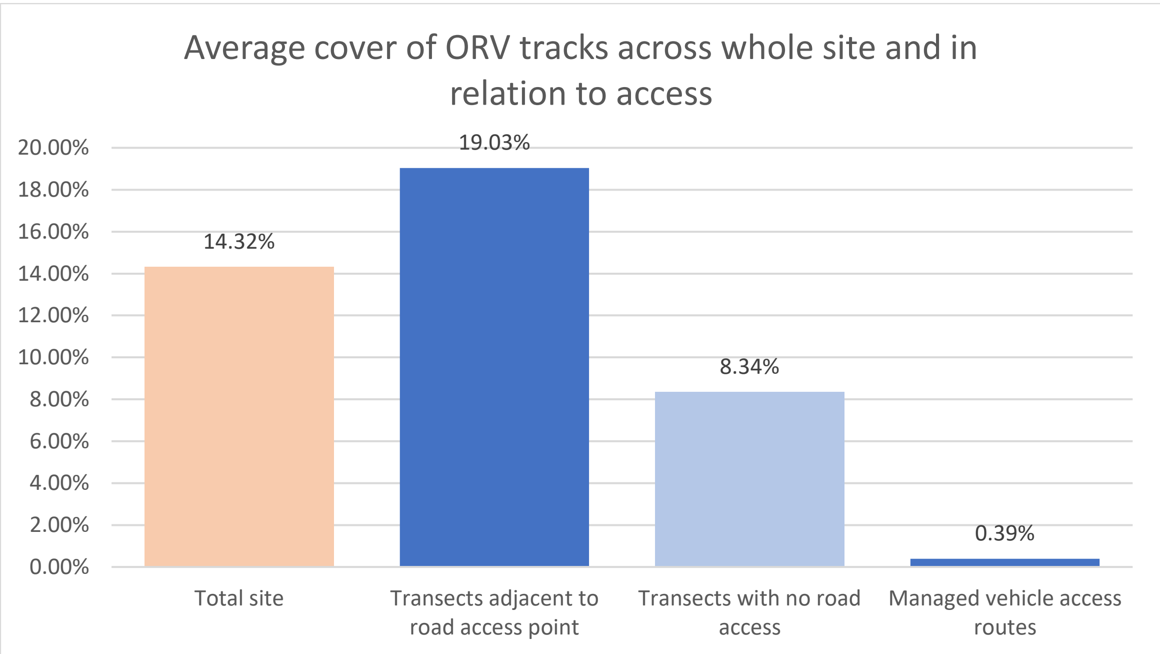


Figure 4.4 Average percentage of impact across total site and in relation to access gates

Table 4.2 Average ORV track damage across total site

	Total area of transects (ha)	Total area of ORV damage (ha)	Average cover of ORV tracks
Total site	404.5975918	57.94443	**14.32%**

Table 4.3 Comparison of average cover of ORV tracks between transects with road access gates and transects without road access gates

	Total area of transects (ha)	Total area of ORV tracks (ha)	Average cover of ORV tracks
Transects adjacent to road access points[6]	226.3774545	43.08405	**19.03%**
Transects with no road access points[7]	178.2201373	14.86038	**8.34%**

Table 4.4 Estimated cover of ORV tracks if vehicles stayed on managed vehicle access routes

	Area of Greenpark Sands Conservation Area (ha)	Estimated area of ORV tracks (ha)	Estimated cover of ORV tracks
Managed vehicle access routes	1224.7	4.779549[8]	**0.39%**

At 14.32%, the average cover of ORV tracks may sound underwhelming, but it is necessary to remember that this damage is spread across the entire 1200ha of Greenpark Sands Conservation Area and contains pockets of extreme concentration of damage. In their study of ORV scars on wind-tidal flats in Texas, USA, Martin et al. (2008) found average cover of ORV track damage was around 5%. However, it is worth noting that Martin et al. measured only the area of the tyre marks, and not the whole width of the vehicle track, as in this study. By comparison, Mize et al. (2005) estimated 30% of a small bog in Texas, USA to be directly damaged by ORV tracks, which is similar to the average cover of vehicle damage measured at Transect 2.

The lower concentration of vehicle track cover at transects not adjacent to road access agrees with Forgues (2010), who found that ORV abundance decreased with increasing distance from vehicle entry points on Maryland and Virginia beaches, USA. Whitbeck and Fehmi (2016) also predict a

[6] Transects 2,3,4,8,9 and 10
[7] Transects 1,5,6 and 7
[8] Area based on approximate length of managed vehicle access routes as outlined in the Te Waihora Joint Management Plan (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005) and multiplied by a width of 5m to give an estimate of the area of damage if ORV users kept to the specified tracks.

higher density of track networks in proximity to existing tracks, which was confirmed in this study, with concentrated ORV damage near access tracks originating at the road ends.

Although Transect 1 is not adjacent to a road end, ORV damage on this site is influenced by a managed vehicle access route running through the transect, as outlined in the Te Waihora JMP, and causing an increase in the cover of vehicle tracks. Likewise, although Transect 3 is adjacent to a road end, two closed gates and overgrown bushy vegetation prevent most vehicles from accessing the site from the end of Clarks Rd. Most vehicle damage at Transect 3 appears to come along the lake edge from Embankment Rd and Jarvis Rd.

Because the cover of ORV tracks were measured in November, after the winter's high lake level had been drained to the sea, pre-existing vehicle tracks may have been obscured by water movement and shifting sediments, and spring vegetation growth is likely to have hidden other ORV tracks. Therefore, further research is required to determine if the cover of ORV tracks increase with extended periods of low lake levels, especially towards the lake edge, and if more tracks are visible when much of the saltmarsh vegetation dies off over winter.

4.1.4 Maimai do not appear to be highly correlated with track cover

Within a 100m buffer around the maimai, the cover of ORV track damage averaged 12.52%; slightly lower than the average across the total Greenpark Sands area (Figure 4.5, Table 4.5).

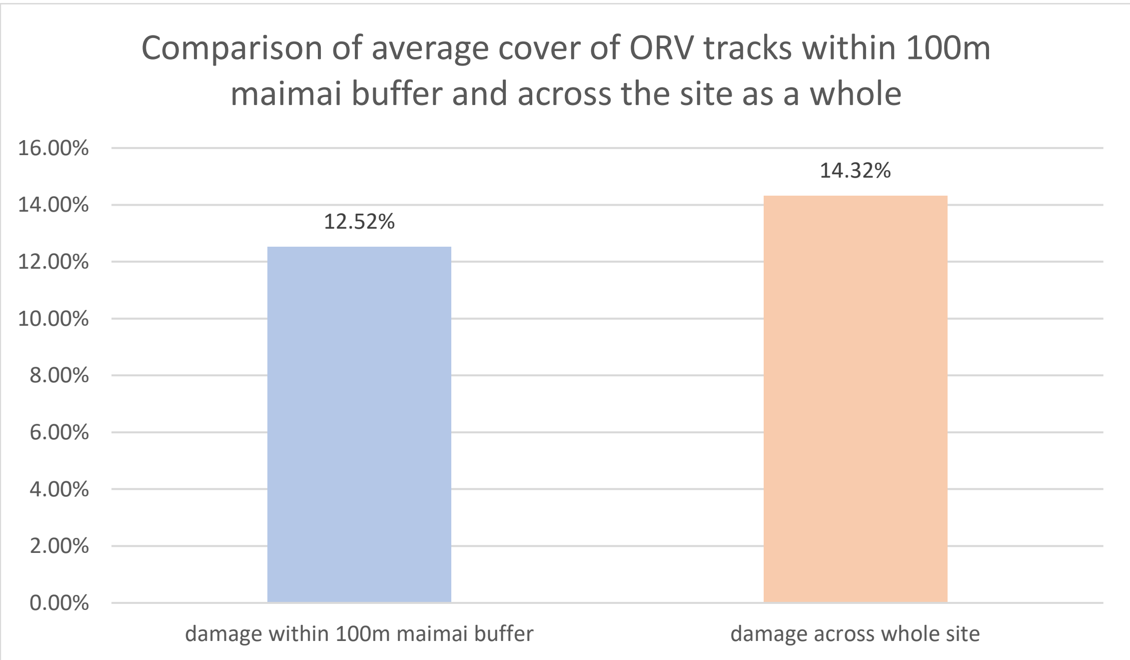


Figure 4.5 The average cover of ORV tracks is slightly lower around the maimai

Table 4.5 Cover of ORV track damage within 100m buffer around the maimai

Buffer around maimai	Total area of buffers (ha)	Total impacted area (ha)	Average cover of ORV tracks
100m	42.71679532	5.347566855	**12.52%**

The cover of ORV tracks around maimai has not previously been measured. Because recreational impacts are typically concentrated around attractions (Hammitt et al., 2015), it was surprising to find that average cover of ORV tracks within 100m of maimai was slightly lower than the total site average. However, it is likely that the high lake level over the winter of 2019 obscured some of the vehicle tracks. Further research is necessary to measure the area of vehicle tracks around the maimai after a period of low lake levels to determine if this hypothesis is true.

4.1.5 Change in cover of ORV impacts with distance from access gates

When comparing the average cover of ORV tracks within concentric 200m buffer rings from the road access points, no clear trend emerged and the pattern of damage varied greatly between points of entry, as shown in Figure 4.6. What can be observed from this chart does not demonstrate the finding by Forgues (2010) that vehicle abundance decreases with distance from access points. If the samples were extended beyond 1000m, they might begin to show a downward trend. Further work is required to establish this.

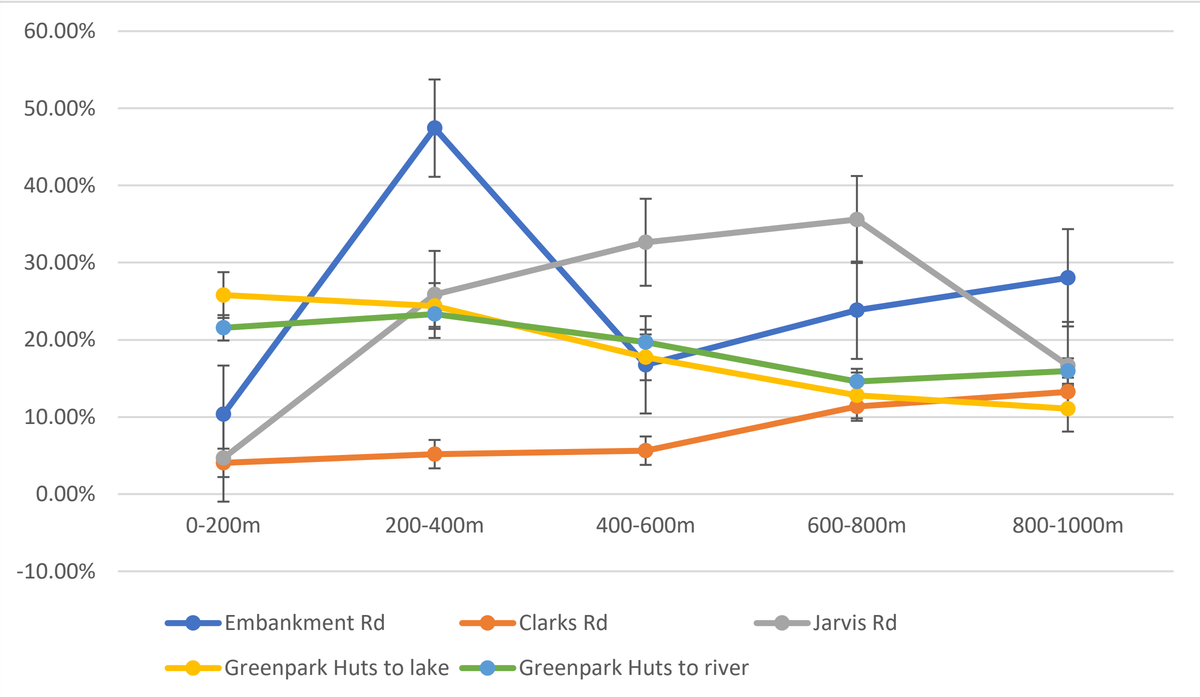


Figure 4.6 Percent cover of ORV tracks with distance from boundary access points

At Embankment Rd, the concentration of vehicle track cover spiked to almost 50% between 200-400m from the access before dropping down to 17% within the next 200m. At Jarvis Rd the level of damage jumped by 20% between 200-400m and continued to increase until the 600-800m mark; here the cover of damage peaked at 36% before it dropped to 17% within the next 200m. The variations in vehicle cover at both of these sites appeared to relate to vegetation communities, with the ORV tracks increasing in areas of low stature herbfields and decreasing where there was taller grassland and rush vegetation. This observation is in agreement with Smith (2014), who found that ORV users were more likely to drive over areas of low stature vegetation.

