Return to main text: sfc230.pdf

Figures 1–11

Figure 1. Seasonal water fluctuation

- Turfs form in the marginal zone of channels, ponds, tarns, kettles and lakes experiencing fluctuating water levels.
- Wide variations in landforms and changes in water levels lead to many different types of turf communities.
- Water inputs to water bodies come from rainfall, groundwater seepage, surface stormwater from the catchment slopes and from inflowing streams. Water losses result from evaporation, evapotranspiration, underground drainage and, sometimes, from a surface outlet.
- As an introduction to seasonal changes in water level, we have chosen two entirely closed systems, with no inlet or outlet streams: A–D, a lake terrace system; E, a kettle system.

A–D Seasonal water fluctuations in a closed depression

A typical closed depression, lacking any inflowing stream or surface outlet, but able to hold ponded water during wet seasons, or after heavy rainfall events in drier months. This example (Dublin Bay, Lake Wanaka, Otago) is contained behind a gravel storm ridge (scrub-covered in distance) deposited when the adjacent lake had higher levels earlier in the postglacial period.

In early spring (1 September 1999, Fig. 1A) water level was falling and the pond was 20 cm deep. By 23 October 1999 (Fig. 1B) the depression base was moist but not ponded. At the height of summer (12 February 2000, Fig. 1C) the base was dry and firm underfoot. In the winter situation (21 July 2000, Fig. 1D) the depression held water to a depth of 40 cm, almost fully ponded.

This depression of c. 40 × 20 m is in a rain-shadow climate so is ponded for quite a short portion of the year. Being shallow and temporary, it has poorly defined vegetation zones. Relatively fertile soils combined with sheep grazing probably account for an abundance of naturalised plants as dominants. Native turf plants (*Glossostigma elatinoides, Limosella lineata, Galium perpusillum*) persist all year in the base, under a sward (tall in summer, matted in winter) of *Lachnagrostis filiformis, Juncus articulatus, Eleocharis acuta, Agrostis stolonifera*, and *Carex gaudichaudiana*. At the perimeter are *Carex ovalis*, and soft rush (*Juncus effusus*). Clumps of soft rush visible in the foreground of Figs 1C and 1D had increased in density and height during the autumn; they would not necessarily survive prolonged ponding over winter.

E Moraine kettles drying in early summer

Kettles are closed depressions in moraines deposited by glaciers. In these kettles, water level fluctuates over several metres, with highest levels probably in spring. By early summer (photo date 17 December 1993) some kettles have only shallow ponds or dry bases, revealing their zones of turf plant communities which reflect degrees of inundation.

The Cluster Tarns, west of Lake Tekapo, Canterbury, lie upon a complex of ice margin glacial deposits accumulated where two glaciers met. This system, some 6 × 3 km in extent and at around 1000 m altitude, is mostly ablation moraine, deposited at a time of glacial retreat (c. 13 000 years ago). Figure 1E illustrates a portion of the system having numerous small kettles in a landform of complex origin. High ridges (on right) are terminal moraine. Lower parallel ridges which arc south-west represent gougings by a short re-advance of ice which over-rode the earlier moraine, but not for long enough to obliterate its surface topography. On a finer scale, there is extensive 'knob and kettle' topography. The knobs represent mounds of rubble which slipped into meltwater lakes that dotted the debris-covered glacier at the time it decayed. When the intervening ice hummocks melted, they left the kettle depressions.

Figure 1. Seasonal water fluctuation

A

B

C

D

E

Figure 2. Kettles

- Kettles are depressions on hummocky moraine surfaces, formed as glacier ice melts during a time of glacial retreat. True kettles are relatively small and steep-sided, and are often seasonally ponded. Larger, more shallow depressions occur on glacial outwash surfaces having water-sorted alluvium.
- Kettles have enormous differences in vegetation composition due to their patterns of size and shape and their drainage, which is modified by the amount of infilling with silt or loess.

A. Depressions on young moraine

Retreat of the Tasman Glacier has left a series of terminal moraine ridges with intervening closed depressions. This is one of the four Blue Lakes, enclosed by moraines dated at 850 to 750 years BP (right) and 580 years BP (left). At the time the photo was taken (December 1993), ponded water was 0.5 m deep, but the lower line of scrub indicates that a depth of 3.5 m can be reached. Fine glacial silt in the bed supports a few native aquatic and turf plants, but the boulder and gravel shores lack the veneer of loess which would support a dense turf vegetation in depressions of older moraine surfaces.

B. Every hollow is different: a small kettle and a kettle-lake

The small kettle (left) shows concentric zones of different vegetation composition determined by degrees of seasonal inundation. The horizontal line of the lowermost hard tussocks marks maximum water level, though this might be reached only once every few years. The small kettle has a complete vegetation cover upon fine sediments, while the kettle lake (right) is sufficiently large (c. 400 m across), and is never empty, such that wind-generated wave action maintains a partly stony shore. Glenmore Tarns, west of Lake Tekapo, Canterbury, December 1993.

C. A large shallow depression on glacial outwash

Depressions down-valley of the large Canterbury glacial lakes are upon outwash plains, so are large with gently sloping sides and a great extent of turf vegetation. Sheep-grazing here appears to have no major impacts upon survival of the rich native wetland flora. Human impacts visible in this photo include the use of the upper turf zone by vehicles, and the planted willow, possibly having arisen from stakes used in a maimai. South of Lake Ohau, May 2000.

D. A paradise for botanists

Even the smallest depressions hold a large number of different plant species, and the habitat type is a specific one for many threatened plants. This kettle has the tiny rare sedge *Isolepis basilaris*. Von Valley, northern Southland, January 1997.

E. A kettle having little water fluctuation

The degree of drainage varies within kettle systems. Poorly drained kettles can either maintain a permanent stable pond or else accumulate organic matter under bog or swamp vegetation. The permanence of this pond is obvious from the tall sedges of *Eleocharis acuta* emergent from the water. Mounds of Misery, Esk River, Canterbury, March 1988.

F. A kettle variant with moss-dominant vegetation

In some small shallow kettles the usual vascular plant turf communities are largely replaced by mosses and their moist upper margin can be dominated by bog plants. This example has a muddy base with *Crassula* and *Galium*, a bright zone of the mosses *Aulacomnion* and *Polytrichum*, then an upper fringe of comb sedge (*Oreobolus pectinatus*). Moss-dominated depressions seem to occur where ponding is brief but frequent. Glenmore Tarns, Canterbury, December 1993.

G. Turf vegetation has tightly interlaced, low-stature plants

A turf community of the uppermost perimeter zone of a Glenmore kettle. The most obvious plants are *Euchiton traversii* (grey), *Hieracium pilosella* (green), and *Gonocarpus micranthus* (red). Also present are species of *Epilobium, Galium, Hydrocotyle, Plantago, Poa, Pratia,* and *Stackhousia*.

