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RESEARCH

Loss of wetlands since 1990 in Southland, New Zealand

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Abstract: Reports of wetland loss in New Zealand are typically related to the historical, pre-European coverage of wetland ecosystems. It is widely accepted that large areas of wetlands were converted to other land uses prior to the 1990s before comprehensive national and regional environmental legislation was established. We sought to investigate recent (post 1990) changes in wetland extent to determine if current rates of wetland loss remain a concern for natural resources management. Remote sensing images from 1990–2012 for three regions of Southland, New Zealand, were analysed to determine whether wetlands present at 1990 exhibited 'little or no change', were 'at risk' due to recent drainage, were 'restored' due to revegetation, or had been 'lost'. Of the 32 814 ha of wetlands assessed across Southland 3452 ha were no longer present in the landscape and a further 3943 ha were at risk. Most of the change in wetland extent occurred on the Southland Plains. A large proportion of the wetlands mapped as being lost or at risk were within the catchment of the Awarua Wetland, a large coastal Ramsar site. The rate of wetland loss in Southland since 1990 (0.5% of wetland area yr^{-1}) is equivalent to the global average (0.5% yr^{-1}). Taking into account wetlands that have been partially drained, the rate of decline increases to 1.0% yr^{-1}. The predominant cause of the loss of wetlands is conversion to other land use, typically to pasture used for agriculture. A review of policy mechanisms and enforcement efforts intended to protect wetlands at regional and national levels is urgently called for, as well as increased effort to promote sustainable wetland management in agricultural environments.

Keywords: conservation, drainage, remote sensing, wetland area

Introduction

Most wetlands in New Zealand formed following the last glacial period, c. 18 000 years ago (McGlone 2009). Inland palustrine wetlands, comprising of freshwater swamps, bogs, gumlands, pākihi, fens, marshes and seepages (Johnson & Gerbeaux 2004), are estimated to have occupied 9% of the New Zealand land mass or 2 500 000 ha prior to European settlement (Ausseil et al. 2011). It is estimated that 250 000 ha of wetlands now remain, or 10% of the original extent, with much of the decline in extent due to drainage and clearing of wetlands for other land uses (Myers et al. 2013). Wetland conversion was particularly prevalent in lowland environments (Ausseil et al. 2011).

Conservation effort is now focused on protecting remaining wetlands. The advent of the Resource Management Act 1991 (RMA) provided measures to preserve the natural character of wetlands across New Zealand, including protection of them from inappropriate subdivision, use, and development (section 6(a)). The RMA enabled regional authorities to be formed with a focus on environmentally sustainable land and water management. The Department of Conservation (DOC), formed under the Conservation Act 1987, has statutory responsibility to advocate for the conservation of natural resources under section 6(b) of the RMA. In support of these advances, the New Zealand Biodiversity Strategy (DOC & MfE 2000) established a 2020 goal to maintain the extent and condition of remaining natural freshwater ecosystems and habitat, including wetlands. Further priority was given to protecting indigenous wetlands on private land by government in 2007, recognising wetlands as an ecosystem type that had become depleted due to human activity (MfE & DOC 2007). Recently, the National Policy Statement for Freshwater Management (MfE 2014) outlined policy that requires all regional councils to protect the significant values of wetlands. If these acts and policies have been implemented effectively, this should be reflected in a decline in the area of wetlands lost (ha yr^{-1}) from 1990 to now, compared to 1850–1990.

Ongoing wetland loss due to drainage and vegetation clearance is observed in some regions of New Zealand. For example, Pompei and Grove (2010) completed a study of 2004 wetlands in the Canterbury region. They identified 102 wetland sites as having a substantial (>25%) reduction in extent since 1990, with a further 42 sites exhibiting some (<25%) reduction in extent. Myers et al. (2013) also referred to wetland loss in Taranaki, Waikato and the Tasman District.

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While some regional council plans seek to enhance wetland extent (e.g. Waikato Regional Plan; WRC 2007), it is often not known, or reported, whether this goal is being achieved.

Degradation of wetlands is not unique to New Zealand. While there are calls for improved wetland protection under multilateral international treaties such as the Ramsar Convention (e.g. Convention Text, 1987 revision), wetland degradation continues on a global scale. Davidson (2014) reported that loss of the area of natural wetlands across the world is likely to be >50% since 1900, and although the rate of loss has slowed since the 1980s in some countries, large-scale and rapid conversion of wetlands to other land uses is continuing. Davidson (2014) observed that since 1980, the Asia region had higher rates of wetland loss than Europe and North America. However, even in developed countries such as the United States wetland loss continues to be greater than wetland reestablishment (Dahl 2011). Further, where re-establishment does occur, the wetlands created often do not represent the ecological function or species composition of the natural systems that have been lost (e.g. Zedler & Callaway 2002).

Given the competing demands for natural resources and continued expansion of agriculture, horticulture and urban centres to meet human demands, both in New Zealand (MfE and Stats NZ 2018) and globally (Gardner et al. 2015), wetlands will remain vulnerable to exploitation or disturbance. Wetlands on private land that are not legally protected within reserves, conservation covenants (Robertson 2016) or protected by specific statutory regulations (Myers et al. 2013) are particularly at risk.