The Clarks Rd entrance began with minimal damage and gradually increased with distance from access. Although there is legal access at Clarks Rd, two closed gates with a grazed paddock between them are enough to deter most vehicle users. These two closed gates act as physical barriers, which are often recommended as a recreational management strategy for limiting the area of recreational impacts (Hammitt et al., 2015; McWilliam, 2007). The grazing horses also act as a cue to care, with Nassauer (2011) noting that people value and respect landscapes that show traces of care and ownership. It appears that vehicle use at the Clarks Rd transect (Transect 3) is mostly influenced by ORV users travelling around the lake edge form Embankment Rd and Jarvis Rd.

Following similar trends to each other, the damage from access gates at Greenpark Huts, towards the lake and the Halswell/Huritini River respectively, began with 22-26% damage at 0-200m and decreased to 11-16% by 800-1000m. The cover of damage along the Greenpark Huts to river access had a slight increase at this point and continued to spike beyond 1000m, which is unsurprising because the ground level is higher along this route, allowing vehicles to access the lake edge when all other routes are inundated. Hammitt et al. (2015) notes that recreation impacts tend to be concentrated around attractions, such as lake edges.

Table 4.6 Cover of ORV tracks within concentric buffer rings out from each access road

Embankment Rd access			
Distance from access point (m)	Area within buffer (ha)	Damage within buffer (ha)	Cover of ORV tracks within buffer
0-200	4.846087	0.501471	**10.35%**
200-400	5.651885	2.680683	**47.43%**
400-600	6.38951	1.070797	**16.76%**
600-800	12.52952	2.986019	**23.83%**
800-1000	12.71127	3.5645	**28.04%**
Clarks Rd access			
Distance from access point (m)	Area within buffer (ha)	Damage within buffer (ha)	Cover of ORV tracks within buffer

0-200	5.897277	0.238846	**4.05%**
200-400	5.672813	0.293645	**5.18%**
400-600	5.456448	0.307391	**5.63%**
600-800	5.387301	0.610749	**11.34%**
800-1000	5.710313	0.756596	**13.25%**
Jarvis Rd access			
Distance from access point (m)	Area within buffer (ha)	Damage within buffer (ha)	Cover of ORV tracks within buffer
0-200	4.960841	0.231133	**4.66%**
200-400	5.667793	1.466889	**25.88%**
400-600	5.432784	1.773046	**32.64%**
600-800	5.390444	1.918284	**35.59%**
800-1000	12.42363	2.071796	**16.68%**
Greenpark Huts access towards Te Waihora/Lake Ellesmere			
Distance from access point (m)	Area within buffer (ha)	Damage within buffer (ha)	Cover of ORV tracks within buffer
0-200	6.164174	1.590229	**25.80%**
200-400	15.04084	3.667346	**24.38%**
400-600	15.52861	2.753963	**17.73%**
600-800	18.79478	2.40403	**12.79%**
800-1000	27.21749	3.013635	**11.07%**
Greenpark Huts access towards Huritini/Halswell River			
Distance from access point (m)	Area within buffer (ha)	Damage within buffer (ha)	Cover of ORV tracks within buffer
0-200	5.030754	1.084309	**21.55%**
200-400	11.95825	2.790056	**23.33%**
400-600	17.37217	3.417386	**19.67%**
600-800	16.63483	2.427112	**14.59%**
800-1000	17.53532	2.796071	**15.95%**

4.2 Intensity of off-road vehicle impacts

There is a high intensity of vehicle use impacts on the saltmarsh wetlands at Greenpark Sands Conservation Area. According to Cole's framework of total impact, intensity of impact is affected by environmental conditions, frequency of use, type and behaviour of use and season of use (Cole, 1994). The results of measurements and observations of ORV impacts on each of these factors is discussed in the following sections.

4.2.1 Environmental conditions

The following two sections discuss measurements of the cover of ORV tracks across different vegetation types and demonstrate observations of erosion and compaction occurring at Greenpark Sands Conservation Area.

Comparison of the cover of ORV tracks across different vegetation types

Analysis of Environment Canterbury's Te Waihora 2017 vegetation survey indicates that saltmarsh herbfields cover 80.57% of the sampled area of Greenpark Sands Conservation Area (Figure 4.7). Of the main vegetation types, herbfields had the significantly highest average cover of ORV track damage, at 16.32%, while the areas classified as naturally sparsely vegetated had the lowest average cover of impact, at 1.75% (Figure 4.8, Table 4.7). Figure 4.9 on page 67 shows a map of the vehicle impacts overlaid on the vegetation types. For more detailed descriptions of the vegetation communities listed in this section, see the Environment Canterbury notes on vegetation types in Appendix A.

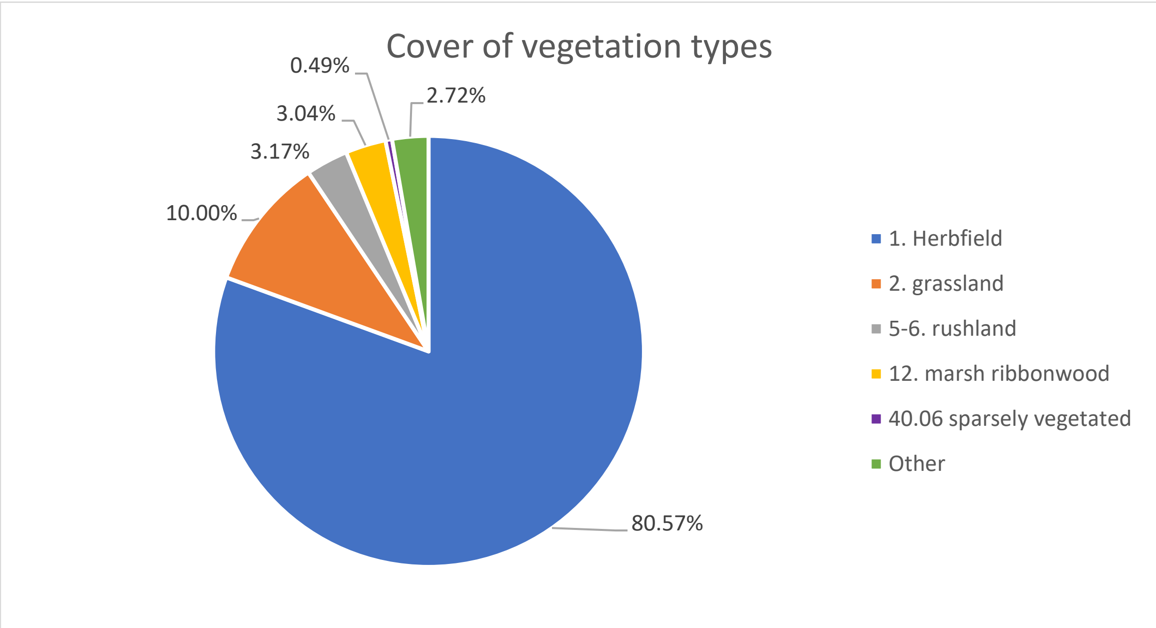


Figure 4.7 Herbfields are the largest vegetation type by area at Greenpark Sands

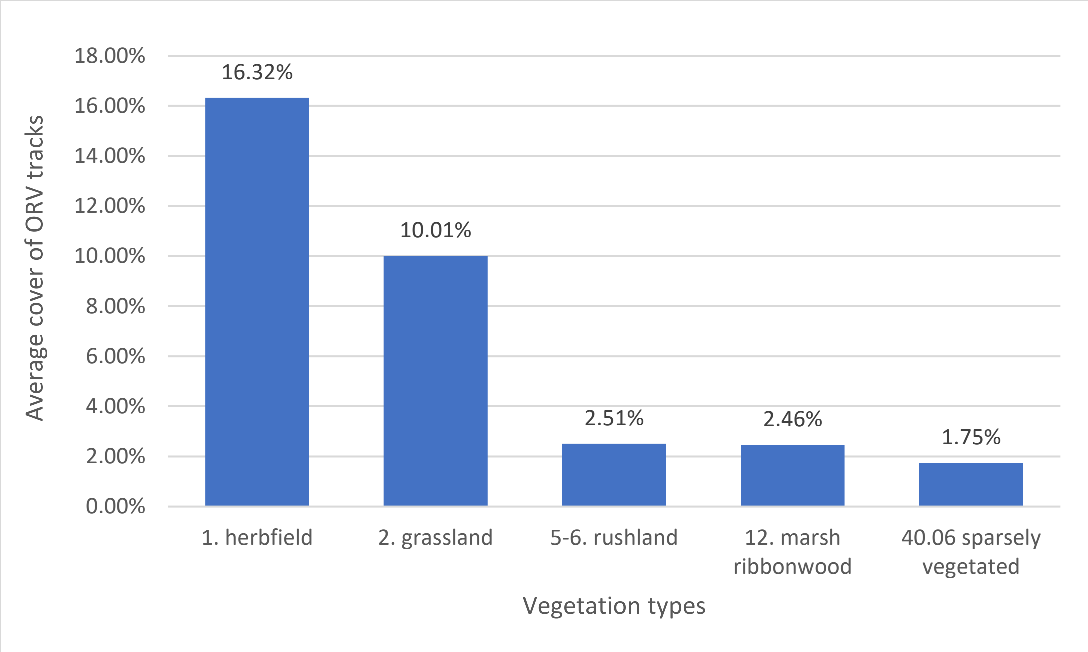


Figure 4.8 Herbfields have the highest average cover of ORV impacts

Table 4.7 Cover of ORV track damage by vegetation type

Vegetation type	Vegetation area (ha)	Percentage of total transect area (404.60ha)	Area of ORV damage (ha)	Cover of ORV tracks
1. herbfield	326	80.57387928	53.20968	**16.32%**
2. grassland	40.46782	10.00199225	4.051397	**10.01%**
5-6. rushland	12.82962	3.170958074	0.322239	**2.51%**
12. marsh ribbonwood	12.30285	3.040762427	0.302272	**2.46%**
40.06 sparsely vegetated	2.000053	0.49433133	0.035079	**1.75%**

Figure 4.9 Herbfields are the largest vegetation type by area and they also have the highest levels of ORV impact

Because bare or sparsely vegetated areas have been shown to attract initial ORV use (Kelleway, 2006; Smith, 2014), it is unsurprising that short-stature herbfields had the highest average cover of vehicle tracks. However, having the lowest ORV track cover of any vegetation type, at 1.75%, the 40.06 sparsely vegetated areas directly contradict the findings of Kelleway (2006) and Smith (2014). This anomaly may be due to inaccurate representation of the 40.06 vegetation type because of its small sample size area. Additionally, these naturally sparsely vegetated areas tended to be located along or within the lake edge, where the water's movement may have removed traces of ORV tracks.