H. Turf with a rich flora at a fine scale

Even at a c. 10 × 10 cm scale, a particular area of turf may contain many species. Present in this example are: *Neopaxia linearifolia* (flowering), *Epilobium angustum* (bronze leaves), *Galium perpusillum* (green stems), *Leptinella pusilla* (top left), *Glossostigma elatinoides* (small paddle-shaped leaves), and at least four other plant species.

Figure 2. Kettles

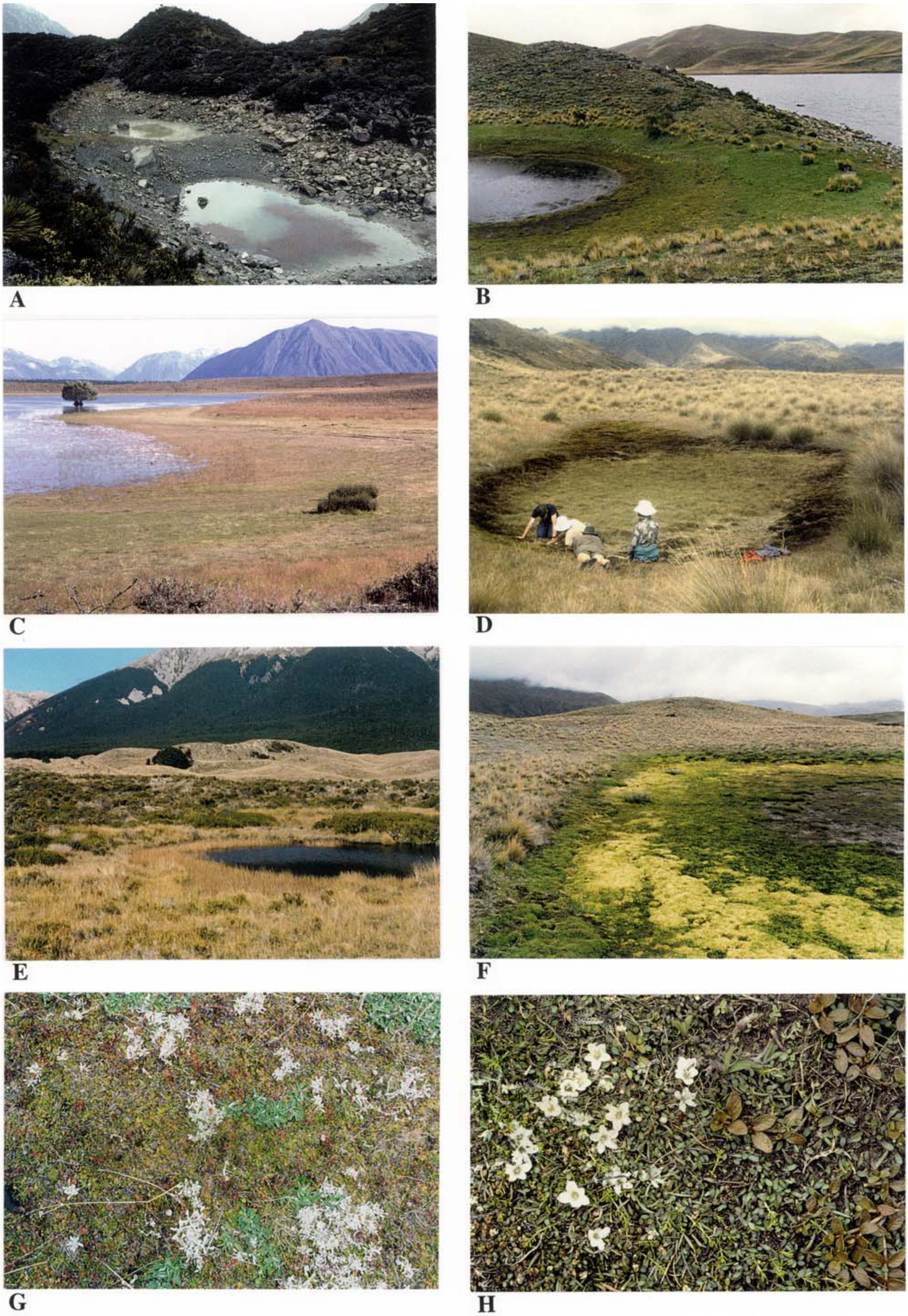

Figure 3. Dune hollows

- Coastal dunes with moist hollows or dune slacks develop on prograding coasts with a good supply of wind-blown sand. Turf communities do not get a chance to form where sand supply and dune instability is greatest.
- Turfs essentially exist as early successional vegetation in damp hollows as dunes begin to stabilise. They tend to disappear under competition from later successional and taller communities. Unfortunately for early successional vegetation, most dunes have been artificially stabilised because sand supply is intercepted by plantings of marram grass, lupin shrubs, and conifer trees. A shifting mosaic of turfs is therefore disappearing from dunelands.
- Several rare plants of turfy hollows are dependent on maintaining early successional vegetation and therefore present a management challenge in artificially stabilised dunes.

A. Young dune hollows are unstable and unvegetated

One of the ways in which hollows are formed among coastal sand dunes is by wind-deflation, sand being eroded down to the level of the water table, where groundwater keeps the sand moist and immobile. Despite its location in a high rainfall area this dune hollow does not retain ponded water very often or for very long, and is therefore unvegetated. Martins Bay, Fiordland, March 1999.

B. Vegetated hollows on a stable sand flat

Hollows on a stable sand flat may pond to a varying extent seasonally, and between wet and dry years. Many of these at Okia Flat, Otago Peninsula have a central pond, a rushland base, then a turf perimeter in the zone where wetting and drying is most pronounced. Now retired from grazing, these turf hollows are being monitored to assess how grass and rush increase will affect the turf. June 1982.

C. Dune turf vegetation at a late stage of succession

Turf vegetation in a periodically ponded dune hollow, surrounded by *Isolepis nodosa* rushland and toetoe (*Cortaderia toetoe*). Background dunes are being invaded by tree weeds: *Acacia sophorae, Cupressus macrocarpa,* and *Pinus radiata*, which have the potential to greatly alter the dune hollow hydrology by reducing water tables. Tangimoana, Manawatu coast, January 2000.

D. Experimental creation of early succession disturbance in a dune hollow

Colin Ogle, ex. Department of Conservation, inspects an experimental scrape, designed to test whether soil disturbance and removal of late successional vegetation, especially *Apodasmia similis* rushland, might be of benefit to this one of the two remaining known New Zealand populations of *Sebaea ovata*. Whitiau, Wanganui coast, January 2000.