Underlying the risk to wetlands in New Zealand is an absence of evidence on the ongoing rate of habitat loss, the causes of wetland decline, and the ecological, social and economic consequences. Wetland loss has been typically reported relative to pre-European extent (e.g. Ausseil et al. 2011; Robertson 2016), yet it is widely accepted that large areas of wetlands were converted to other land uses prior to the 1990s before comprehensive national and regional legislation for natural resource management was in place. Consequently, it may be assumed no further decline of wetland habitat is occurring and there is no need to update regional and national policy or to improve enforcement efforts.

Our paper will quantify the recent (since 1990) changes in the extent of inland palustrine wetland ecosystems. We also evaluate the change in wetland extent on private and conservation land, to test our assumption that wetland loss would predominantly occur outside of conservation areas, given regulations to restrict the development of protected areas. The analysis is centred on a region of New Zealand (Southland) subject to land use development and where remote sensing imagery was available for the study period (1990–2012). Our study aims to contribute to global knowledge on the status and trend of wetland extent and condition, and inform policy development and implementation for protecting the significant values of all wetlands.

Methods

Study area

Southland, New Zealand (Fig. 1), was selected as the study region due to the varied landforms present including montane basins, coastal lowlands and hill country. Southland is of national importance for wetland conservation as it contains 47 200 ha (~18%) of remaining inland palustrine wetlands in New Zealand (Ausseil et al. 2008). Prior to European settlement (c. 1850), the region is estimated to have supported over 450 000 ha of wetlands (Ausseil et al. 2008). The remaining wetlands in Southland are dominated by bog, fen, marsh and swamp wetland types. According to the study by Clarkson et al. (2011), which included Fiordland and Stewart Island, bogs have been depleted the least (64% of pre-European extent remaining) while fens (13%), marshes (4%) and swamps (1%) have been substantially lost from the landscape. Despite this decline, Southland contains various wetlands of regional, national (Campbell et al. 2003; Clarkson et al. 2011) and international importance, both within protected areas and on private land. The largest wetland complex that remains is the Awarua Wetland (c. 19 500 ha, including estuarine habitat), an internationally recognised Ramsar site situated on the southern coastline.

Since 1990, many wetlands in Southland have been protected within conservation areas (Robertson 2016). The major reorganisation of government conservation agencies in 1987 resulted in the reallocation of public conservation land (PCL), including wetlands, for conservation purposes. Large wetland areas held by development agencies (including Lands and Survey, and the New Zealand Forest Service) were allocated to DOC. Increased legal protection also occurred because of land purchase (e.g. Nature Heritage Fund) and through private conservation mechanisms. This period coincided with the formation of the Southland Regional Council, an agency with increased focus on protecting the environment in Southland, following the enactment of the RMA 1991.

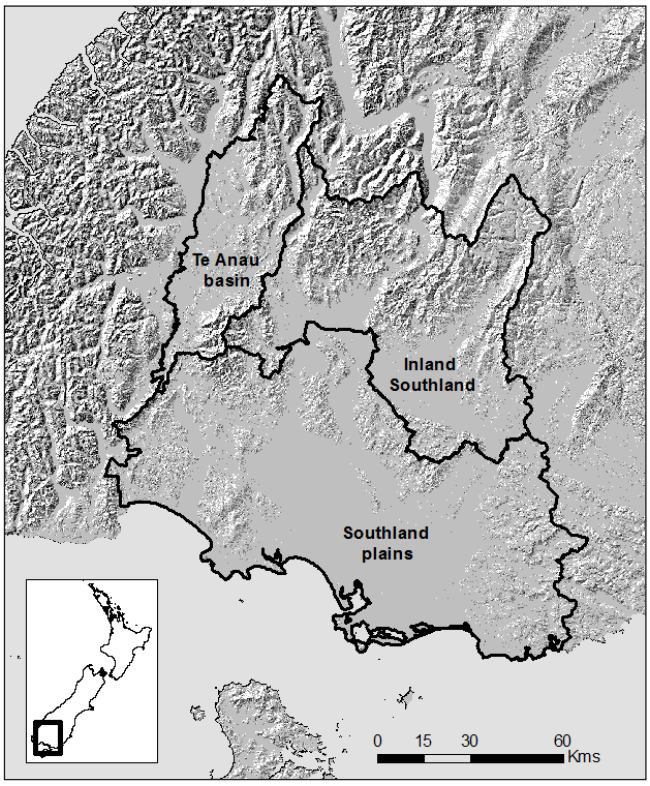

Figure 1. Study area in Southland, New Zealand, encapsulating the Southland Plains, Inland Southland and Te Anau Basin sub-regions. Fiordland National Park and Stewart Island/Rakiura were excluded from the analysis.

Substantial land development has also occurred in the region over the past two decades that is likely to have impacted wetlands. The Land Cover Database (LCDB), which maps land use across New Zealand, shows an increase in land under intensive agriculture (high producing grassland) in Southland by 8600 ha between 2001 and 2012 (Landcare Research 2014). An increase in land used for dairy production was a key driver of this land conversion. Ledgard (2013) reported that the number of dairy cows in Southland increased four-fold between 1995 and 2011, with 614 648 cows in 2011. Dairy farms have subsequently expanded from 87 109 ha in 2000 to 195 500 ha in 2011. A study by Ewans (2016) examined changes in wetlands situated on private land over half of the Southland Region. They estimated that of the 13 120 ha of wetlands present in 2007, 1235 ha (~10%) had been lost, or 1.3% per year. The Ewans study covered a relatively short period (7 years) and does not consider the broader changes in wetland extent that may have occurred since the enactment of environmental legislation in New Zealand since 1990. The short time-period was due to relying on high resolution aerial photographs, rather than other remote sensing sources, such as Landsat or SPOT satellite imagery. While satellite images are of lower resolution, they enable longer-term change in wetland extent and larger study areas to be examined.