Seven herbfield sub-types, as identified in Environment Canterbury's 2017 vegetation survey of Te Waihora, were present within the sample transects (Figure 4.10). The glasswort and grass herbfields (1.05) were the most impacted, with 28.30% of the vegetation sub-type damaged by ORV tracks. All the herbfield sub-types containing glasswort (1.01, 1.04, 1.05 and 1.08) had levels of ORV track damage exceeding 11% cover (Figure 4.11, Table 4.8).

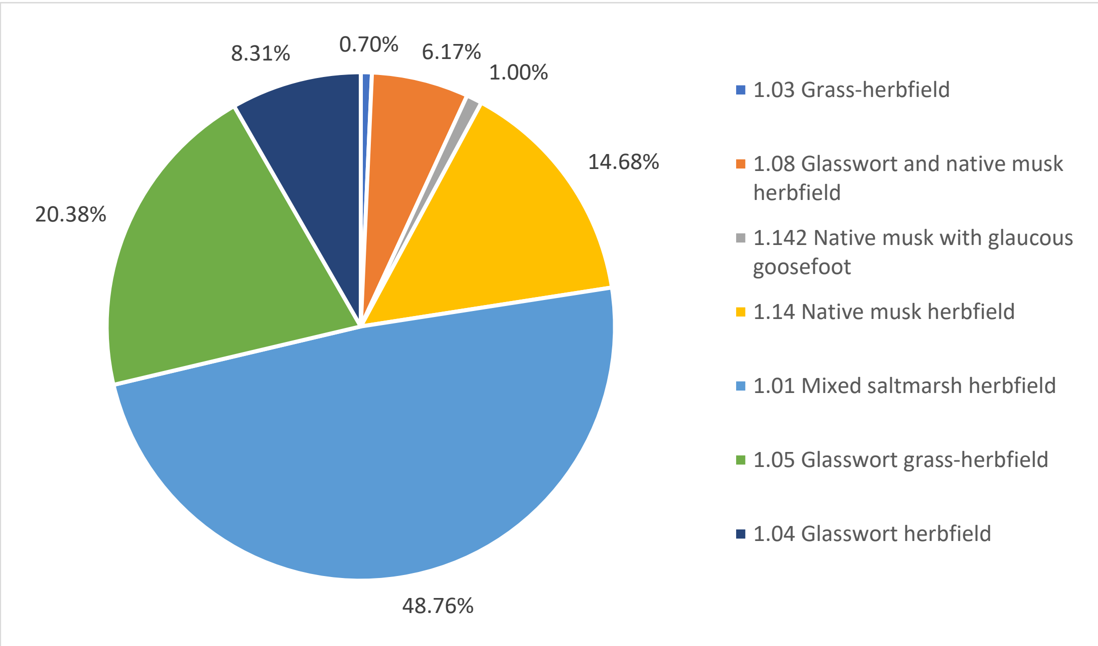


Figure 4.10 Cover of herbfield sub-types within the herbfield vegetation type

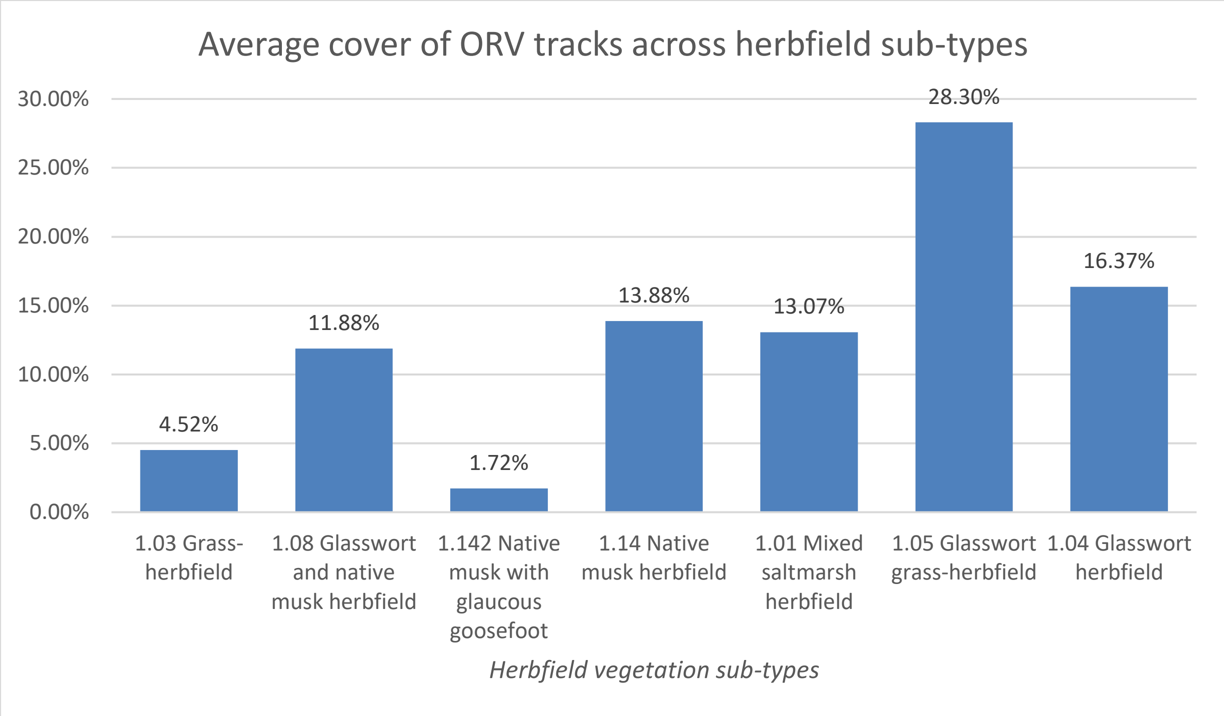


Figure 4.11 Average cover of ORV tracks across herbfield sub-types

Table 4.8 Area of herbfield sub-types and cover of ORV tracks

Herbfield sub-type	Vegetation area (ha)	Percentage of herbfield area (326.00ha)	Area of ORV damage (ha)	Cover of ORV tracks
1.03 Grass-herbfield	2.295539	0.704153	0.103667	**4.52%**
1.08 Glasswort and native musk herbfield	20.11027	6.168796	2.389181	**11.88%**
1.142 Native musk with glaucous goosefoot	3.26351	1.001077	0.056045	**1.72%**
1.14 Native musk herbfield	47.86106	14.68131	6.643129	**13.88%**
1.01 Mixed saltmarsh herbfield, glasswort present	158.9646	48.76217	20.78302	**13.07%**
1.05 Glasswort grass-herbfield	66.42933	16.41861795	18.80138	**28.30%**
1.04 Glasswort herbfield	27.07561	6.691984681	4.433251	**16.37%**

Although glasswort *(Sarcocornia quinqueflora)* is a common native coastal plant, found in both New Zealand and Australia (Taranaki Educational Resource: Research Analysis and Information Network, 2018), it is highly sensitive to vehicle impacts, with observations by Kelleway (2006) suggesting that *Sarcocornia quinqueflora* could be killed by a single pass of an ORV.

Of particular concern is the ORV damage to native musk (*Thyridia repens*), which is classified as an At Risk – Naturally Uncommon species (Grove & Pompei, 2019). The cover of ORV track damage on the 1.08, 1.14 and 1.142 herbfield sub-types that contain *Thyridia repens* may be under represented, due to the native musk being located on the lower margins of the lake edge, where vehicle tracks are more likely to have been obscured by water movements. Because Te Waihora is a key stronghold for this species (Grove & Pompei, 2019), any damage to *Thyridia repens* is of regional and national significance.

Through both image analysis and on ground observations, this study found that change in plant community composition is likely to be occurring at Greenpark Sands as a result of vehicle use. Figure 4.12 shows vehicle ruts in which only glasswort *(Sarcocornia quinqueflora)* has regrown, and supports Kelleway's suggestion that "vehicle related depressions may promote growth of lower [salt]marsh species" (Kelleway, 2006, p. 60). This observation is in agreement with other studies that have recorded change in community composition of plant species as a result of ORV impacts (Charman & Pollard, 1995; Kelleway, 2006; Stephenson, 1999).

Figure 4.12 A vehicle rut in which only glasswort *(Sarcocornia quinqueflora)* has regrown, surrounded by salt grass. (Johanna Blakely, January 2020)

Because recovery of vegetation from ORV damage is determined by an individual species' growth and reproduction habits (Stephenson, 1999), time periods for natural recovery vary greatly. However, Kelleway (2006) writes that after anthropogenic damage, natural recovery of saltmarsh vegetation may not always be possible. Further study is required at Greenpark Sands Conservation Area to determine the recovery time of native saltmarsh species.

Soil erosion and compaction

Observations from this study, shown in Figures 4.13 and 4.14, suggest that there are high levels of soil erosion and compaction occurring at Greenpark Sands as a result of vehicle use. Soil compaction and erosion are well studied impacts of ORV use (Kelleway, 2006; Nortjé et al., 2012; Trip & Wiersma, 2015) and the effects are shown to be more severe where there is high soil moisture content (Kelleway, 2006; Trip & Wiersma, 2015). In organic wetland soils Arp and Simmons (2012), observed a continued widening and braiding of vehicle track networks. More research is required to support this finding at Greenpark Sands.

Figure 4.13 Compaction and erosion at Jarvis Rd (Robin Smith, August 2018). Figure 4.14 Damage to the soil at Embankment Rd (Johanna Blakely, April 2019).

4.2.2 Frequency of ORV use

While 34.18% of the Greenpark Sands site had low cover of ORV tracks (1-10% cover), 18.09% had received moderate impact (10-25% cover), 8.36% had experienced high impact (25-50% cover), 2.89% had received very high impact (50-75% cover), and 2.40% had extreme levels of impact (75-100% cover), as shown in Figure 4.16 and Table 4.9. A map illustrating the density of ORV tracks across Greenpark Sands Conservation Area is shown in Figure 4.15.

Because there is a curvilinear relationship between frequency of use and area of impact (Schlacher & Morrison, 2008) (see Figure 2.5), it can be concluded that areas with a high cover of vehicle tracks have also experienced a high frequency of ORV use, even if that use is a single vehicle making 100 passes over the same area.