E. *Sebaea ovata*: one of New Zealand's most threatened plants

A plant with a c. 8 week lifespan but with several generations in a year, *Sebaea ovata* requires moist early successional hollows without too much competition from taller plants. Once known in New Zealand from Northland to Canterbury, but now present only at two Wanganui sites, it is classified in the threat category 'Critically Endangered'. It is found also in Tasmania and mainland Australia.

F. *Selliera rotundifolia*, a threatened plant of Manawatu coastal dune plains

This plant, classified as Vulnerable, is restricted to moist dune hollows on the Wanganui to western Wellington coast (Heenan 1997). The photo also shows concentrations of rabbit droppings; rabbits are attracted to many areas of low turf vegetation. Rabbit burrowing may be an undesirable physical disturbance, but rabbit grazing may be of benefit to plants of turf stature by cropping of taller vegetation.

G. Marginal vegetation of a dune lake

The length of this dune lake, about 1 km, provides enough wind fetch to generate waves that will erode and redeposit ridges and veneers of sand which can variously bury, nourish, or rejuvenate turf and sward communities. The lower turf zone here comprises *Myriophyllum triphyllum, Lilaeopsis novae-zelandiae,* and *Limosella lineata*. The upper zone is a sedge sward of *Schoenoplectus pungens* and weeds such as the grass *Holcus lanatus*. Tennants Lake, Chatham Island, March 2000.

H. Dune hollow colonisers

Ranunculus acaulis (centre) grows mainly on coastal sand, and *Limosella lineata* on wet silt or mud; both are colonists of bare ground. They grow together in a dune hollow at Coal River, Fiordland.

Figure 3. Dune hollows

Figure 4. Volcanic country, Central North Island

- Ignimbrite sheets form extensive undulating plateaux of pumice or welded lava. Turfy ponds have collected within shallow depressions or basins on this often impervious bedrock.
- Turf composition varies mainly in response to seasonal water levels and not so much to differences in the fertility of soils or basement rock.
- Some turfy ponds on ignimbrite plateaux are still surrounded by remnants of once-extensive podocarp forest; other turfy ponds occur among frosty, nutrient-poor shrub-tussocklands.
- Small-scale deflation hollows in ash-covered plateaux of the southern Kaimanawa Mountains and northern Ruahine Range have their own distinctive communities and rare plants.

A. A tephra-based depression at its dry phase

Complete summer drying of this shallow depression reveals a turf floor, irregularly studded with *Carex rubicunda* (short tufts), *C. dipsacea* (spreading tussocks), and *Juncus gregiflorus* (erect dark rushes). Upper Rangitaiki catchment, January 2000.

B. Base of a tephra depression at its drought phase

The base of the hollow shown in Fig. 4A has dried and cracking silt, only partly vegetated, indicating insufficient ponding for an aquatic basal zone. Water level has probably dropped rapidly, to a deep subsurface water table, allowing only a brief period, between inundated and drought phases, of moist soil for young tufts and expanding mats of colonising opportunists: *Lachnagrostis* sp. (the grass seedlings), *Glossostigma* spp. (brownish mats), and *Lythrum portula* (green and red mats).

C. Marginal zones of a permanently moist depression in tephra

In contrast to the dried depression (A and B) an adjacent site remains ponded for a longer period, and exhibits a more aquatic basal zone (of *Myriophyllum propinquum* and *M. pedunculatum*; left). Upslope (centre) is a zone of *Eleocharis acuta* with *Ranunculus flammula*, a sward of *Carex gaudichaudiana, C. dipsacea,* and *Holcus lanatus*, then scrub of *Dracophyllum subulatum*.

D. Turf systems still yield unnamed plants

The New Zealand flora of turf plants includes taxa which are not yet named, such as the small brown-leaved plant currently referred to as *Hypericum* sp. aff. *japonicum*, which at this Rangitaiki site is clearly distinct from the real *H. japonicum* which has green leaves and larger yellow flowers.

E. A wet upland depression susceptible to animal trampling

A deflation hollow that remains wet all year and therefore susceptible to damage by feral horses, at Moawhango, Kaimanawa Mountains. Here, localised ponds occur in intermontane basins at c. 1000 m altitude in a subcontinental rain-shadow climate having pronounced wet and dry seasons.
The surrounds are red tussock (*Chionochloa rubra*) and dracophyllum scrub. December 1996.

F. A deflation hollow with a firm base

A contrasting Moawhango deflation hollow that is baked dry in summer has a basal pavement of blocky pumice lag gravels, and is therefore less prone to trampling damage. December 1996.

G. A sediment-nourished depression

This tarn, an extensive pond in winter and often completely dry in summer, is unusual in receiving a periodic input of fine sediment from andesitic tephra and its underlying greywacke, and a consequent fertility boost, when an adjacent stream alters its usual course and enters the tarn during heavy rain events. These Moawhango, Kaimanawa Mountains, sites are important as the only North Island occurrences of several rare and local plant species. February 1993.

H. A closed depression surrounded by forest

In summer this tephra-based and turf-lined depression of 400 × 100 m can hold only small basal ponds. During wet periods ponding to c. 2 m depth inundates the marginal zone of manuka scrub and the buttressed lower trunks of tall kahikatea trees. Arahaki Lagoon, Whirinaki, December 2000.

Figure 4. Volcanic country, central North Island

Figure 5. Limestone and schist country

- Limestone and schist often form planar landforms, unbroken by tectonic folding and faulting. Turfy ponds may form in shallow weathered depressions on these impervious bedrocks.
- These base-rich rocks produce comparatively fertile capping soils and turf communities.
- In dry climates, salt concentrations from rock weathering influence turf composition.
- These rock types are valued for farming and so the native turfs are prone to degradation.

A. Pool upon limestone bedrock

Because limestone is water-soluble it erodes to convoluted shapes, both above ground and along underground watercourses. Collapse or dissolution of near-surface limestone can create closed depressions in the land surface. This small and shallow example, sitting almost directly upon bedrock, is an ephemeral pool lacking aquatic or semi-aquatic vegetation zones. Castle Hill, Canterbury, 780 m altitude, September 1988.

B. Pool on an upland limestone plateau

The Makirikiri Tarns, northwest Ruahine Range, occupy shallow depressions on a plateau of horizontally bedded limestone. This almost-permanent pool has turf margins and is surrounded mainly by red tussock wetland, but the subfossil log of pink pine (*Halocarpus biformis*) is a reminder that many turf depressions in open country have a prehistory of being surrounded by scrub or forest. December 2000.

C. A doline in farmland upon limestone

This sinkhole or doline, one of many near Oamaru, north Otago, is an example of one which is very seldom ponded, and probably never to capacity. Because of the relatively well-drained soil and the agricultural setting, it is almost wholly vegetated with pasture grasses. April 2000.

D. Ephemeral ponds on Otago schist

In Otago, gently sloping areas of land underlain by schist (variously portions of an ancient peneplain or else the broad crests of block-faulted ridges) are dotted with closed depressions. Middlemarch, Otago, June 1994.