Spatial analysis

The Southland Region was delineated into three sub-regions: the Southland Plains, Te Anau Basin and Inland Southland (Fig. 1). The sub-regions represent different geological landforms and were delineated based on *a priori* observation that the rate of wetland habitat change was likely to be higher in some regions (Southland Plains) due to land use conversion (Ledgard 2013). Fiordland National Park, Stewart Island/Rakiura and other offshore islands were excluded, since these areas are predominantly conservation land and not subject to recent land use change.

Our primary input data to identify changes in wetland extent were satellite image mosaics from the period 1990 to 2012. The mosaics were derived from Landsat TM 1990, Landsat ETM+ 2001, Landsat ETM+ 2003, PALSAR 2009, SPOT 2008, SPOT 2009, and SPOT 2012. Wetlands have a distinctive spectral signature that can be distinguished from pasture and other land uses (e.g. plantation forestry, quarry). Landsat and SPOT images have got bands in the near infrared that helps discriminate vegetation cover, especially pasture, exotic forest and native forest. PALSAR (Phased Array type L-band Synthetic Aperture Radar) images are radar images that can show differences in vegetation structure, and aided the identification of wetlands.

The definition of 'wetland' for this study was limited to palustrine wetlands, as defined by Johnson and Gerbeaux (2004), encompassing the swamp, marsh, fen, pākihi and bog wetland types. We used existing geospatial data of current wetland extent (Clarkson et al. 2011) as a base layer. The existing data mapped the c. 2010 extent of palustrine wetlands in Southland at a scale of 1:50 000 and was derived by refining previous national wetland mapping (Ausseil et al. 2008; Leathwick et al. 2010) using local knowledge and aerial photography. The boundaries of the 700 wetlands/polygons mapped in 2010 were checked by visually interpreting the sequence of images available (1990, 2001, 2003, 2008, 2009, 2012). Wetlands present in earlier (e.g. 1990 or 2001) or more recent (2012) remote sensing images but not present in the base layer were added to the geospatial layer, with each addition visually checked by three reviewers to confirm by consensus the area as wetland habitat.

We flagged all changes in wetland extent since 1990 that were detected from the satellite images. A total of 142 wetland sites were identified that had been affected by land use change since 1990. We digitised changes in wetland extent and classified each polygon as: (1) 'lost' where the wetland had been converted to other land use and vegetation could not be classified as wetland vegetation in the 2012 satellite image, (2) 'at risk' for sites with a visible presence of drains, partial loss of dominant vegetation type and a degree of fragmentation, (3) 'restored' for sites that were not present in 1990 but were observed in more recent imagery, and (4) 'little or no change' for sites with no major conversion detectable and retaining natural wetland character that may or may not have been affected by natural hazards such as fires (Fig. 2).

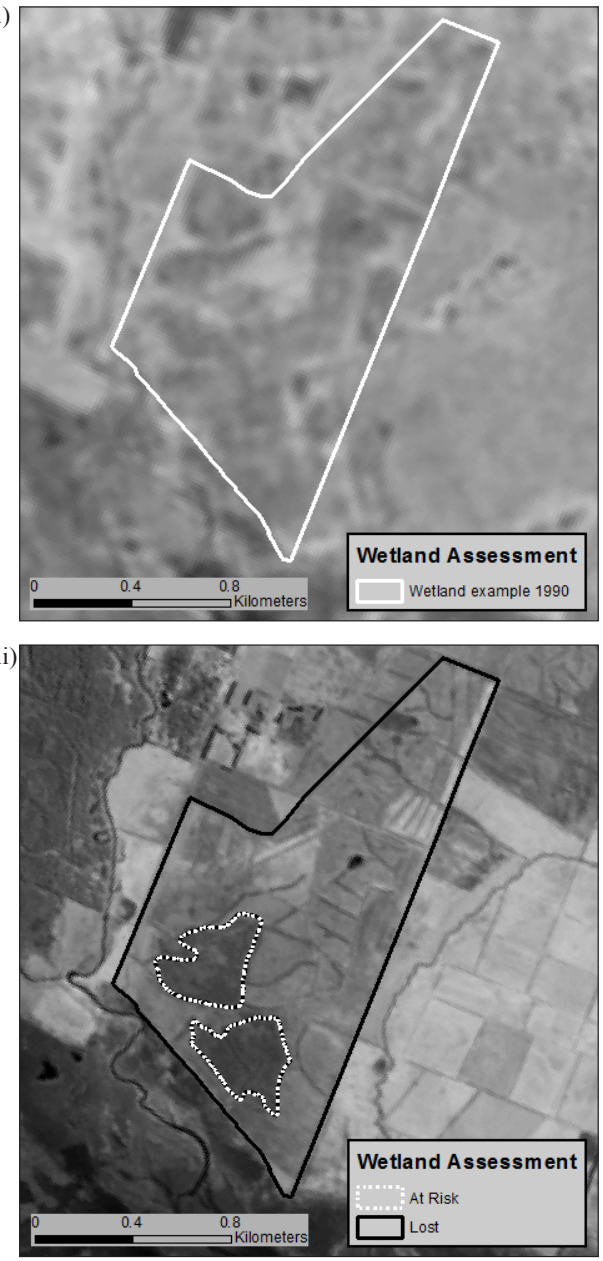

Figure 2. Remote sensing imagery from 1990 (i) and 2012 (ii) illustrating a change in wetland extent. The remaining wetland fragment is classified as 'at risk' whereas the area converted to pasture is classified as 'lost'.