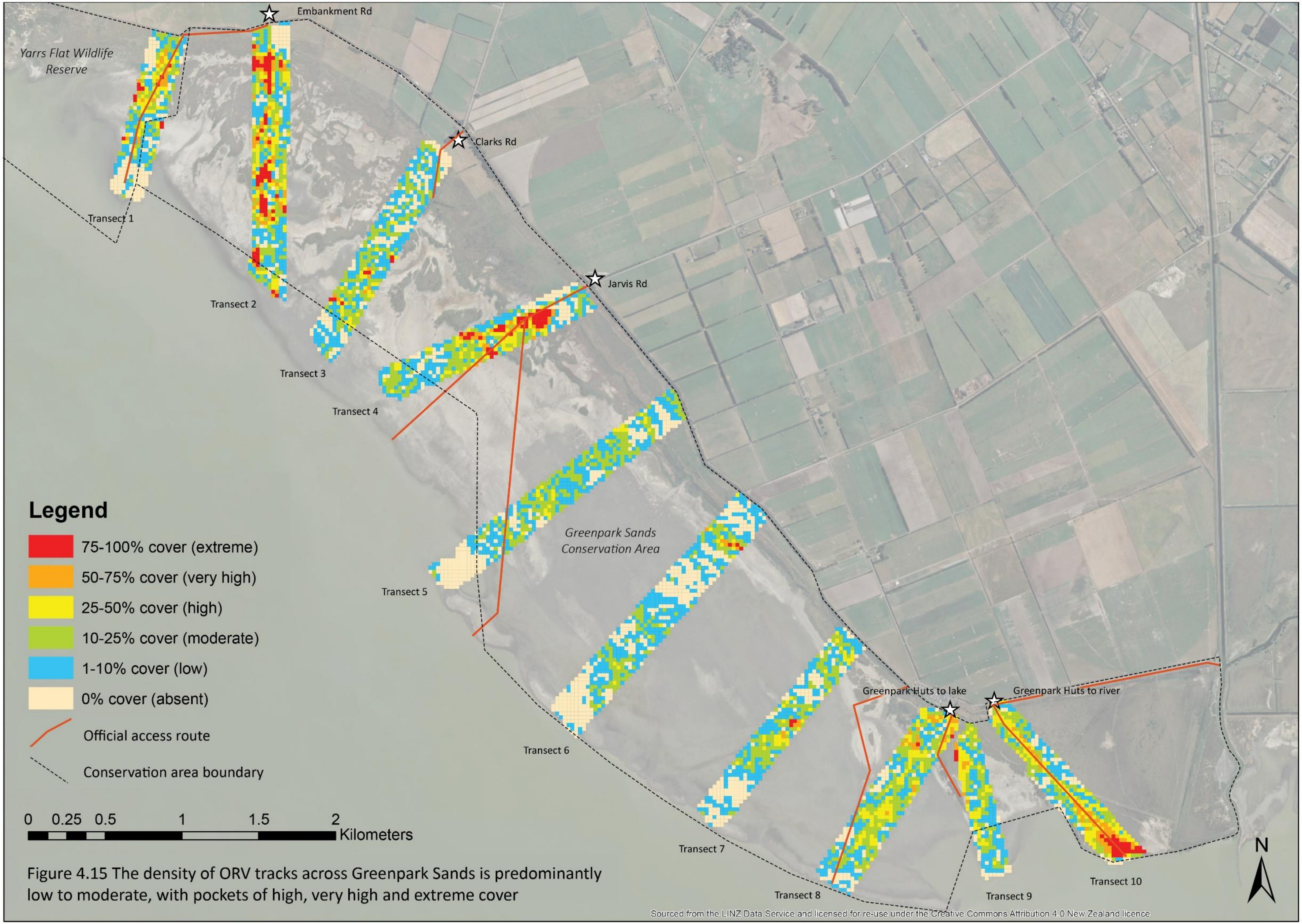


Figure 4.15 The density of ORV tracks across Greenpark Sands is predominantly low to moderate, with pockets of high, very high and extreme cover

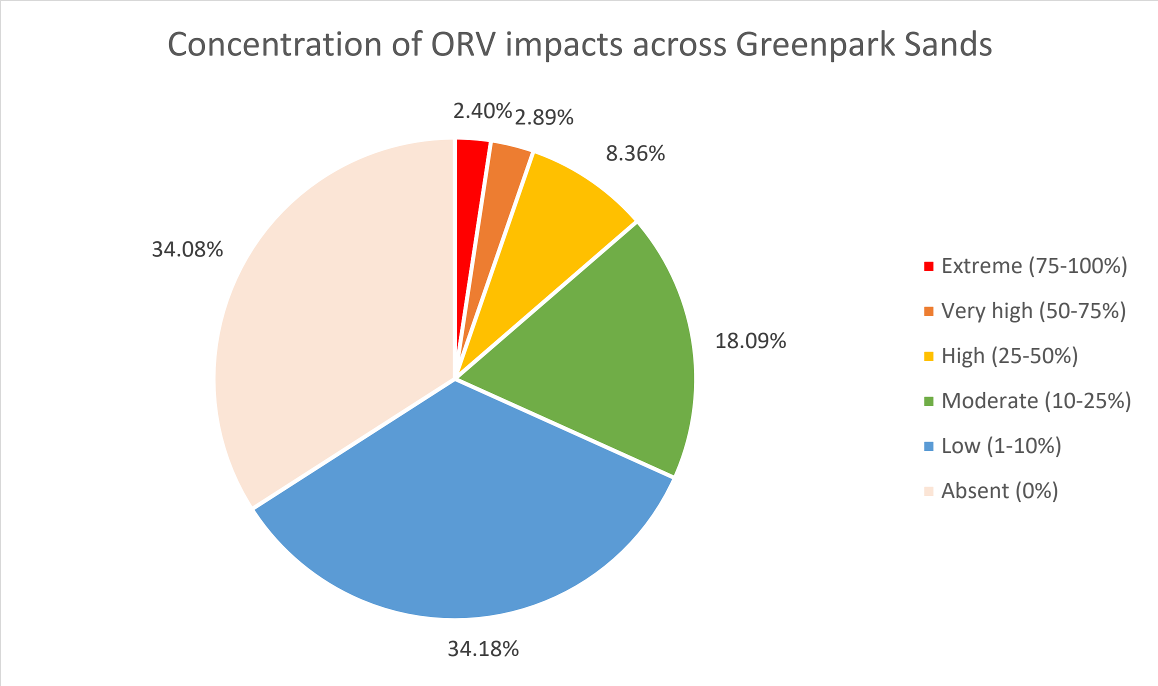


Figure 4.16 13.6% of the saltmarsh had levels of ORV impact exceeding 25% cover

Table 4.9 Number of grids affected by each impact density

Cover of ORV track impacts	Frequency of this density of impact	Total number of 25x25m grids	Percentage of site
Extreme (75-100% cover)	178	7403	**2.40%**
Very high (50-75% cover)	214	7403	**2.89%**
High (25-50% cover)	619	7403	**8.36%**
Moderate (10-25% cover)	1339	7403	**18.09%**
Low (1-10% cover)	2530	7403	**34.18%**
Absent (0% cover)	2523	7403	**34.08%**

Across three sites measured in 2002 and again in 2005, Martin et al. (2008) found a range of 27.0-67.9% of the 100x100m grid cells contained light scarring (<5% cover), while 1.1-41.2% of the grids had moderate scarring (5-20% cover). Only one site had a 1.1% presence of severe scarring (>20% cover) in 2002, which climbed to a 2.3% presence in 2005. Because Martin et al. (2008) measured only the area of tyre treads within each grid, their scale of track damage cover gives an approximate comparison, but is not directly comparable with the scale used to measure cover of ORV tracks in this study, which measured both the tyre treads and the axel width between them, thus giving a larger area of impact. Presumably wind tidal flats are inundated more frequently than the saltmarshes of Te Waihora's Waituna type lagoon, which are covered with water only seasonally. More frequent inundation is likely to lead to increased sedimentation and therefore to less visible ORV tracks.

At Greenpark Sands, the higher concentrations of ORV track damage tended to be located along or near well-defined, existing tracks, which is in agreement with Whitbeck and Fehmi (2016), who found a positive correlation between high densities of informal ORV tracks and proximity to existing vehicle tracks. This finding is illustrated in Figures 4.17 and 4.18.


Figures 4.17 and 4.18 High frequency of use along existing routes near Greenpark Huts and at Jarvis Rd

In this study there were generally low densities of ORV track cover around maimai or at the lake edge, which appears to contradict Hammitt et al. (2015), who write that recreational impacts tend to be concentrated around attractions. However, the high lake level between June and October 2019 may have shifted sediment and obscured some vehicle tracks, thus reducing observed density.

Vehicle tracks were also less frequent where grazing still occurs within fenced paddocks (at Clarks Rd and to the east of Embankment Rd) or has only recently been removed (at Jarvis Rd). All grazing leases are due to expire in June 2020, with the land retired for conservation (Robin Smith, 19th March 2019, personal communication), which may make these areas more accessible to ORVs. Areas with a low frequency of use are shown in Figures 4.19 and 4.20.

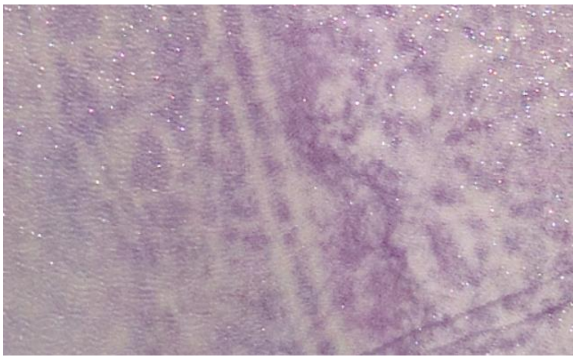



Figure 4.19 and 4.20 Low frequency of use near the park’s inland boundary and on the edge of Te Waihora

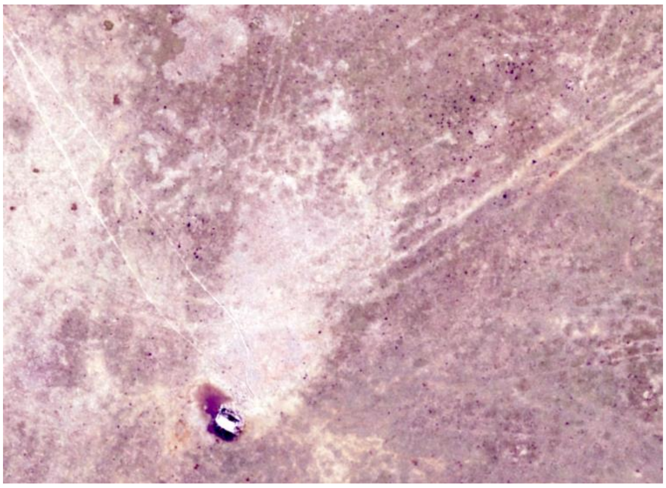
The curvilinear relationship between frequency of use and recreational impacts is well-established in recreation ecology (Cole, 1994) and has been shown to apply to ORV impacts also (Schlacher & Morrison, 2008). While damage increases with each vehicle pass (Onyeanusi, 1986), the most damage occurs from the first pass of a vehicle's tyres (Nortjé et al., 2012; Stephenson, 1999). Therefore, even where frequency of ORV use is low, impacts can be intensive (Trip & Wiersma, 2015).

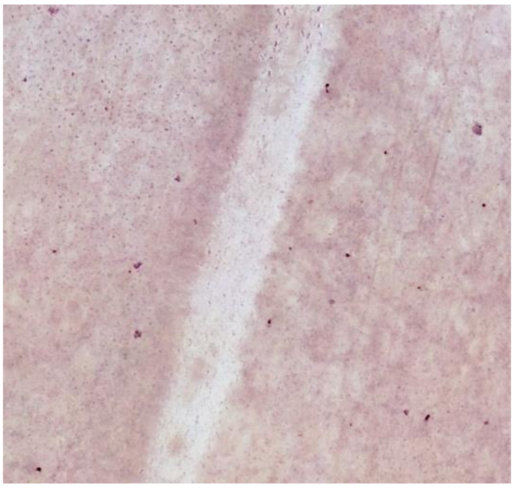
An exception to the trend of low density on the lake edge was at Transect 10, where the ground level is higher and would have avoided winter inundation. Here, the lake edge has become a destination, with high counts of extreme or very high cover of ORV track damage, as shown in Figure 4.21. This finding at transect 10 supports the observation by Trip and Wiersma (2015) that most unauthorised ORV tracks in a Canadian boreal wetland led to a specific destination, such as a lake or a campsite.