E. Ephemeral pond upon schist bedrock

Lying upon bedrock, this shallow pond (20 cm deep, 60 cm deep when full) can be dried out from early summer. Margins of this and similar pools are a characteristic habitat of the New Zealand mousetail (*Myosurus minimus* subsp. *novae-zelandiae*), a threatened member of the buttercup family (threat category: Declining), and one of the few annual plants in the native flora. Flat Top Hill, Central Otago, September 1991.

F. An inland saline lake

The low rainfall and high evaporation rates of semi-arid inland Otago can result in a concentration of soluble salts at the ground surface, within salt pans, saline seepages and, in this case, a small salt lake (350 × 200 m, altitude 250 m), here fringed mainly with the salt grass *Puccinellia fasciculata*. The turf or sward plants of these systems are similar to those of coastal salt marshes, and distinct from the usual flora of inland freshwater turfs. Sutton Salt Lake, Otago, April 2000.

G. A marshy depression on peneplain schist

An example of a closed depression upon a schist plateau that is ponded relatively frequently but for short periods. This remains almost permanently moist, and the fertile substrate encourages a lush growth of naturalised rushes: a sward of jointed rush (*Juncus articulatus*) and tufted clumps of soft rush (*J. effusus*). Nenthorn, Otago.

Figure 5. Limestone and schist country

Figure 6. Rivers and lakes

- On alluvial floodplains, turfs form around two types of water bodies. First, the migrations of meandering streams produce periodically inundated, cut-off meanders or oxbows. Second, lakes with gentle shoreline gradients form in wide shallow depressions.
- The watercourses of floodplains receive siltation from flooding, and because they are valued for agriculture are subject to modification by eutrophication, and weed encroachment.
- Turfs of lakeshores often have to contend with erosion from wave action generated on the large bodies of water.

A. A scroll plain of river meanders and oxbows

Abandoned watercourses of rivers and streams can be periodically ponded. A striking example is the upper Taieri River, Otago, at 550 m altitude, where faulting has reduced the gradient of the valley, producing an intricate pattern of meanders and abandoned channels with a wide array of ponding regimes and vegetation patterns.

B. A seasonally wet stream channel

One of many elongated oxbows produced by a stream meandering across a broad upland basin at 700 m altitude. Red tussock grassland covers much of the basin; the lowermost elevation of the tussocks along the oxbow margin indicates maximum ponding level. Beneath these marginal tussocks is one particular habitat of the rare buttercup *Ranunculus ternatifolius*. Fortification Creek, Lake Onslow, Otago, December 1985.

C. A weed-modified lake-shore sward

The shallow lakes of the lower Waikato Valley have become highly modified by siltation, eutrophication, and weeds. Shore zones that were once probably turfy have been invaded by many naturalised plants of taller or more robust stature. Lake Wahi has a water level fluctuation of about 1 m amplitude. This eastern shore displays a zone of tall sedges emergent from the water. Although the sward zone in the centre still has persistent native plants such as *Carex gaudichaudiana* and *Eleocharis acuta*, the dominants are now numerous naturalised grasses and marsh herbs such as species of *Ludwigia*, *Ranunculus*, *Mentha*, and *Rumex*. Also present are shrubs of grey willow (*Salix cinerea*), which, like other naturalised willows, will invade turf and sward wetlands that do not naturally contain native woody plants. September 1999.

D. Broad turf and sward zones on a lake shore

Like small turf hollows, larger fluctuating lakes also have obvious but often much wider zones of shore vegetation. This gentle eastern shore of Lake Wairarapa has a muddy zone of *Glossostigma* and *Lilaeopsis* (right), grading into a sward of three-square (*Schoenoplectus pungens* (left). Several processes are more pronounced on lakes than on smaller ponds, such as the extensive deposit of organic matter (mainly algae) covering both plants and silts upon this shore. January 2000.

E. Sharp zonation, and downslope seepage on a lake shore

With a water level fluctuation range of 4.6 m, Lake Manapouri, Fiordland, has broader vegetation zones than most small ponded depressions, but the turf and sward communities are similar in both habitats. Four zones are evident here: turf, *Carex gaudichaudiana* sward, rushland of *Apodasmia similis*, and scrub of manuka (*Leptospermum scoparium*). Wave action on large lakes will move coarse sediments, such as the large gravels that veneer both silt and turf on this shore. This site illustrates a feature that can occur also, but less obviously, on smaller bodies of water: seepage from upslope, which is maintaining saturated turf and permanent ponds in a turf zone that lies above current lake level. March 2000.

F. Small-scale turf zonation

A pool margin adjacent to Lake Manapouri showing closely spaced vegetation zones dominated by *Carex gaudichaudiana* (left), *Callitriche petriei* (centre), and *Ranunculus flammula* (right).

G. and H. Two collections of turf plants

G: *Hypsela rivalis* (top left), *Neopaxia linearifolia* (top centre), *Selliera radicans* (bottom right), and *Glossostigma elatinoides* (bottom centre).

H: *Gratiola sexdentata* (top left), *Utricularia novae-zelandiae* (top right), *Centrolepis pallida* (bottom left), and *Myriophyllum votschii* (bottom right). Lake Manapouri.

Figure 6. Rivers and lakes

Figure 7. Man-made and modified habitats

- Mankind has found many creative ways to impound water, thus supplementing the range of available habitats for turf plants.
- However, a big drawback for development of turfs around man-made reservoirs is the wide amplitude of water fluctuations. Most turf plants cannot cope with sustained deep drowning followed by long periods of drying exposure. The result is that many reservoirs have unvegetated eroding margins.
- Other reservoirs have silty deltas around inflowing streams, ideal for turfs.

A. A roadside 'borrow pit' turned wetland

Excavation of roading fill alongside the Taupo–Napier road (map ref. NZMS 260, U19/ 097492) has removed tephra to below water table level. The gently graded shores have been colonised by a suite of wetland plants similar to those found in natural closed depressions in the upper Rangitaiki catchment. Clumps of the tall sedge *Eleocharis sphacelata* emerge from the permanently ponded base. The turf zone is mainly *Myriophyllum pedunculatum*, but with *Juncus bufonius* providing a reddish tinge in the upper part of the zone. 17 January 2000.

B. A farm dam

A large farm pond in limestone country. Low water level reveals a muddy and mainly unvegetated base, and marginal zones sequentially colonised as water level dropped in summer and autumn. Native turf plants are present in the mid-level green zone; the red upper zone is mainly of docks (*Rumex* spp.) at seeding stage. Awahokomo Creek, south of Lake Waitaki, north Otago. May 1992.