As automated and visual interpretation of satellite images can be quite subjective, we used three experts with detailed knowledge of Southland wetlands and interpretation of remote sensing images to check mapping and confirm the classes applied. In instances where the presence of a wetland identified from remote sensing in 1990 was not confirmed by the experts, we erred on the side of caution and excluded this site from analysis. A validation exercise was undertaken where the three experts visually checked 135 randomly selected polygons. From this review, we assessed that the initial image analysis had 79% accuracy. In addition, all large polygons (>40 ha) were checked during validation to ensure summary statistics on change in wetland extent have low error.

We calculated the overall change in wetland extent between c. 1990 and c. 2012 by summing the total wetland area (ha) with 'little or no change', 'at risk', 'restored' or 'lost'. The change in the extent wetland habitat was summarised for each of the three sub-regions. The rate of wetland change per annum was determined by assuming a constant rate for the 22-year investigation period.

We assessed if sites subject to habitat change were restricted to small-sized wetlands (<5 ha). Each wetland polygon was assigned to one of five size classes (<5 ha, 5–20 ha, 20–50 ha, 50–100 ha, >100 ha) and the total wetland area of individual wetlands with 'little or no change', 'at risk', 'restored' or 'lost' calculated.

The proportion of the change in wetland extent that occurred on private land was determined by excluding all polygons that occurred on conservation land administered by DOC. To investigate underlying causes of wetland loss we recorded the current land use for all 'lost' and 'at risk' wetlands. The primary land use was derived from the LCDB version 4.1 (Landcare Research 2015), which contains 35 land cover classes, such as 'high producing grassland', 'exotic forest' and 'herbaceous freshwater vegetation'.

The rate of wetland loss in Southland for 1990–2012 was compared to wetland loss rates reported for other regions of New Zealand, as well as global trends in wetland loss. We used data from Canterbury (Pompeii & Grove 2010, study period 1990–2008), Taranaki (Nemsome & Heke 2010, study period 2001–2007) and Southland (Ewans 2016, study period 2007–2014) in New Zealand, and the global rates of wetland loss since 1990 reported by Davidson (2014).

Results

Change in wetland extent

A total of 32 814 ha of wetlands were present in the Southland study area in 1990. Of this total extent, 24 854 ha (76%) of wetlands were in the Southland Plains sub-region, with the Te Anau Basin and Inland Southland sub-regions having 3411 ha (10%) and 4549 ha (14%), respectively.

Extensive conversion of wetlands to other land uses between 1990 and 2012 was found. We calculated a total loss of 3452 (ha). Wetland loss was greatest in the Southland Plains sub-region where 3223 ha were no longer present (Table 1), including extensive wetland loss near the Awarua Wetland Ramsar site (Figure 3). The Inland Southland and Te