Figure 4.21 Vehicle tracks at Transect 10 leading to and concentrating around the lake edge

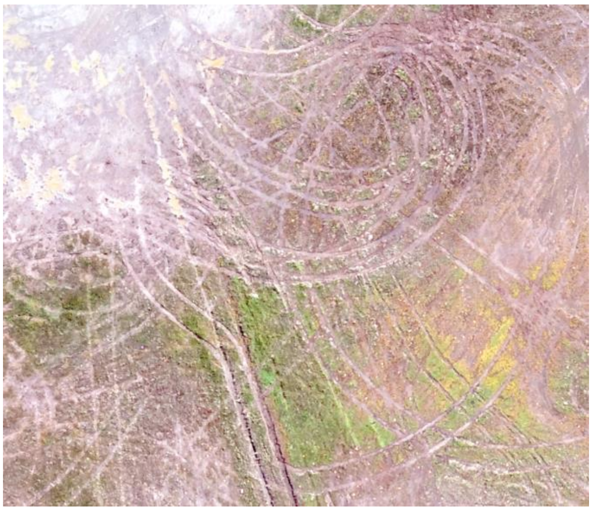
4.2.3 Type and behaviour of use

Results suggest that the behaviour of ORV users at Greenpark Sands Conservation Area varies across user groups. As shown in Figures 4.22 and 4.23, some ORV tracks have a clear destination; generally towards the lake edge or a maimai. By contrast, Figures 4.24 and 4.25 show ORV tracks that lack any destination and appear to have been created for the sake of recreational ORV use. In some areas, it appears that there is a combination of destination and recreational behaviours occurring (Figures 4.26).





Figures 4.22 and 4.23 Tracks with a destination; the maimai and lake respectively



Figures 4.24 and 4.25 Recreational ORV tracks

Figures 4.26 Combination of destination and recreational track patterns

Because vehicle tracks have been shown to be more destructive to vegetation at the curves than on straight lines (Onyeanusi, 1986), it is likely that recreational behaviour of ORV use is more damaging than that of vehicle users travelling to a specific destination. Figures 4.24-4.26 suggest that recreational ORV drivers are also more likely to repeatedly tear up the same piece of ground with criss-crossing vehicle tracks. Research is required to determine if the ORV user groups at Greenpark Sands have distinctive behaviours of use or if there is an overlap of behaviours across different user groups.

Further impacts of recreational activities at Greenpark Sands include abandoned vehicles (Figure 4.27), discarded rubbish (Figure 4.28), empty bullet shell casings (4.29) and derelict maimai (Figure 4.30).




Figures 4.27-4.30 Abandoned car (Don Royds, March 2019), discarded mattresses, bullet casings and derelict maimai (Johanna Blakely, April 2019)

In a survey by Lynn and Brown (2003) of hikers in a Canadian forest park, littering, vegetation damage and fire pits were ranked as having the most impact on hiker's wilderness experience. Therefore, the impacts shown in Figures 4.27-4.30 are likely to have a detrimental impact on other users of Greenpark Sands Conservation Area. Apart from fire pits, which were found on two occasions, littering and vegetation damage were common across Greenpark Sands. In addition to improving the aesthetic experience of a place, the removal of rubbish has been linked with reduced crime and vandalism rates and an improved sense of safety in urban USA (Nassauer & Raskin, 2014). Future studies on the behaviours, attitudes and values of recreational user groups at Greenpark Sands would be beneficial for informing management decisions and practices.

4.2.4 Season of use

In field work undertaken in March and April 2019 and in January 2020, ORVs were observed on the saltmarsh wetland, as shown in Figures 4.31 and 4.32. The vehicle sighted in April 2019 was driving directly after rain, when the lake edge was soft and muddy. Observations of ORV users in wet conditions have also been made during the game bird hunting season, as shown in Figures 4.33 and 4.34. This is despite the Te Waihora JMP's stipulation in section 6.2(i) that vehicle use is only allowed in the conservation area when ground conditions are dry and firm (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005).

Figure 4.31 ORV observed during March (Don Royds, March 2019) and Figure 4.32 ORV observed during April, directly after rain (Johanna Blakely, April 2019)

Figures 4.33 and 4.34 ORV use in wet seasons increases intensity of impact (Robin Smith, May 2014)

Because the North Canterbury game bird hunting season is from the first weekend in May to the last weekend in July (Fish and Game New Zealand, n.d), when the saltmarsh wetland is likely to be soft from autumn and winter rains, it is expected that more ORVs are present at Greenpark Sands during and in the lead up to this season. Further research is required to establish this and to determine seasonal patterns of use.

Where soil moisture is high, ORV impacts are more severe (Kelleway, 2006; Trip & Wiersma, 2015). As a recreation ecology principle, Cole (1994) writes that users should be kept off trails when soils are saturated or plants are rapidly growing.

4.3 Total impact

Based on the results of this study, it has been concluded that the total impact of ORVs on Greenpark Sands Conservation Area is significant, being both extensive and intensive.

Traces of ORV use covered a large area of the park, being found in 66% of the samples (section 4.1.1) and with an average cover of 14.3% across Greenpark Sands (section 4.1.2). Although the damage was highly dispersed, the average percentage of ORV track cover more than doubled at sites adjacent to road access points, rising from 8.3% with no road access to 19.0% with access (section 4.1.2).

The use of ORVs showed a high intensity of impact across the saltmarsh. This was demonstrated through environmental factors, with herbfield vegetation communities, particularly glasswort/grass herbfields, averaging the highest percentages of vehicle track cover (section 4.2.1.1), indicating a low resistance to ORV use. The saltmarsh soil also displayed a susceptibility to erosion and compaction (section 4.2.1.2). Across the park were pockets of very high (50-75%) and extreme (75-100%) cover of ORV tracks, indicating a high frequency of vehicle use in those locations (section 4.2.2). Even at low frequencies of use, ORV have been found to have significant impacts on saltmarsh wetlands, such as erosion, compaction and loss of vegetation (Kelleway, 2006). While ORVs in themselves are a heavy type of use (Huddart & Stott, 2019; Kobryn et al., 2017; Trip & Wiersma, 2015), the traces of vehicle tracks at Greenpark Sands also show a damaging behaviour of use, with criss-crossing vehicle routes and doughnuts etching out tracks across the saltmarsh (section 4.2.3). Off-road vehicles have been found to have more intense impacts on soil compaction and vegetation cover where they turn (Onyeanusi, 1986), such as in doughnuts and at sharp corners. At Greenpark Sands, ORV use has been observed to continue even when soils are waterlogged (section 4.2.4), which is when the soil is most susceptible to compaction and erosion (Kelleway, 2006; Trip & Wiersma, 2015).

4.4 Implications for the planning, design and management of Greenpark Sands Conservation Area

4.4.1 Implications for planning

The results of this study indicate that the objectives of Te Waihora's JMP are not being met through the current design and management of Greenpark Sands Conservation Area. Under Te Waihora's JMP, Te Rūnanga o Ngāi Tahu and the Department of Conservation, along with relevant stakeholders, seek to protect mahinga kai, conserve the lake's landscape integrity, restore and protect indigenous wetland biodiversity, improve the mauri of the lake and provide public access and recreation where there are no likely adverse effects (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005). The stipulation that there should be no likely adverse effects resulting from public access and recreation is a loose statement that is open to interpretation and needs to be further defined. However, if monitoring of the conservation area identifies that significant adverse effects are occurring as a result of vehicle use, section 6.2(f) of the Te Waihora JMP allows for the review and implementation of additional vehicle use controls (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005). This study concludes that due to the extensive and intensive impacts of ORVs on Greenpark Sands, additional vehicle use controls are necessary.

4.4.2 Implications for design

Results demonstrate that the current design of Greenpark Sands Conservation Area is not effective in restricting the area or intensity of ORV use. This is despite the objectives of the Te Waihora JMP, which aim to conserve landscape integrity through high levels of environmental design (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005). Factors that contribute to the problem of widespread ORV use include the following:

- The legal access routes are not hardened or well-defined and many of the markers are missing
- Other than entrance signage, there is no site design that signals for appropriate behaviour of use
- Gates at Embankment Rd and Jarvis Rd are always open, allowing high accessibility, as shown in Figure 4.35. Access gates at Clarks Rd and at Greenpark Huts are closed, but remain unlocked
- The openness and short stature of the saltmarsh vegetation encourages dispersion of ORVs

Figure 4.35 Open vehicle access at the end of Embankment Rd

4.4.3 Implications for management

The current management of Greenpark Sands is not adequate for restricting and preventing ORV impacts. The following factors contribute to these management issues:

- The access guidelines outlined in section 6.2(i) of the Te Waihora JMP, which stipulate that vehicles can only be used on the access routes when conditions are dry and the lakebed is firm, are not enforced at Greenpark Sands
- Greenpark Sands covers a large area and there is a lack of Department of Conservation staff capacity to monitor and enforce the behaviour of vehicle users
- Other than at than at the southeast corner of the conservation area, near Greenpark Huts, there is no passive community surveillance to observe and monitor ORV user behaviour
- A culture of hooning[9] appears to have developed around ORV driving at Greenpark Sands

[9] "A hoon, in Australia and New Zealand, is a person who deliberately drives a vehicle in a reckless or dangerous manner, generally in order to provoke a reaction from onlookers. Hoon activities (or hooning) can include speeding, burnouts, doughnuts, or screeching tyres." (*Hoon*, 2020, March 9)

Chapter 5

Recommendations for the Planning, Design and Management of Off-Road Vehicle Use in Saltmarsh Conservation Areas

This chapter reviews strategies for reducing the area and intensity of vehicle impacts on saltmarsh wetlands and discusses the need for community consultation to achieve the best outcomes.

5.1 Design and management strategies for reducing off-road vehicle impacts

The following strategies for reducing ORV impacts in saltmarsh wetlands are based on recreation management strategies outlined by Hammitt et al. (2015) and by McWilliam (2007) for mitigating human activity impacts within conservation areas, as discussed in chapter 2, section 2.3.3. They are also informed by recommendations from similar published studies about ORV impacts on vulnerable conservation areas and how to protect them. The strategies outlined in this chapter are generic, with the intention that they could be selectively applied to any saltmarsh conservation area in need of protection from damaging ORV use.

5.1.1 Area of use

The most effective way of reducing recreational impacts in conservation areas is to reduce the area in which human activities are occurring (Cole, 1994; Hammitt et al., 2015; McWilliam, 2007). Because ORV users have both the desire and the ability to go through obstacles (Huddart & Stott, 2019), mud and water are viewed as technical challenges and do not prevent vehicle use. The results of this research, in agreement with studies by Kelleway (2006) and Martin et al. (2008), show that in coastal wetlands that have both vehicle access and few natural or artificial barriers, ORVs have accessed large proportions of the site. Therefore, this section discusses strategies for reducing the area of vehicle use in saltmarshes.

Concentration

Dispersion of vehicles is often enabled across saltmarsh wetlands because of their predominantly low-stature vegetation. To reduce the area of impact, it is recommended that ORVs are concentrated into smaller areas through zoning of vehicle use (McWilliam, 2007; Taylor, 2013), as shown in Figure 5.1.

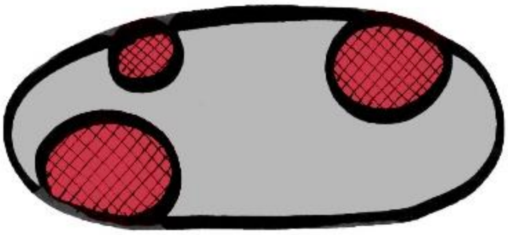


Figure 5.1 Concentration of ORV use into red hatched zones.

Surface hardening to delineate areas of use, and physical or natural barriers such as shrubs, fences or waterways can be used to define the spatial limits of this zoning (Hammitt et al., 2015; McWilliam, 2007). The provision of hardened and clearly defined routes can also be used to concentrate vehicle use and limit the spread of impacts (Hammitt et al., 2015; McWilliam, 2007; Taylor, 2013). A combination of these strategies is recommended for concentrating ORV activity into specified areas of use, as illustrated in Figure 5.2. Where vehicle access is necessary across a saltmarsh, concentration is a useful strategy because it allows access, but limits the area of use.