C. A hydro lake with unvegetated shores

In many artificial lakes used for hydroelectricity generation, large and rapid drawdown occurs when electricity demand is highest over winter. Shores can remain exposed for too long for aquatic vegetation to develop, and become too dry or too deeply drowned for too long for land plants to colonise permanently. Their margins become unvegetated, erosion-prone, and not necessarily favourable for plant establishment. Lake Mahinerangi, Otago, October 1988.

D. An upland irrigation reservoir

Poolburn Dam, Central Otago, at 830 m altitude, has numerous silty indentations and bay-heads suitable for marginal rush and turf vegetation. Water level drops gradually during summer and autumn. Cattle graze, trample, and add nutrients to this shore. Grassland (left) of hard tussock (*Festuca novae-zelandiae*) and sweet vernal (*Anthoxanthum odoratum*) descends to maximum water level. The rush zone is of *Juncus gregiflorus*, and the green sward is mainly the naturalised grass creeping bent (*Agrostis stolonifera*) and jointed rush (*Juncus articulatus*). Native turf herbs are also present, including *Parahebe canescens*, with cryptic grey-brown foliage, a tiny plant yet sometimes so abundant that it colours a shore such as this mauve when in full flower. April 2001.

E. Siltation and turf on a reservoir head delta

The head of Falls Dam, Central Otago, has extensive deposits of silt that has accumulated on the deltas of inflowing streams, providing both suitable substrate and moisture retention properties for turf vegetation to flourish during summer and autumn when water levels are low.

F. A dewatered reservoir in autumn

Complete autumn emptying has left a muddy reservoir base, which for about two months has been exposed, yet moist, encouraging a phase of rapid growth of turf mats (*Myriophyllum, Callitriche, Leptinella, Elatine*) before the mud has dried and caked. Moisture remains only along the stream channel. West Eweburn Dam, Central Otago, April 1998.

G. Silt accumulations in a reservoir bed

A small reservoir, dewatered in autumn, its persisting inflow stream revealing by erosion the depth of fine sediments which accumulate on the bed of such habitats. Old Man Range, Otago, March 2001.

H. A closed depression modified by pastoral use

This 6-m-wide hollow is surrounded by pasture, and bordered by kneed foxtail grass (*Alopecurus geniculatus*). The base contains much *Callitriche petriei* subsp. *chathamensis*. Other native herbs persist among the pasture plants despite grazing. Pitt Island, Chathams, October 1999.

Figure 7. Man-made and modified habitats

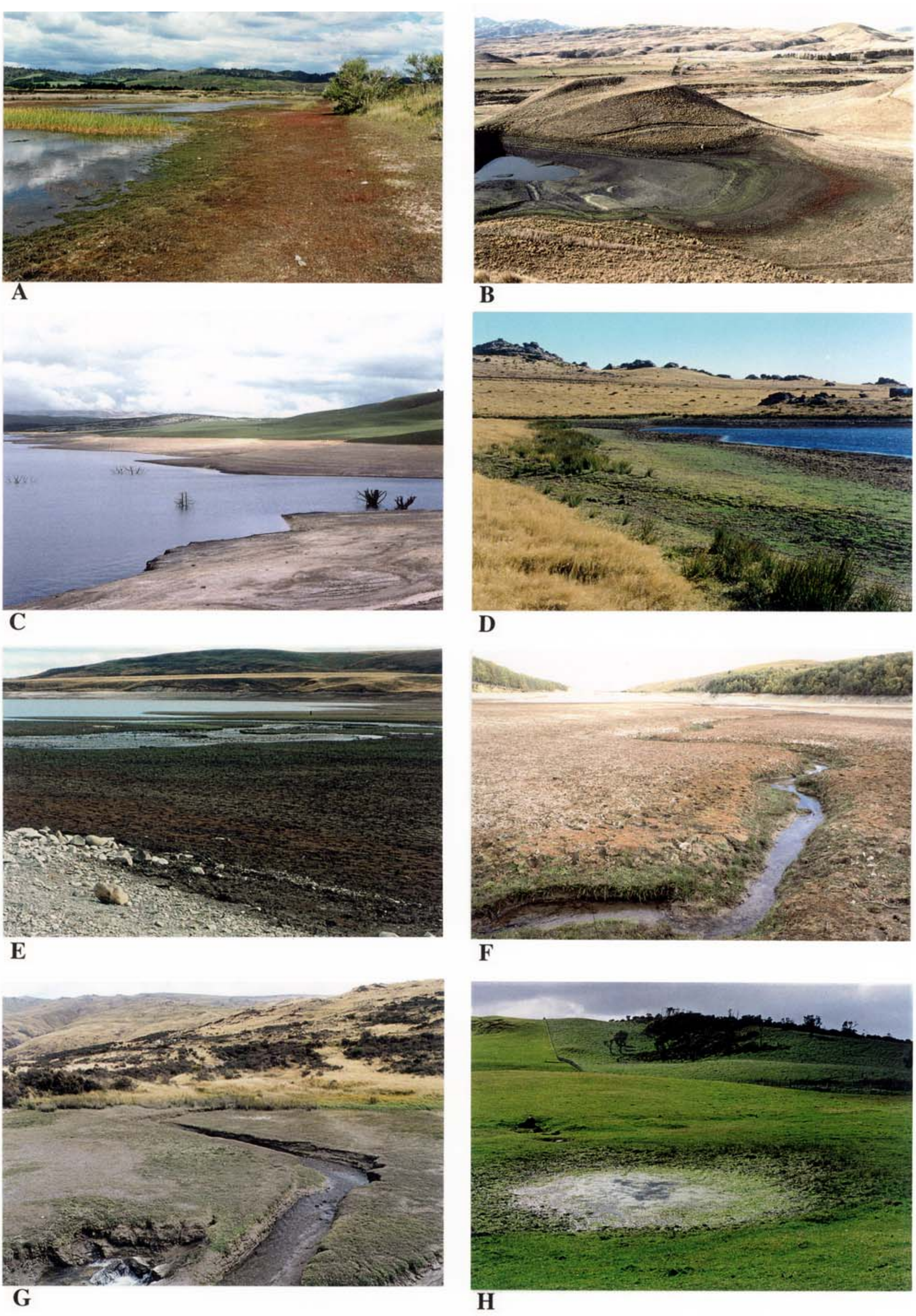

Figure 8. Upland turfs

- Upland tarns with turfy margins feature on slump features, glacial benches, peneplain remnants, and around seepages in shallowly incised gullies on mountain crests.
- Turfs may be associated with peaty soils because of the slow decomposition of plant litter in cold wet climates or the short growing season resulting from seasonally late snow-lie.
- Because they are generally intact, and not threatened by stock, weeds etc., turfs of upland tarns pose few problems for conservation management.