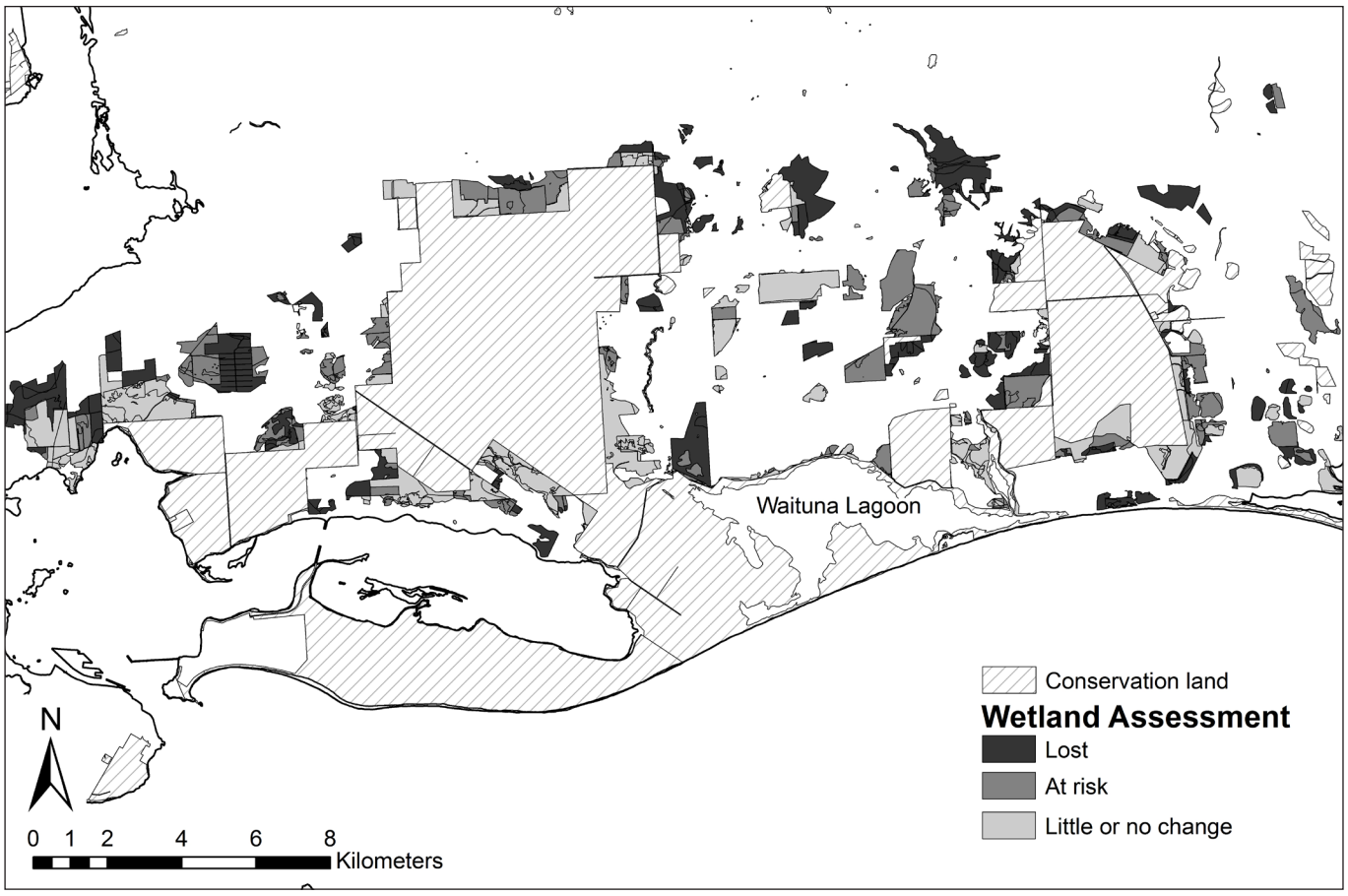

Figure 3. Geographical extent of land use change (wetlands lost and at risk) in the vicinity of Awarua Wetland (conservation land) and Waituna Lagoon, Southland, New Zealand.

Table 1. Extent of wetlands lost, at risk, restored and with little or no change since 1990 in Southland, New Zealand.

Sub-region	Area with little or no change (ha)	Area at risk (ha)	Area lost since 1990 (ha)	Area restored* (ha)	Total area (ha)
Southland Plains	18 020.7	3610.4	3222.9	0.0	24 854.0
Inland Southland	2938.8	267.6	204.7	0.0	3411.1
Te Anau Basin	4459.0	65.1	24.4	0.0	4548.5
TOTAL	25 418.5	3943.1	3452.0	0.0	32 813.6

*No restored wetlands were identified from the remote sensing images assessed during this project. The authors note that some small-scale wetland restoration (revegetation) has occurred during the study period, but these projects were not detectable from satellite imagery.

Anau Basin sub-regions had relatively few wetlands subject to land-use change.

The potential for ongoing wetland loss was also evident. A further 3943 ha wetlands were classified as 'at risk' due to presence of drainage and degradation of vegetation. The Southland Plains and Inland Southland sub-regions both had many wetlands vulnerable to further wetland decline (Table 1). If the extent of wetlands no longer present and at risk are combined, to represent the overall decline in wetland habitat, a total of 7395 ha has been impacted since 1990, which represents a 23% decline of wetlands between 1990 and 2012. Across the Southland study area, no areas of 'restored' wetland were detected from the remote sensing (Table 1).

Our analysis calculated wetland extent at two time periods, 1990 and 2012. During this 22-year period, the average rate of wetland loss was 157 ha per annum, or 0.5% yr^{-1}. This rate increases to 1.0% yr^{-1} if excluding wetlands that occur within conservation reserves. The rate of wetland loss in Southland is comparable to other regions of New Zealand, and global reported rates (Fig. 4).

Wetland size

We found that wetland loss, and polygons classified 'at risk', occurred at small (<5 ha), medium (5–50 ha) and large (>50 ha) wetlands (Fig. 5). The proportion of the wetland area lost or at risk in the Southland Plains was generally similar across all size classes (Fig. 5), except for the 50–100 ha wetlands that had a much higher proportion of its area (>60%) affected by land conversion. A smaller proportion of wetlands were impacted in the Te Anau Basin and Inland Southland sub-regions (Fig. 5). However, it was observed that ~20% of wetlands of >50 ha in size have been subject to land use change in Inland Southland since 1990 (Fig. 5), which is consistent with the overall rate of wetland loss we found across Southland.