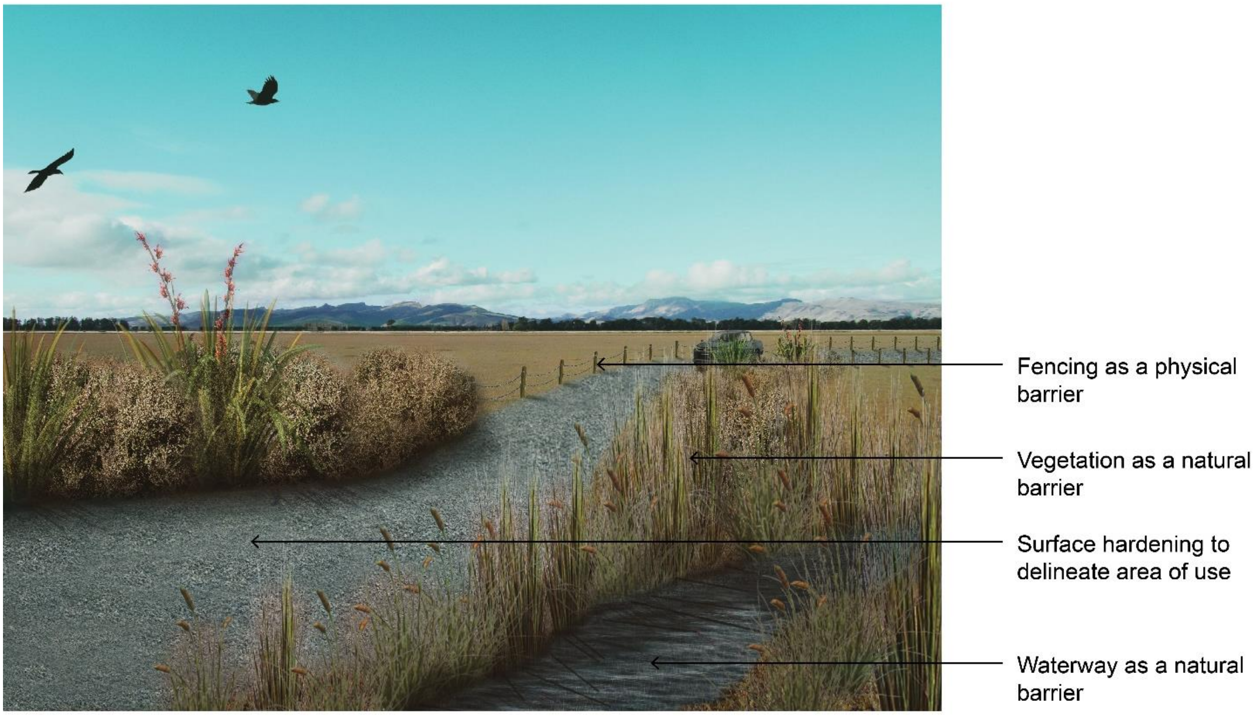


Figure 5.2 Concentration strategies, such as physical and natural barriers and hardening of access routes, can be used to restrict areas of vehicle use (Johanna Blakely, March 2020).

Segregation

Segregation strategies are used for protecting sensitive ecosystems, or areas of high ecological value (Hammitt et al., 2015; McWilliam, 2007). They work by segregating that area from particularly damaging activities.

5.1.1..1 Permanent or seasonal closure

Permanent or seasonal closure is a segregation strategy for protecting especially vulnerable ecosystems (Hammitt et al., 2015; McWilliam, 2007), as shown in Figure 5.3. Permanent closure to motorised vehicles is a commonly recommended management strategy across wetland and beach ecosystems (Charman & Pollard, 1995; Mize et al., 2005; Stephenson, 1999; Taylor et al., 2012) as it is the most effective method of halting vehicle impacts in sensitive ecosystems. However, it is a heavy-handed approach that would require stakeholder support. Loss of access to natural areas can lead to loss of cultural and indigenous identities (Dick et al., 2012). Therefore, it is necessary to assess whether vehicle access is needed for cultural activities. In some saltmarshes, seasonal closure may be more appropriate in order to maintain access for cultural hunting and fishing practices. Careful monitoring would be required during these seasonal openings to stop irresponsible vehicle use.

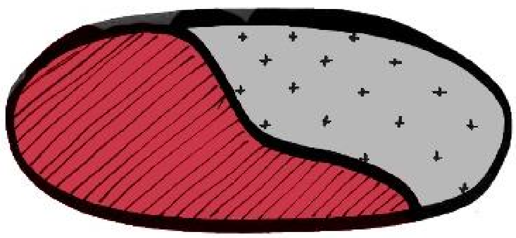


Figure 5.3 Permanent or seasonal closure of red striped area to ORVs.

For example, while the Te Waihora JMP allows for prohibition of vehicles if required (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005, section 6.2(f)), the JMP's objectives require cultural access and protection of historic values, along with public recreational access where appropriate (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005). Therefore, seasonal access at Greenpark Sands may be more appropriate than permanent closure for meeting the park's objectives. This seasonal closure could be enforced through rāhui, with the lake edge opened on specified weekends for game bird hunters to access and prepare their maimai for the hunting season. Preferably, these openings would be under the supervision of volunteers, as it has been shown that the presence of volunteers improves visitor compliance with guidelines (Megnak et al., 2019).

Kelleway (2006) notes that permanent or seasonal closure of an area will likely require heavy duty gates and fences to deter dedicated ORV users.

5.1.1..2 Buffers

The implementation of buffer distances are a widely accepted way of reducing ORV disturbance to wader birds and waterfowl (Aikins et al., 2018; Glover et al., 2011; Megnak et al., 2019) and of protecting vulnerable ecosystems (Hammitt et al., 2015; McWilliam, 2007). They work by absorbing impacts, such as noise and movement, from ORV zones in order to protect affected wildlife species, as shown in Figure 5.4. To shelter especially sensitive bird species form disturbance, buffers may need to be at least 125m wide (Glover et al., 2011).

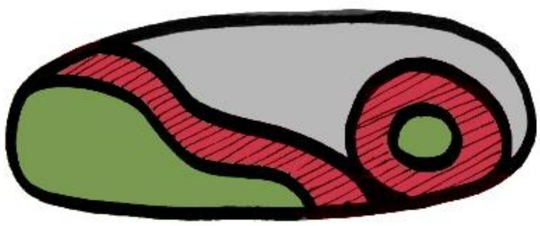


Figure 5.4 Buffer zones (red) to protect ecologically sensitive areas (green) from impacts and disturbance in ORV zones (grey).

A drawback to buffers is that they rely on high levels of public compliance to be effective (Glover et al., 2011; Megnak et al., 2019). The results of this study show that ORV impacts are dispersed across the entire width and length of the saltmarsh conservation area. The findings also demonstrate low levels of compliance from ORV users with existing access guidelines. Therefore, in themselves, buffers are unlikely to be effective. To enforce buffers, woody plantings and fences would be required.

Where possible, wide sections of saltmarshes should be set aside for wader birds and waterfowl, as it has been shown that shorebirds spend more time on wider coastal areas (Megnak et al., 2019). In some saltmarshes, buffers may not be appropriate, as the whole area may be sensitive to disturbance from ORV use and may need to be protected. According to Christchurch City Council ecologist Andrew Crossland, the entire width of the Greenpark Sands saltmarsh is well used by birds and is of very high value, because conditions change daily at the lake and the birds move across the saltmarsh in response to what areas are wet or dry (Andrew Crossland, personal communication, 2nd March 2020). Figures 5.5 and 5.6 show the dramatic contrast at Greenpark Sands between high and low water levels and thus the area of most importance to wildlife.

Figures 5.5 (July 2015) and 5.6 (September 2018) Due to fluctuating water levels, the entire saltmarsh at Greenpark Sands acts as an important feeding ground for birds (both images retrieved from Google Earth, 13th March 2020).

5.1.2 Intensity of use

Although reducing the area of use is the most effective way of reducing area of impact in sensitive ecosystems such as saltmarshes, several other strategies can be used to reduce the intensity of impact and are outlined in more detail below.

Frequency of use

Because there is a curvilinear relationship between frequency of use and intensity of impact (Cole, 1994) (see Figure 2.4), reducing the frequency of ORV use on saltmarshes is not an effective way to reduce intensity of impact. With heavy types of use, such as ORV driving, different frequencies of use may have similar impact levels (Cole, 1994). Writing from the context of Australian national parks however, Jones et al. (2016) point out that there is a demand for ORV recreational areas. The pressure of ORV use on vulnerable saltmarsh wetlands could be reduced by developing a regional 4WD park network on brownfield lands in the neighbouring vicinities; reducing the frequency of vehicle use on saltmarshes while also catering for the needs of 4WD enthusiasts (Jones et al., 2016). Figure 5.7 illustrates how alternative recreation areas could deflect ORV use from a saltmarsh. The provision of alternative recreation areas is not an effective strategy in itself and would need to be implemented alongside of other ORV controls within the conservation area.

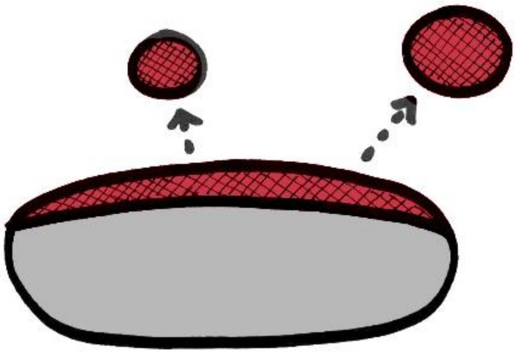


Figure 5.7 Alternative recreation areas to reduce demand and frequency of ORV use on saltmarshes.

Dispersion

Because dispersion is only effective for low impact recreation types within high resistance and high resilience environments (Hammitt et al., 2015), it is not recommended as a strategy for dealing with ORV impacts on saltmarshes. The findings of this study reveal that ORV use is already dispersed across Greenpark Sands, causing impacts that are extensive and intensive. Dispersion is illustrated in Figure 5.8.

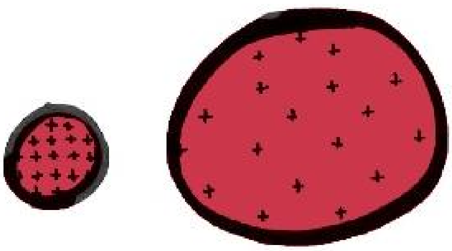


Figure 5.8 Dispersion spreads the impacts across a larger area so that the points of impact (illustrated by crosses) become less dense. It is not suitable in low resistance environments.

Type of use

Because certain types of impact are caused only by specific types of use (Cole, 1994), it is possible to restrict certain activities and therefore their impacts without blocking all recreational users. This filtering of activities could be implemented through use of bollards, footbridges over waterways or narrow paths through vegetation, as shown in Figure 5.9. Additional filters include topography, woody vegetation and impassable water bodies. These design interventions would allow pedestrians and cyclists into a saltmarsh but restrict four-wheel vehicles. Although such strategies would not be effective at stopping motorised two-wheelers, they may discourage their use. With a filtering strategy, it is necessary to be mindful of dedicated ORV users who may not be compliant and who might look for weak points. For example, while barrier plantings are establishing, they will need to be protected from vehicle damage.

Figure 5.9 Design interventions to filter type of recreational use (Johanna Blakely, March 2020).

Behaviour of use

In some situations, it is possible to reduce recreational impacts by altering the behaviour of users (McWilliam, 2007). Education interventions such as signage, social media and planting events can be used to alter the perception of an environment (Gobster et al., 2007) and to let people know how they are expected to behave there and why (Megnak et al., 2019). It is important that the cultural, environmental and historic significance of the site is highlighted to visitors. While education is important, site design can also be used to improve the perception and understanding of the area (McWilliam, 2007; Nassauer, 1995) because people value landscapes that show traces of care (Nassauer, 2011).