A. A fluctuating alpine tarn

Alpine tarns on bedrock have stable water levels and generally little development of turfs. Those with fluctuating water levels have turf shores but with a smaller flora than found at lower altitudes. This site (Countess Range, northern Southland, 1050 m) is the only known upland locality of the rare cress *Cardamine lacustris* (Fig. 11H), known otherwise only at lower altitude on the shores of Lakes Te Anau and Manapouri. Photo: Brian Rance, April 1999.

B. Dried depression in a subalpine slump hollow

Even the smallest hollows can have a zoned vegetation pattern. The bare muddy base indicates that a basal pond is often present. The marginal zone of *Polytrichum* moss is characteristic of a depression that fills with water frequently yet remains fully ponded for only a few days at a time. Mt Shrimpton, Makarora Valley, Otago, 1400 m, October 2000.

C. A snowbank: turf with a difference

Snowbanks range from being snow-covered, irrigated by meltwater, or dried out. Their vegetation is of turf stature, growing upon mineral rather than peaty soils, but they share only a small proportion of the flora of closed depression wetlands. This snowbank, at a low-alpine altitude of 1100 m, grades down to permanently moist streamside turf communities. Lammerlaw Range, Otago, November 1987.

D. Turfs at the head of a string bog

In string bogs peat accumulates on the water-nourished rims (strings) which impound terraced pools of almost constant water level. But in this example at the upper elevation of a string bog, the smallest depressions do experience alternate ponding and drying. The moisture gradient upslope is accompanied by a decreasing peat depth, increasingly mineral soil, and a gradation to snowbank turf. Lammerlaw Range, 1100 m, November 1987.

Figure 9. Colonising and invading plants

- Cycles of ponding, drying, and sediment disturbance create fresh surfaces for those species of native turf plants which behave as colonists, but also opportunities for invasion by weeds.

A. Bryophyte colonists on a dewatered shore

Some bryophytes can dominate newly exposed silty shores. These are the thallose hepatics *Riccia bifurca* (green rosettes), *R. ciliata* (pale rosettes), and *R. fluitans* (narrow thallus, below right), plus an unidentified moss (top). Greenland Reservoir, Otago, April 1986.

B. A choking sward of naturalised plants

This depression, intermittently ponded or dry, is here seen at a time when Mercer grass (*Paspalum distichum*) is dominant in the wet sward. This is a site for the rare native grass *Amphibromus fluitans* (Fig. 11A). Near Boggy Pond, Wairarapa, January 2000.

C. Naturalised plants colonising a strand line

Colonising terrestrial plants can be concentrated along a shore contour where a higher water level deposited seeds: woolly mullein (*Verbascum thapsus*) and Californian thistle (*Cirsium arvense*) grow along the same strand line. Mouse-ear hawkweed (*Hieracium pilosella*), dominant on the hillslope, has patchily invaded the uppermost turf zone. Glenmore, Canterbury, December 1993.

D. Relictual turf after weed invasion

A kettle shore where the turf has been invaded by a sward of naturalised grasses, especially sweet vernal (*Anthoxanthum odoratum*) and browntop (*Agrostis capillaris*), along with Scotch thistle (*Cirsium vulgare*). Spider Lakes, Ashburton River, Canterbury, December 2000.