Land use

Of the total extent of wetlands at 1990, 16 171 ha were determined to be outside of protected areas. By 2012 there were 8962 ha of wetlands with little or no change outside of protected areas, while 7208 ha were no longer present or at risk

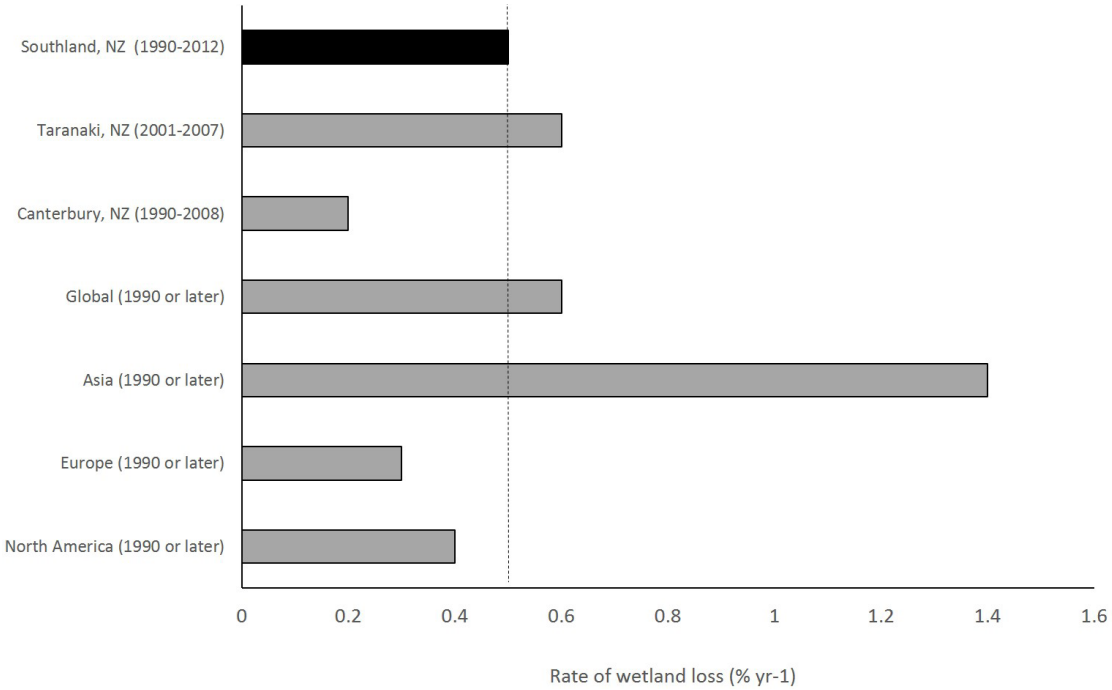

Figure 4. Rate of wetland loss (% of total area per year) in Southland, relative to other regions of New Zealand, and reported global rates of wetland loss. Southland data from this study; Taranaki data from Newsome and Heke (2010); Canterbury data from Pompei and Grove (2010); global data from Davidson (2014).

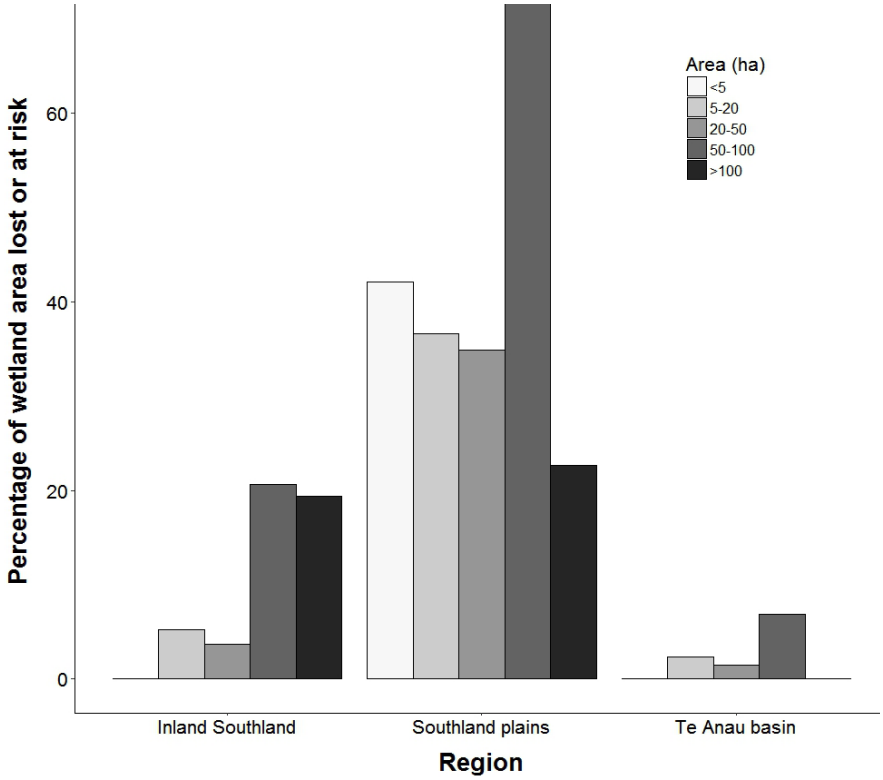

Figure 5. Proportion of wetland area lost or at risk relative to the size (area) of individual wetlands. Note: An individual wetland is defined as a polygon >30m from any neighbouring wetland polygon.

Table 2. Land use of recently modified and extant wetlands in Southland, indicating the predominant land use based on the LCDB version 4.1.