For example, at Greenpark Sands Conservation Area appropriate design interventions could include entrance plantings, mown borders, low fences or bollards, clear signage and removal of rubbish (Gobster et al., 2007; Nassauer, 2011; Nassauer & Raskin, 2014), which are also associated with an increased sense of safety and lower rates of crime and vandalism (Nassauer & Raskin, 2014). Because Te Waihora is under joint management with Te Rūnanga o Ngāi Tahu and is of such high cultural value (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005), it is important to bring a mana whenua narrative into the site design through use of pou or tomokanga, native plant species and interpretive signage. When people arrive at Greenpark Sands Conservation Area, the entrance design should help them to experience a unique sense of place and a respect for the lake and its wetlands. Figure 5.10 shows the entrance to Greenpark Sands at Embankment Road as it could be.

Figure 5.10 The entrance to the saltmarsh from Embankment Road as it could be, with the aim of enhancing public perception, cultural understanding and ecological valuing of the site (Johanna Blakely, March 2020).

Another way to alter behaviour of use at saltmarsh areas is through fulfilment of user needs (McWilliam, 2007). For example, if anglers are wanting to access the water’s edge with their boat, a hardened access route may need to be put in or upgraded. This would discourage those towing boats from finding their own route across the saltmarsh. Fulfilment of user needs would require a survey of local residents and recreational users.

Behaviour of use and site design strategies may alter the actions of some visitors, but not all of the site’s visitors are likely to change their habits of use. Therefore, these approaches should be used in conjunction with other strategies.

Season of use

Cole (1994) advises that recreational users should be kept off trails when soils are saturated or when plants are rapidly growing. Seasonal use strategies require an understanding of the most vulnerable plant or wildlife species, the soil typology, and the season in which these are most sensitive to impact. While seasonal use may be suitable in some saltmarshes, other tidal saltmarshes may require permanent closure, as the soils are regularly waterlogged.

At Greenpark Sands, where inundation is periodic, both the JMP and entrance signage specify that the access routes across the saltmarsh should only be used in dry conditions when the lake edge is firm (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005). However, ORV users have been ignoring this stipulation. Therefore, it is recommended that seasonal closure is enforced when the lakebed is soft (see section 5.1.1..1 Permanent and seasonal closure).

Ecosystem of use

Because environmental tolerance varies across ecosystems, it is recommended that recreational use occurs primarily in areas of high resistance and resilience where impacts can be minimised (Cole, 1994), as shown in Figure 5.11. According to the findings of this study, herbfield vegetation communities within the saltmarsh were most susceptible to ORV damage. These areas were also identified by Christchurch City Council ecologist Andrew Crossland as being of the most importance to wader birds and waterfowl (A. Crossland, personal communication, 2nd March 2020). Therefore, any ORV use zones should be located in areas of grass or shrubland communities that are most resistant to vehicle damage. Ecosystem of use strategies are only applicable in conservation areas that have areas of high resistance and resilience.

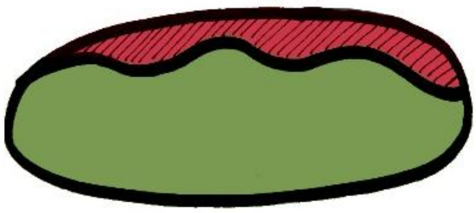


Figure 5.11 Zones of ORV use (red) located in areas of high resistance and resilience to protect areas of ecological importance (green).

5.1.3 Integrated strategies

To maximise the reduction of recreational impacts in large conservation areas, Hammitt et al. (2015) and McWilliam (2007) recommend using an integration of strategies that occur at different spatial scales and across varying time frames. Each of the above strategies have their pros and cons, and some are not effective if implemented in isolation. However, an integration of strategies for reducing ORV impacts can be used to support and strengthen each of the other approaches.

Integrated strategies at Greenpark Sands Conservation Area

As an example of this method, Figure 5.12 demonstrates how an integration of strategies could work at Greenpark Sands Conservation Area. The plan is hypothetical and shows how some, but not all, of the above strategies could be applied at Greenpark Sands, based on what is appropriate at this site. In the conceptual plan, four strategies are used, including:

- Concentration of ORV use into a small area of high resistance and high resilience, with a reduced number of hardened access routes that are contained by barriers. In appropriate locations, these routes would still allow access to the lake edge
- Segregation of the vulnerable herbfield ecosystems through permanent or seasonal closure
- Filtering of the type of use at the ends of vehicle access routes, to allow pedestrian and cycle access, but block ORV entry
- Site design, particularly at entrances, to enhance visitor perception of the conservation area and to alter the behaviour of use

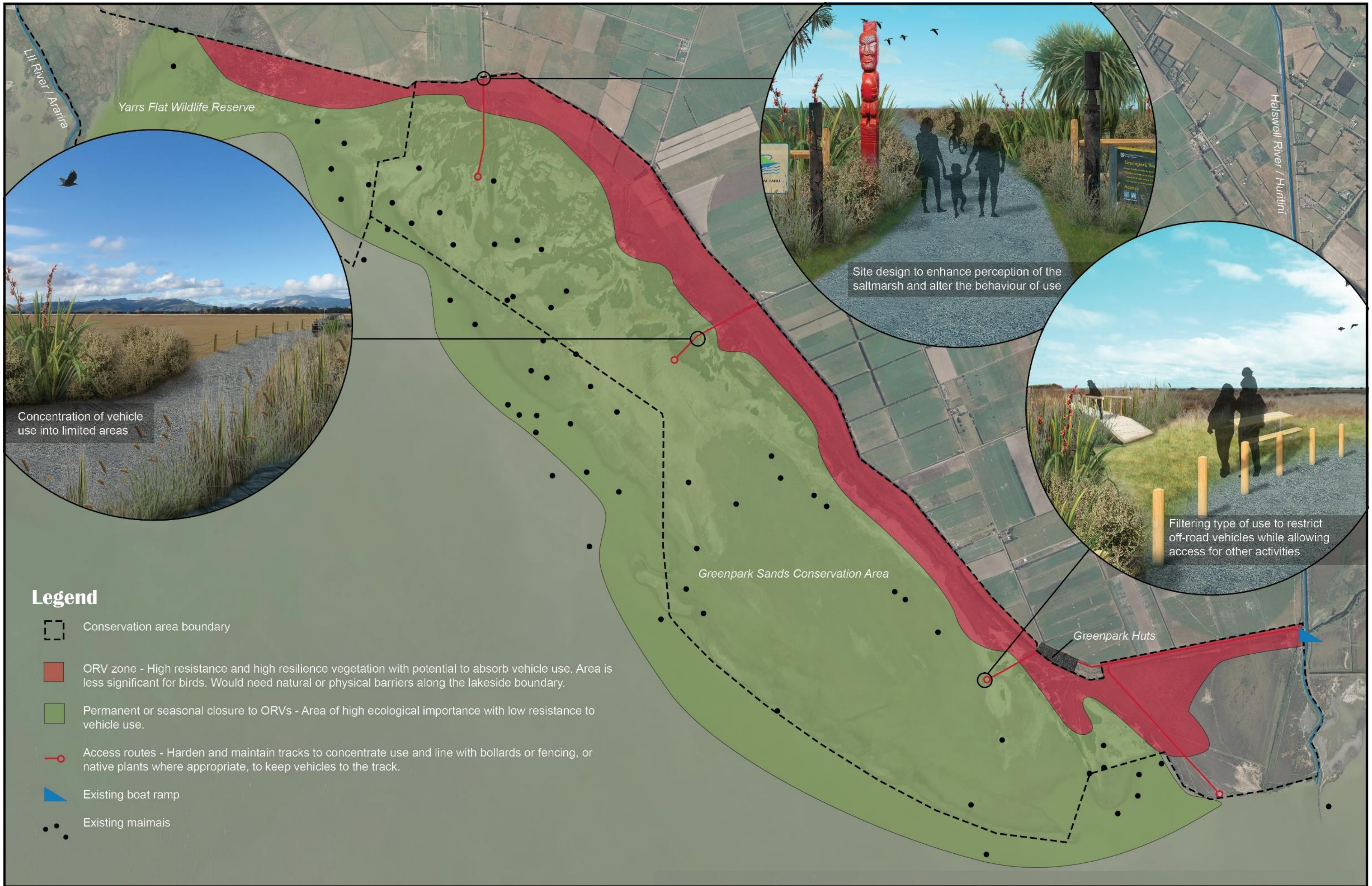


Figure 5.12 Greenpark Sands Conservation Area
Conceptual plan of integrated design and management strategies

Johanna Blakely
13th March 2020

0 0.35 0.7 1.05 1.4 Kilometres
Scale: 1:25,000 @A3
N

5.2 Community consultation for best outcomes

Before making any decisions on the design and management of a saltmarsh conservation area for protection from ORV use, it is necessary to consult with relevant stakeholders, including mana whenua or indigenous communities, local residents, community groups, recreational users and governing bodies (Megnak et al., 2019). Based on the characteristics of the individual saltmarsh and the priorities of its stakeholders, each saltmarsh wetland's design and management plan will aim to protect different biophysical and cultural values. Therefore, different strategies are likely to be chosen situationally. Because compromise is always required, it will be necessary to weigh up factors such as the cost to visitors, effectiveness, likely side effects and the cost of implementation and maintenance (Hammitt et al., 2015). However, it is important to remember that the cost of inaction is that of a scarred and fragmented saltmarsh wetland, as shown in Figure 5.13. Coastal wetlands have been observed to show no sign of recovery from ORV impacts after 38 years (Martin et al., 2008) and may never fully recover after anthropogenic damage (Kelleway, 2006). Although it is challenging to make decisions for both conservation of ecological integrity and for quality of recreational experience (Lynn & Brown, 2003), the implementation of strategies to restrict ORV impacts on a saltmarsh will help to improve biodiversity, protect the area for future generations and restore the regulatory functions of the ecosystem.

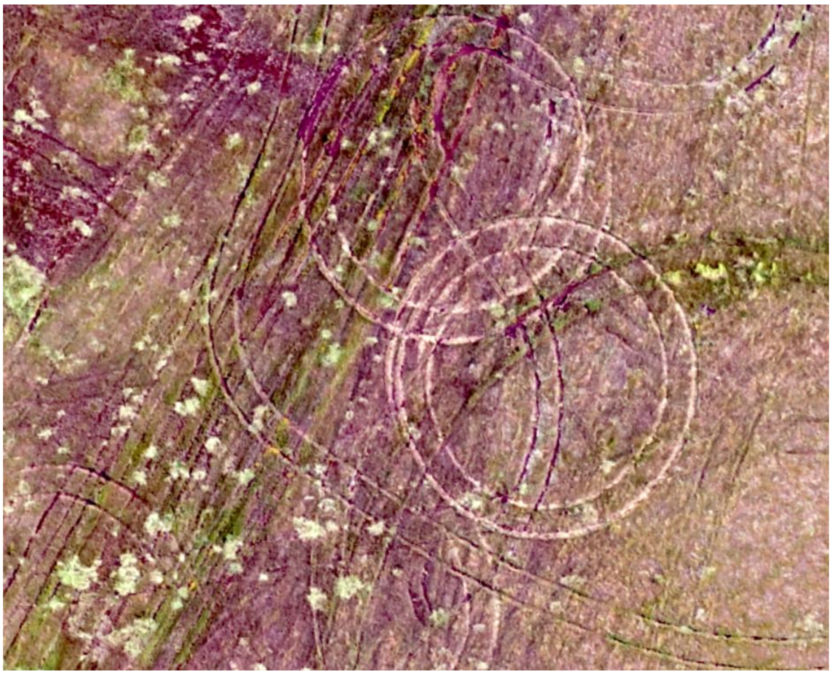


Figure 5.13 The cost of inaction is a scarred and fragmented saltmarsh that may never fully recover from ORV impacts.