Figure 8. Upland turfs

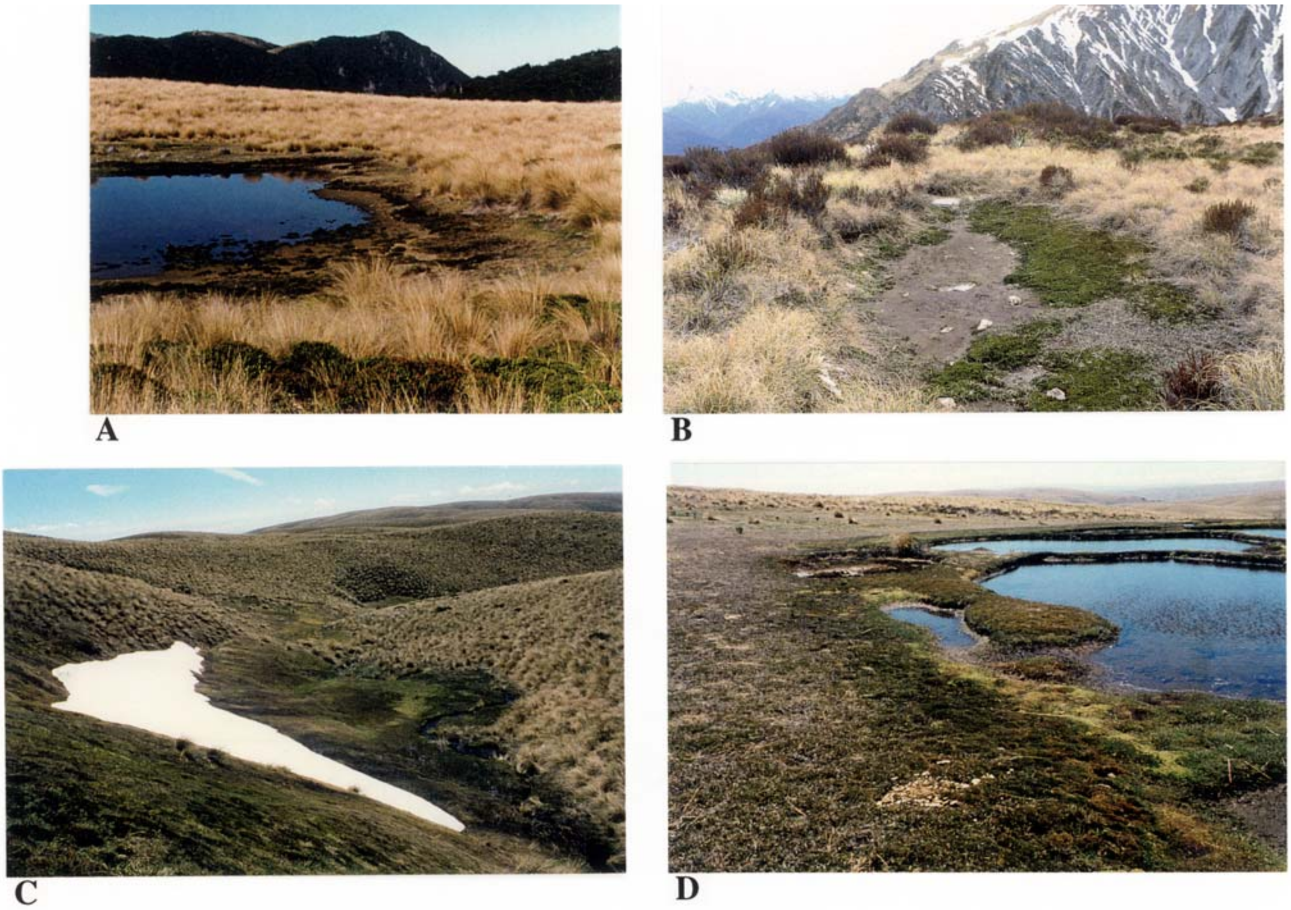

Figure 9. Colonising and invading plants

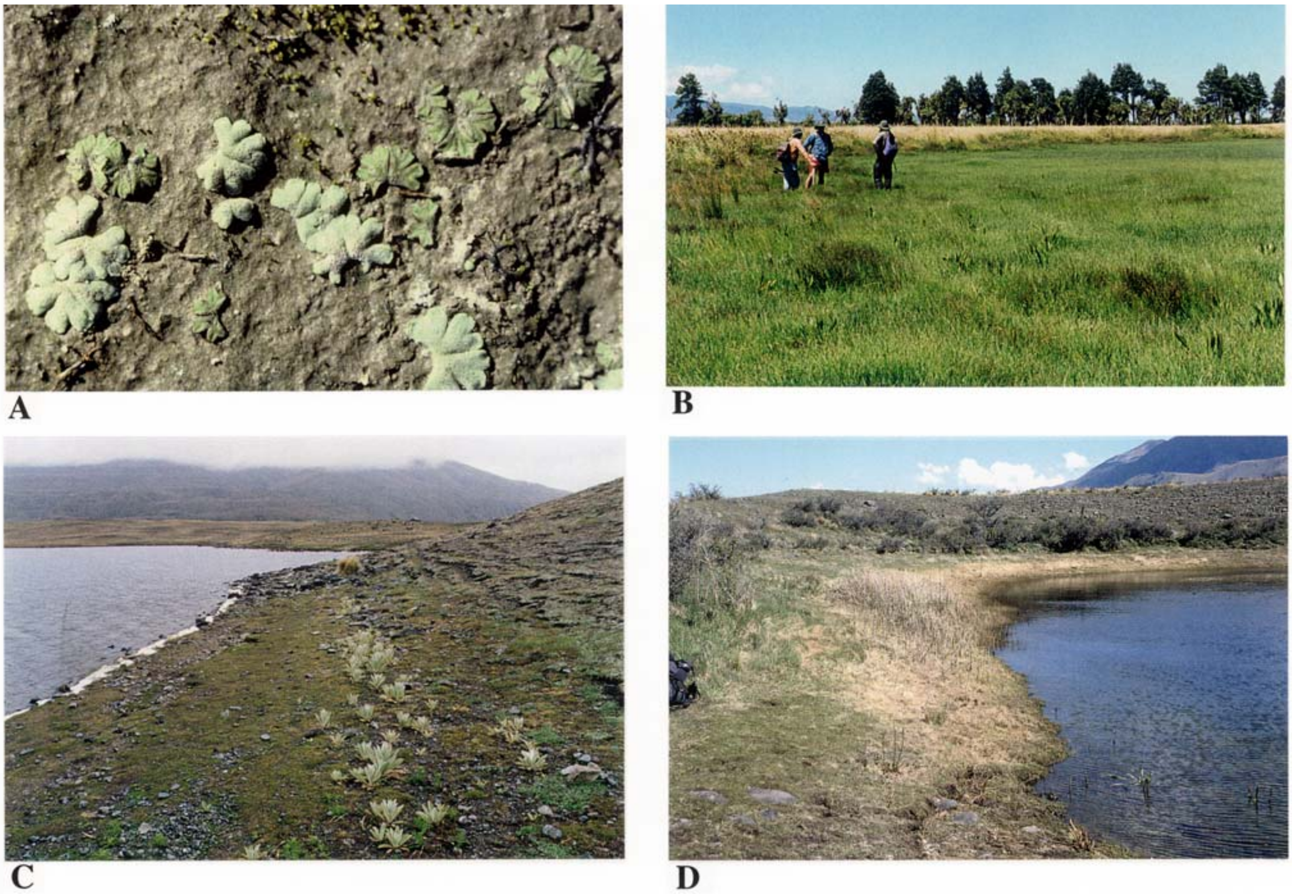

Figure 10. Impacts

- Turfs, agriculture, and recreational vehicles have an uneasy coexistence.
- Cattle and deer can be deleterious to turfs because they pug shorelines by fracturing turf and soil surfaces.
- Sheep, on the other hand, are less destructive, being less attracted to water margins and because they crop some of the naturalised plants. On drier turfs, their hooves create less disturbance.
- The vulnerability of turf communities to weeds is reduced in systems exposed to the twin seasonal stresses of water inundation followed by summer aridity. Equably moist systems, however, are susceptible to smothering by naturalised rushes, sedges, and grasses.

A. Sheep grazing on a turf shore exposed in autumn

The volume of edible herbage in a turf wetland cannot be great, but the pickings must be floristically diverse and may be nutritionally so. Most New Zealand turf wetland communities seem to have tolerated 1.5 centuries of grazing by introduced mammals, especially by sheep, just as they must have evolved in the presence of concentrations of grazing and defecating water birds. Lake Lyndon, Canterbury, March 2001.

B. Cattle trampling in a kettle

Impacts of trampling by cattle upon soft-substrate turf includes the mixing of soil and sediment layers, alterations to soil aeration, and the repeated rejuvenation of soil surfaces to the benefit of those plant species which recolonise rapidly, and the corresponding reduction in benefit to slower-growing turf plants. Ahuriri Valley, North Otago, January 2000.

C. Carex pedestals grazed by cattle

A marshy kettle margin where the basal pedestals of former tall-statured species of *Carex* have been reduced, probably by fire as well as cattle grazing, and are now clothed in *Carex gaudichaudiana* and pasture grasses, maintained as a short sward by cattle and waterbird grazing. Taller tufts are the naturalised soft rush, *Juncus effusus*. Ahuriri Valley, January 2000.

D. Soil enrichment and weeds at a deer carcass site

Deer skulls indicate a place where red deer carcases have been beheaded and gutted. The lush surrounding growth of the weedy grass *Poa annua* is a response to the increased soil nutrients. Such enrichment is not uncommon in turf wetlands: any localised patch of lush plant growth is usually found to be associated with dead animal remains. Coal River, Fiordland, March 1991.

E. Enrichment and weed growth associated with dairy effluent

A former meandering stream channel, reactivated as a watercourse carrying dairy shed effluent. Eutrophication to this degree is not common in freshwater turf wetlands, but this site illustrates some of the naturalised plant species which also become abundant in enriched closed depression turfs: *Alopecurus geniculatus, Ranunculus sceleratus, Juncus effusus, J. articulatus, Agrostis stolonifera*, and *Callitriche stagnalis*. Patearoa, Otago, February 1995.

F. Off-road vehicle impacts in turf

What more inviting place to do wheelies in a 4WD or off-road bike than a moist turf wetland that offers a challenge to not getting bogged, plenty of black muck to spray around, and a skin of vegetation that can be turned into wheel pattern ruts that show where you've been and what fun it all was? What more is there to say? Ocean Mail, Chatham Island, August 2000.