Land use*	Area with little or no change (ha)	Area at risk (ha)	Area lost since 1990 (ha)	Total area (ha)
Conservation land	16 455.7	158.1	29.0	16 642.8
Non-conservation land	8962.8	3785.0	3423.0	16 170.8
Alpine grass/herbfield	4.3	0.0	0.0	4.3
Agricultural/horticultural	1009.3	486.3	2056.2	3551.8
Aquatic	46.6	22.8	4.5	73.9
Exotic/harvested forest	121.3	158.4	153.5	433.2
Gravel/rock/sand total	9.2	0.0	0.0	9.2
Herbaceous wetland	5373.9	2194.3	878.4	8446.6
Mānuka and/or kānuka	825.8	661.2	216.7	1703.7
Native forest/scrub/fernland	450.0	46.6	19.7	516.3
Other exotic	135.6	192.6	88.5	416.7
Tall tussock grassland	985.3	22.8	5.2	1013.3
Other	1.5	0.0	0.3	1.8
TOTAL	25 418.5	3943.1	3452.0	32 813.6

*Land use (for non-conservation land) derived from the LCDB version 4.1. Landcover categories were combined for several classes, as follows: alpine grass/herbfield (retained); aquatic (lake or pond, river, estuarine open water); exotic/harvested forest (deciduous hardwoods, exotic forest, forest-harvested); agricultural/horticultural (high producing exotic grassland, low producing grassland, short-rotation cropland), gravel/rock/sand (gravel or rock, sand or gravel), herbaceous wetland (herbaceous saline vegetation, flaxland, herbaceous freshwater vegetation), mānuka/kānuka (retained), native forest/scrub/fernland (broadleaved indigenous hardwoods, indigenous forest, fernland, matagaouri or grey scrub), other exotic (gorse and/or broom, mixed exotic shrubland); tall tussock grassland (retained).

(Table 2). This means that 97% of wetland loss or degradation has occurred outside of conservation reserves, predominantly on private land. It also indicates that between 1990 and 2012 there was a 45% decline of wetlands on private land, or 21% if excluding at risk wetlands. The 3% assessed as being within conservation areas, was largely an artefact of the geospatial data, in that information is lacking on the designation date of some conservation areas.

The predominant form of land use that wetlands were converted to was high producing grassland (Table 2). The LCDB version 4.1 mapping indicates that agricultural and horticultural land uses, particularly high and low producing grassland, account for over 60% (2056 ha) of wetland loss in the region. Change in land use to forestry has also occurred. Some of the wetlands that were no longer present were still characterised by LCDB as herbaceous wetland, where our

method indicated these were typically grassland sites and reflect limitations of LCDB version 4 to differentiate some wetland and non-wetland classes.

Discussion

Loss of wetlands

There has been a substantial change in wetland extent since 1990 in the Southland Region of New Zealand, with 7395 ha lost (no longer present) or considered at risk. This change represents a decline of 23% of wetlands in the region since 1990. While there have been other accounts of wetland loss in specific regions (e.g. Canterbury, Pompei & Grove 2010), covering shorter-time periods in Southland (Ewans 2016) or prior to the arrival of humans (Ausseil et al. 2008), this study represents the first detailed analysis of wetland loss since the establishment of substantive environmental regulations and policy for New Zealand, most notably the RMA 1991.

Recognising there are limitations in national-scale mapping of wetland extent, our results suggest that previous (c. 2008) estimates that 10% of New Zealand's wetland remain, is now likely to be an overestimate, given ongoing observations of land use change. Wetland loss occurred at a rate of 157 ha per year in Southland between 1990 and 2012. More recent (2007–2014) rates of wetland loss are in the order of 176 ha per year (Ewans 2016), indicating there has been no obvious behaviour change, or regulatory change to indicate a slowing down on land use change over the past two decades.

Many wetlands subject to land use change in Southland were likely to be dominated by indigenous vegetation (Clarkson et al. 2011). The predominant wetland type in Southland is bog characterised by low-fertility and acidic soils (Clarkson et al. 2011), therefore, the conversion of wetlands to agriculture will often require investment to increase productivity. The observed decline in wetlands could be viewed as example of the tragedy of the commons reported by Hardin (1968), where ecosystem services are declining directly because of development of other resources (Lant et al. 2008), with insufficient regulation or on-ground enforcement to give value to resources that are valued by the wider community.

Putting wetland loss in context

The rate of wetland loss in Southland since 1990 (0.5% yr^{-1}) is comparable to global trends (Davidson 2014), and this rate increases to 1.0% yr^{-1} if taking into account wetlands assessed as 'at risk'. These recent trends in land-use change are similar to the historic (c. 1850–2003) rates of wetland loss for Southland (0.8% yr^{-1}) (Ausseil et al. 2008). Further, the high rates we observed since 1990 have not abated in the last decade. For the period 2007–2014, Ewans (2016) calculated that wetland loss of 1235 ha occurred on private land at 1.3% yr^{-1}, approaching rates observed in Asia (1.4%) where large scale development of peatlands is occurring (Koh et al. 2011).

Consequently, perceptions that New Zealand has relatively good environmental regulations or enforcement of rules relative to other parts of the world should not necessarily extend to the protection of wetland systems. While there were incentives prior to 1990 to progress land development, few such incentives have been in place since 1990 and wetland loss is still occurring.