Chapter 6

Conclusion

Through GIS image analysis, this research has highlighted the impact of vehicles on saltmarsh ecosystems by calculating the areal extent of ORV track impacts. The results demonstrate that where there are limited design and management interventions, like at Greenpark Sands Conservation Area, the impact of ORVs will be both extensive and intensive. Although wetland conservation areas have been set aside for their especially valuable ecosystem services, ORV access to these areas undermines the very values for which they have been protected.

Greenpark Sands Conservation Area is a vital part of Te Waihora/Lake Ellesmere's nationally significant wetland habitats. Despite this, results demonstrate that ORV tracks were present in 65.9% of the conservation area. At the time of the study, when the water level was at 0.78masl, the tracks were present from the park's inland edge right to the lake's edge. Proximity to access points was a strong indicator of vehicle track cover, with transects adjacent to access gates having an average ORV track cover of 19.03%, while transects not adjacent to access gates had an average ORV track cover of 8.34%. By overlaying maps of ORV track impacts and of vegetation communities, the research calculated the cover of ORV track damage across different vegetation types. Where the vegetation communities were composed of low stature herbfields, the average cover of ORV track impacts was considerably higher than in plant communities with taller stature and/or woody vegetation. At 28.3%, the cover of damage was especially high where glasswort (*Sarcocornia quinqueflora*)/grass herbfields were present. This suggests that ORV accessibility, and therefore impacts, increase with decreasing plant stature and woodiness. These areas within saltmarshes need increased protective measures. However, further research is needed to confirm this relationship.

Under Te Waihora's Joint Management Plan (JMP), Te Rūnanga o Ngāi Tahu and the Department of Conservation, along with relevant stakeholders, seek to protect mahinga kai, conserve the lake's landscape integrity, restore and protect indigenous wetland biodiversity, improve the mauri of the lake and provide public access and recreation where there are no likely adverse effects (Te Rūnanga o Ngāi Tahu & Department of Conservation, 2005). The results of this study indicate that the objectives of Te Waihora's JMP are not being met under the current design and management of Greenpark Sands Conservation Area. However, damage to saltmarshes from ORV use can be minimised through implementation of appropriate design and management strategies. A literature review demonstrated that ecosystems characterised by high vulnerability and low resilience, such as saltmarshes, are best protected through integrated strategies. These strategies include:

- Limiting the area of ORV use to specified zones with well-defined and constructed routes
- Protecting areas of ecological importance through permanent or seasonal closure, or through use of buffers
- Altering behaviour of use through site design that both filters the type of use and enhances visitor's perceptions of the site

A limitation of this research is that the results only reflect the impacts that were present in November 2019, when the winter's high water level had recently receded and when vigorous spring growth may have obscured vehicle tracks in more resilient vegetation communities. Because of these factors, it is likely that the findings underestimate the areal extent of tracks, which are expected to change through time. Therefore, further research at other times of the year may lead to a different result than what was found in this study, due to factors such as water level, plant growth and frequency of ORV use.

Although this research provides a quantification of spatial impacts, it does not measure the effects of ORV impacts on specific ecosystem services, such as wildlife habitat, provisioning of resources, cultural services, water filtration and storm buffering.

Further research is required to study specific ecological impacts of ORVs on the saltmarsh ecosystem, such as:

- Disturbance of birds
- Soil compaction
- Change in plant community composition
- Recovery times for vegetation following vehicle impacts

To determine the most effective design and management strategies for protecting the saltmarsh from ORV impacts and to gain community support, research is also required to survey stakeholders and recreational users of the saltmarsh wetland, to better understand their values, attitudes and needs.

This research has demonstrated that saltmarshes are vulnerable ecosystems, being impacted both extensively and intensively by ORV use. It is now necessary to prevent further ORV damage and to allow the recovery of saltmarshes by implementing targeted design and management strategies, with the aim of restoring the regulatory functions and biodiversity values of saltmarsh wetlands for the benefit of future generations.

Appendix A

Composition of Vegetation Groups Present Within the Study Transects[10]

Exotic plant species denoted by *

Herbfield (including turf)
1.01 Mixed saltmarsh herbfield, glasswort present
Glasswort (*Sarcocornia quinqueflora*) is present, and usually the most abundant species, along with a diversity of saltmarsh herbs and some larger plants. Sea blight (*Suaeda novae-zelandiae*) is sometimes co-dominant. Other species present may include buck's horn plantain (*Plantago coronopus**), orache (*Atriplex prostrata**), salt grass (*Puccinellia stricta*), native musk (*Mimulus repens*), sea primrose (*Samolus repens*), selliera (*Selliera radicans*) and *Leptinella dioica*. Dwarf sedges such as *Isolepis cernua* and *Schoenus concinnus* are also common at some sites. Scattered taller plants of oioi (*Apodasmia similis*), marsh ribbonwood (*Plagianthus divaricatus*), sea rush (*Juncus krausii* subsp. *australiensis*), knobby club rush (*Ficinia nodosa*) and three square (*Schoenoplectus pungens*) may also be present at some sites.

1.03 Grass-herbfield
Mixed herbfield vegetation type 1.01 described above forms a mosaic with patches of grassland. Grass species may include exotic creeping bent (*Agrostis stolonifera**), tall fescue (*Schedonurus arundinaceus**), couch (*Elytrigia repens**) and salt barley grass (*Critesion marinum**), as well as native salt grass and adventive salt grasses (*Puccinellia. distans*, P. fasciculata**).

1.04 Glasswort herbfield
Glasswort is the main cover. Low numbers of other saltmarsh herbfield species such as sea primrose, bachelor's button (*Cotula coronopifolia*), orache, sea blight and salt grass species may be present.

1.05 Glasswort grass-herbfield
Glasswort and one or more high salinity-tolerant grass species are co-dominant. Grasses may be adventive salt barley grass, native salt grass or adventive salt grass. Sea primrose, native musk, buck's horn plantain and orache may also be present.

1.08 Glasswort and native musk herbfield
A gradation from herbfield dominated by glasswort into one dominated by native musk at lower elevations. Common associated species are native or adventive salt grass at higher elevations, with marsh arrow grass (*Triglochin striata*) and sea primrose lower down.

1.14 Native musk herbfield
Native musk is the dominant cover. Associated species may include bachelor's button (*Cotula coronopifolia*), *Lilaeopsis novae-zelandiae* and marsh arrow grass at low-elevation brackish sites; creeping bent, salt barley grass, selliera and *Leptinella dioica* at higher-elevation brackish sites; and with *Lilaeopsis* and *Crassula sinclairii* at some freshwater habitats.

Grassland
2.04 Exotic saline grassland with native herbs

[10] Descriptions taken from notes accompanying Environment Canterbury's 2017 Te Waihora vegetation survey. Provided by Environment Canterbury ecologist Philip Grove.

Exotic salt-tolerant grasses (*Puccinellia distans*, Elytrigia repens*, Critesion marinum*, Agrostis stolonifera**) are the main cover but native saltmarsh herbs such as glasswort, bachelor's button, selliera and sea primrose are common in the groundcover.

2.05 Creeping bent grassland
Creeping bent forms a dense sward, growing alone or in association with other salt-tolerant exotic grasses such as tall fescue, couch and salt barley grass. Native shrubs, flax (*Phormium tenax*), sea rush and three square, and herbs such as buck's horn plantain, bachelor's button, glasswort and *Leptinella dioica* are present at some sites.

2.06 Tall fescue dominant grassland with native associates
Tall fescue is the dominant cover, with a range of natives such as marsh ribbonwood, sea rush, oioi, flax (*Phormium tenax*), toetoe (*Cortaderia richardii*), raupō (*Typha orientalis*), *Bolboschoenus caldwellii*, sedges, rushes. and herbfield species present at varying levels of abundance.

2.07 Tall fescue dominant grassland with exotic associates
Tall fescue is the dominant cover with other exotic grasses such as creeping bent, couch, cocksfoot (*Dactylis glomerata**) and marram the main associates. Shrubs of gorse, broom (*Cytisus scoparius**), lupin, elder (*Sambucus nigra**) and blackberry (*Rubus fruticosus* agg.*) may be present in grassland on disturbed upper margins of the estuary.

2.10 Wet pasture
Pastureland subject to periodic freshwater inundation or ponding. Common species include perennial ryegrass (*Lolium perenne**), Yorkshire fog (*Holcus lanatus**), crested dogstail (*Cynosurus cristatus**), creeping bent, tall fescue, couch, cocksfoot and kneed foxtail. Introduced jointed rush (*Juncus articulatus**) and clovers (*Trifolium* spp.*) may also be common.

2.11 Wet pasture with native rushes and sedges
Native rush and sedge species such as *Carex sinclairii, C. coriacea,* spike sedge, raupō, *Juncus pallidus* and *Juncus edgariae* are moderately abundant amongst exotic pasture species. Native groundcovers such as silverweed may also be present.

2.30 Couch grassland
Dense sward of couch grass; other exotic grasses may also be present. Scattered emergent flax and pampas (*Cortaderia selloana*, C. jubata**) occur at some sites.

2.50 Terrestrial exotic grassland
Exotic grasses and herbs such as cocksfoot, tall fescue, browntop (*Agrostis capillaris**), lotus and yarrow dominate the vegetation cover. On drier sites, common grass species include *Bromus hordeaceus**, silvery hair grass (*Aira caryophyllea**) and danthonia (*Rytidosperma* sp.*). Common herbs are sheep's sorrel, plantain (*Plantago lanceolata*, P. major**) and horehound (*Marrubium vulgare**). Scattered trees and shrubs such as gorse, willow, lupin and marsh ribbonwood are present at some sites.

Rushland
5.02 Sea rush with saltmarsh herbfield, glasswort present
Saltmarsh herbfield species such as glasswort, sea primrose, selliera, buck's horn plantain, native musk, and marsh arrow grass occur in the rushland groundcover. Three square, marsh ribbonwood, tall fescue and creeping bent may also be present.

5.05 Sea rush with knobby club rush
Associated ground cover species may include exotic grasses such as creeping bent, native salt grass and saltmarsh herbs.

5.07 Sea rush with exotic grasses
Exotic grasses, especially creeping bent and tall fescue, are the main associate species. Marram, couch, salt barley grass and sweet vernal (*Anthoxanthum odoratum**) are present at some sites. Native saltmarsh herbs may also be present. In addition there may be occasional plants of marsh ribbonwood, oioi, three square and knobby club rush.

6.10 Knobby club rush rushland
May also include sea rush, marram, *Carex pumila* as canopy associates, and saltmarsh herbs in the groundcover.

Shrubland and scrub
12.03 Marsh ribbonwood with sea rush
Here sea rush is the predominant inter-shrub cover. Knobby club rush and tall fescue are generally common while flax or three square may also be present. Groundcover may include glasswort and other saltmarsh herbs, as well as creeping bent.

12.06 Marsh ribbonwood with exotic grass
Exotic grasses, principally tall fescue and creeping bent are the most abundant associates, although sea rush, knobby club rush and oioi can also be common. Scattered flax, native and exotic shrubs and trees such as tamarisk (*Tamarisk chinensis**) are often present in or emergent above the shrub canopy. *Leptinella dioica* is common in the groundcover at some sites. Reed canary grass is common at Wainono.

19.02 Gorse shrubland
Gorse shrub canopy with exotic grass-dominant ground cover. Associated species may include occasional flax, toetoe, pōhuehue, oioi and marsh ribbonwood in the canopy.

Treeland and Forest
24.01 Exotic conifer forest and treeland
Radiata pine and/or macrocarpa are the canopy species. Blackberry, tall fescue and cocksfoot occur in the groundcover with iceplant at some sites.

Sparsely Vegetated
40.02 Sparsely vegetated with exotic grass, herb, shrub species

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