G. Grass and rush increase in an ungrazed exclosure

A recent study has compared two similar kettles, one continuing to be grazed by sheep, the other with an exclosure fence where sweet vernal grass (*Anthoxanthum odoratum*) and jointed rush (*Juncus articulatus*) have overtopped the former turf margin. The exclosure had become a choice site for a pair of paradise ducks to raise a brood. The pond edge has become muddied by the concentrated puddlings of the confined ducklings. Mt Barker Tarns, Canterbury, December 1998.

H. Weed growth after stock removal in a moist depression

Another exclosure illustrating rank growth of weedy rushes and sedges in a former turf community. Nenthorn, Otago.

Figure 10. Impacts

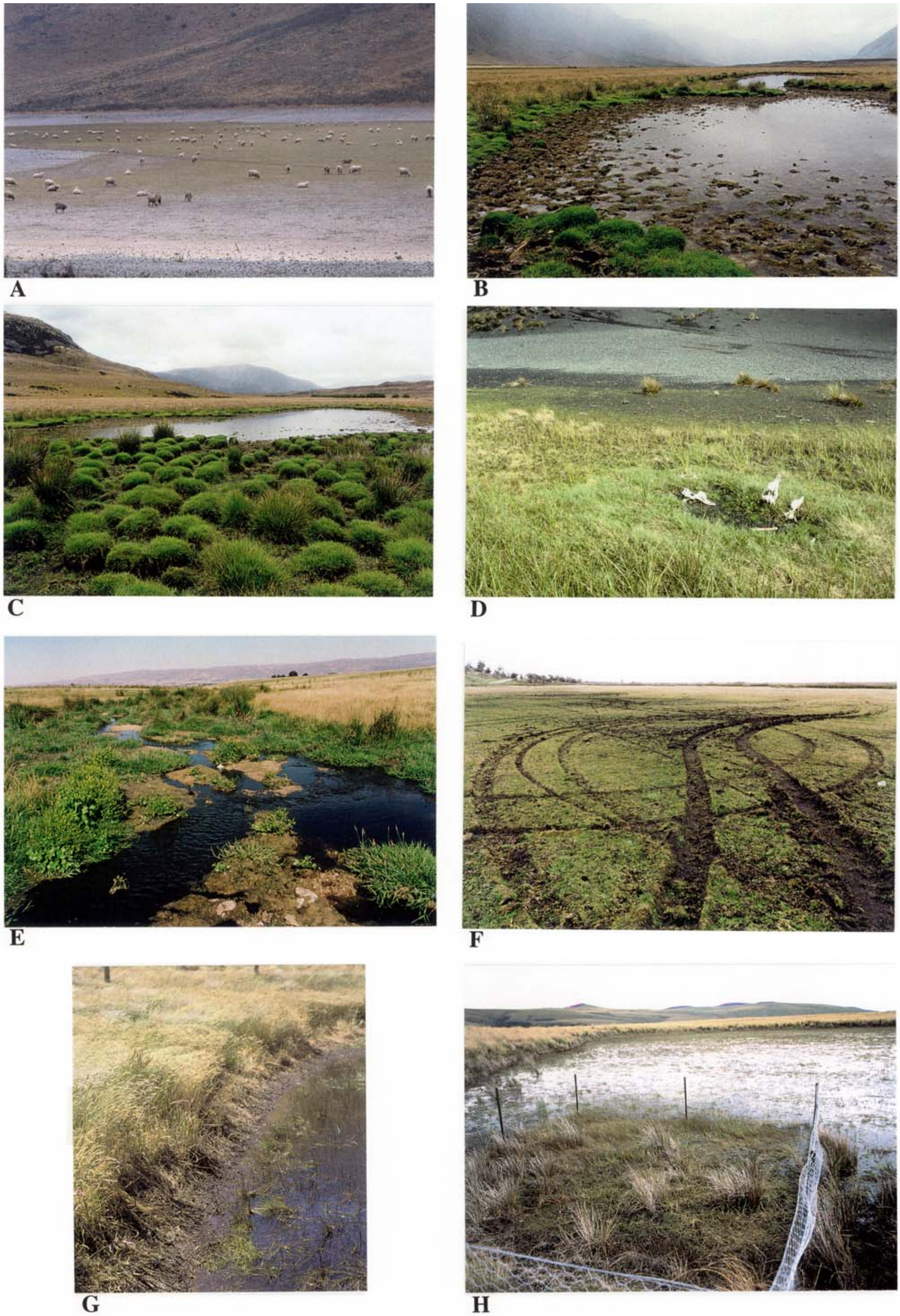

Figure 11. Threatened and uncommon plants

- Of the total of 511 New Zealand plant taxa listed as Threatened or Uncommon, 62 taxa (12.1%) occur in turfs of freshwater wetlands. The following are examples.

A. *Amphibromus fluitans*

A grass; family Poaceae; Critically Endangered; obligate turf plant; Auckland to mid-Canterbury.

Reference: Ogle (1987).

B. *Carex uncifolia*

A small sedge; family Cyperaceae; Naturally Uncommon, Sparse; facultative to turf habitats; Volcanic Plateau to Southland.

C. *Iphigenia novae-zelandiae*

A summergreen bulbous herb; family Liliaceae or Colchicaceae; Vulnerable; facultative to turf habitats; eastern North Island (at least formerly) to Southland.

D. *Deschampsia cespitosa*

A grass of tussock habit; family Poaceae; Vulnerable; facultative to turf habitats; North, South, Stewart, and Chatham islands. Reference: Mark & Dickinson (2001).

E. *Isolepis basilaris*

A small sedge; family Cyperaceae; Vulnerable; obligate to turf habitats; Hawke's Bay to Southland.

F. *Crassula ruamahanga*

A loose, mat-forming herb; family Crassulaceae; Naturally Uncommon, Sparse; facultative to turf habitats; Wairarapa to Southland. Reference: de Lange et al. (1998).

G. *Gnaphalium luteo-album* var. *compactum* (= *Pseudognaphalium* sp.)

A short-lived herbaceous cudweed daisy; family Asteraceae; Naturally Uncommon, Sparse; obligate to turf habitats; Marlborough to Canterbury.

H. *Cardamine lacustris* (= *Iti lacustris*)

A short-lived small cress; family Brassicaceae; Naturally Uncommon, Range Restricted; obligate to turf habitats; Southland. References: Garnock-Jones & Johnson (1987), Heenan (2002).

I. *Ranunculus recens* var. *lacustris*

A small tufted buttercup; family Ranunculaceae; Naturally Uncommon, Range Restricted; obligate to turf habitats; Southland.

Figure 11. Threatened and uncommon plants