In general, the rate of wetland loss is much higher than the loss of other habitat types in New Zealand. Walker et al. (2008), in a national assessment of changes in indigenous vegetation, reported that rates of habitat loss were generally less than 0.1% per year, and often much less. While errors in the Walker assessment of indigenous habitat were highlighted by Brockerhoff et al. (2008), the result provides a relative measure to compare with the rate of wetland loss in the Southland Region.

Our study focused on Southland, as this region contains approximately 18% of all remaining wetlands in New Zealand, second only to the West Coast (34%). If the rates of wetland loss reported in Southland are occurring in other regions that support extensive wetlands, such as West Coast, Waikato, Northland and Otago, then national efforts to prioritise wetland conservation may have only been partially successful at preventing their decline. This suggests a review of regional and national policy for wetland drainage may be required, or increased efforts to ensure wetland policies and rules are being actively enforced.

Cause of wetland loss

The predominant cause for the change in wetland extent in Southland was an increase in the development of high-producing grassland to support agricultural production in Southland (Table 2). We determined that most wetland decline occurred on private land (97%), and conversion to agricultural/horticulture accounted for >60% of wetland loss (Table 2). Wetland conversion will typically require drainage and clearing of vegetation. Under the RMA, and associated statutory planning rules, consents are generally needed by landowners to clear indigenous vegetation, including consents to drain or modify wetlands. The specific rules vary dependent upon the individual local authority in New Zealand. For instance, Myers et al. (2013) noted the regional authority in Southland had only weak rules to limit the drainage/modification of wetlands. Other local authorities (e.g. Invercargill City Council, Southland District Council) also have varied rules to protect wetlands, and even where regulations are in place, considerable loss of wetlands since 1990 was detected. This further supports a need for a review of environmental rules, and increased enforcement of regulations.

A review of rules and enforcement should also consider the viability of ongoing land drainage recognising that efforts can be counter-productive due to land subsidence. Pronger et al. (2014) examined subsidence rates for peatlands in the Waikato Region, New Zealand, and found drainage of peatlands leads to ongoing land subsidence of 2–3 cm per year. Therefore, efforts to increase primary production by draining wetlands may not always be successful, as agricultural land may continue to be water logged as land elevation decreases.

Increased agricultural production is also the primary reason for wetland loss internationally. In the Dakota Prairie Pothole region, USA, Johnston (2013) confirmed that agricultural expansion was a driver of wetland decline of 0.3% yr^{-1}. In Alberta, Canada, Clare and Creed (2014) observed that the majority of wetland losses were for urban/industrial or agricultural development, with 80% of wetland area lost without a permit. Further, in Flanders, Belgium, Decleer et al. (2016) recorded a 75% decline (~175 000 ha) in wetland extent over the last 50–60 years, mainly due to intensification of agriculture. While in a large-scale assessment of China, Gong et al. (2010) recorded a 14% decline in wetlands between 1990 and 2000 and observed that most instances were due to a shift to agricultural land. Our study confirms that the primary causes of wetland loss within New Zealand are mirroring global trends.

Setting wetland loss limits

Given 40% (by area) of wetlands occur on private land in New Zealand (Robertson 2016) key threats such as drainage will continue in the absence of more explicit statutory measures or enforcement to achieve sustainable land use management. If wetland loss continues at the rate found in Southland, a range of ecological consequences will likely occur, including: (1) reduced extent of threatened wetland types, indigenous vegetation and rare ecosystems (Williams et al. 2007); (2) reduced capacity of wetlands to attenuate nutrient and sediment runoff (Hefting et al. 2013; Tanner et al. 2015); (3) reduced storage of carbon (Ausseil et al. 2015); (4) reduced habitat for threatened flora and fauna (Richardson et al. 2015; O'Donnell & Robertson 2016); (5) increased susceptibility to fire (Burge 2015); (6) increased susceptibility to weed encroachment (Zedler & Kerceher 2004); and (7) loss of ecological sequences (Landry & Rochefort 2012).

Our investigation into wetland loss in Southland supports the study of Myers et al. (2013) that identified the need for stronger national policies to prevent further loss, such as through the implementation and enforcement of regulations in regional plans. There is general recognition in New Zealand of the need to set limits on land and water use to maintain the health of natural freshwater ecosystems (Land and Water Forum 2015). Freshwater reforms currently in progress in New Zealand aim to protect river and lake ecosystems through the implementation of national guidelines that require limits for catchment management authorities to apply (MfE 2014). These water reforms include specific objectives that direct councils to protect the significant values of wetlands (MfE 2014). This policy guidance is consistent with the multilateral wetlands agreement of the Ramsar Convention; Article 3.1 of the Convention states 'contracting parties shall formulate and implement their planning so as to promote the conservation of the wetlands included in the (Ramsar) list, and as far as possible the wise use of wetlands in their territory'. Accordingly, there is both national and international basis for working towards wetland loss or drainage limits for New Zealand.

As a minimum, wetland limits, or rules, should be applied nationally and regionally. These rules should take into account the degree that different wetland types are depleted across bioregions and nationally, and the minimum size of wetlands that is required to maintain and enhance a wetland's significant ecological features and natural character. Where rapid changes in land use are occurring, such as Southland and potentially other regions including the West Coast and Northland, implementation of clear limits or targets for all wetlands will help to address the loss of biological diversity and ecosystem services.

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