Low-lying coastal meta-ecosystems and climate change: the example of western Uist, where *everything* is connected

Stewart Angus

Scottish Natural Heritage
Dualchas Nàdair na h-Alba
All of nature for all of Scotland
Nàdar air fad airson Alba air fad

Scottish Government

Nicola Sturgeon 29 April 2019

Roseanna Cunningham 14 May 2019

Scottish Climate Change Emergency declared

Reduction of carbon emissions policy is world-leading – what about the impact of climate change on Scotland?

2020 Challenge for Scotland's Biodiversity









A Strategy for the conservation and enhancement of biodiversity in Scotland

The Scottish Government
Riaghaltas na h-Alba

Ecosystem approach (SBS)

'A strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way, and which recognises that people, with their cultural and varied social needs, are an integral part of ecosystems'.

SBS quote from Convention on Biodiversity

1. Take account of how ecosystems work. Nature connects across landscapes, so we need to consider the broad and local scales. The capacity of ecosystems to respond to impacts and provide resources is not infinite. Ecosystems are dynamic so we must recognise that change will happen. By using up-to-date information, embracing adaptive management principles, and trying to sustain nature's multiple benefits, we can ensure that nature continues to contribute to Scotland's growth.

Biodiversity 2020

High level target of the Biodiversity Strategy is thus not biodiversity itself, but the environmental function on which biodiversity relies

SNH coastal research in Uist aimed at improving understanding of ecosystem function

Dynamic Coast

dynamiccoast.com

Detailed national examination of change at the coastal edge funded by Scottish Government

SNH work described here concerns coastal interior as well as edge, and how this entire ecosystem works


Lewis
Harris
North Uist
Benbecula
Skye
South Uist
Barra

Ocean and Coastal Management 165 (2018) 334–345

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Ocean and Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Beyond the meta-ecosystem? The need for a multi-faceted approach to climate change planning on coastal wetlands: An example from South Uist, Scotland

Stewart Angus

Scottish Natural Heritage, Great Glen House, Leachkin Road, Inverness, Scotland IV3 8NW, United Kingdom

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Sea level rise
Precipitation

ABSTRACT

Exposed, low-lying dune-wetland habitat complexes may have multi-faceted functionality that means they are effectively meta-ecosystems, where inter-acting nearshore, littoral, dune and freshwater components and processes must be considered together, sometimes in conjunction with interactions with contiguous inland habitats. The low-lying dune-machair-marsh-loch (lake) ecosystems of South Uist, Benbecula and North Uist in the Outer Hebrides of Scotland exhibit such functionality, and investigation of a former loch basin at the south end of South Uist has revealed an unexpected level of complexity that also identifies a particularly high exposure to climate change in the coastal hinterland, particularly in terms of water relationships, though the possibility of significant change to the coastal frontage must also be considered in contingency planning. This investigation is described by sector, then drawn together in the context of climate change. It is suggested that the environmental setting of the Uists conforms to the concept of the meta-ecosystem in spatial terms, but with additional legacy and socio-economic components, so that there is effectively a socio-spatio-temporal meta-ecosystem. It is vital

Meta-ecosystem

A meta-ecosystem is defined as a set of ecosystems connected by spatial flows of energy, materials and organisms across ecosystem boundaries

Loreau, M., Mouquet, N. & Holt, R.D. 2003. Meta-ecosystems: a theoretical framework for a spatial ecosystem ecology. *Ecology Letters*,6,673–679.

Meta-ecosystem

Offshore kelp beds

Nearshore marine ecosystem

Littoral

Strandline

Dune

Machair (including arable) – dry and damp

Transitional blackland

Marsh

Swamp

Saltmarsh

Saline lagoons

Lochs (high connectivity, historically higher)

Four issues

- Not sea level rise but Relative Sea Level Rise (RSLR)
- Much land is below MHWS (2.07 m)
- Dune ridge integrity critical
- Rainfall

Four issues

- Not sea level rise but Relative Sea Level Rise (RSLR)
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- Rainfall

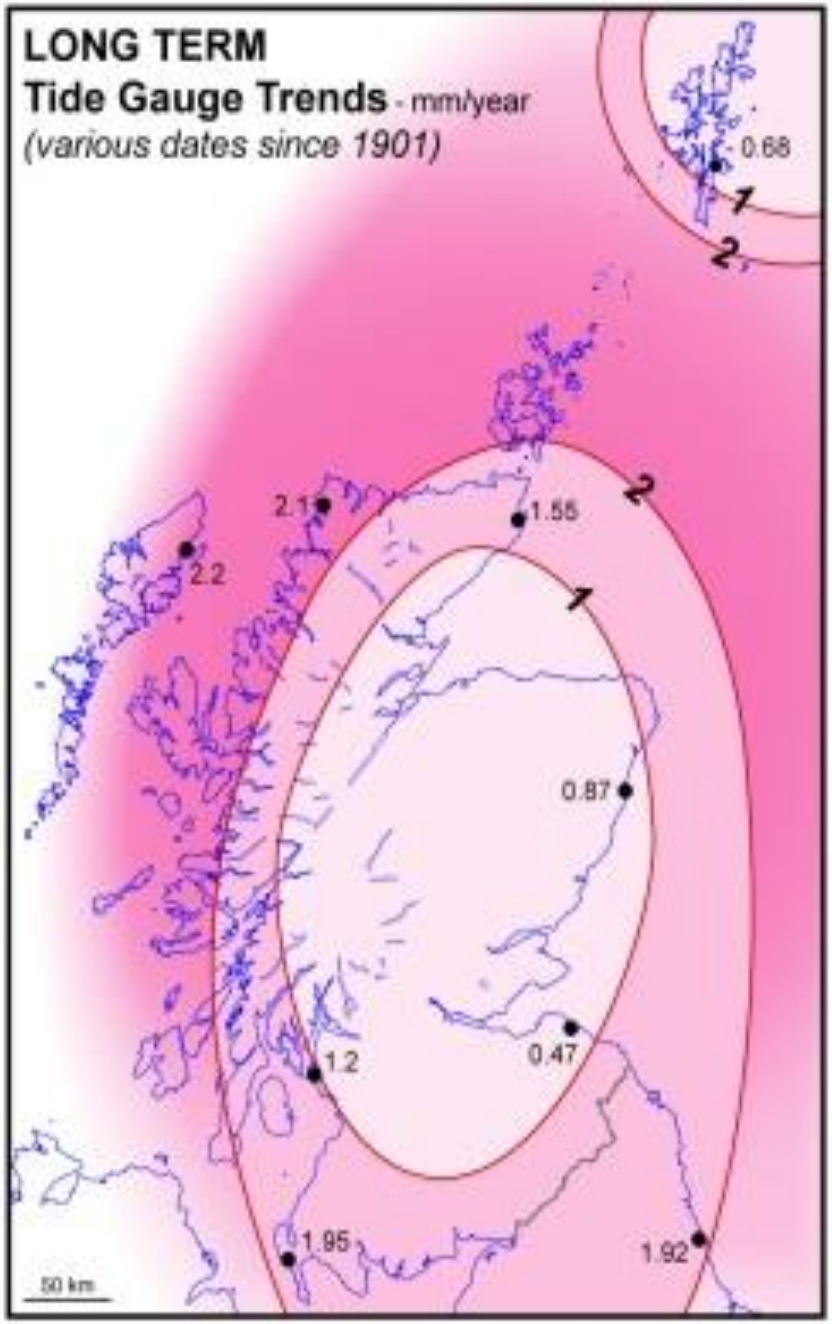
Problem is that these interact. In Uist **everything** is connected

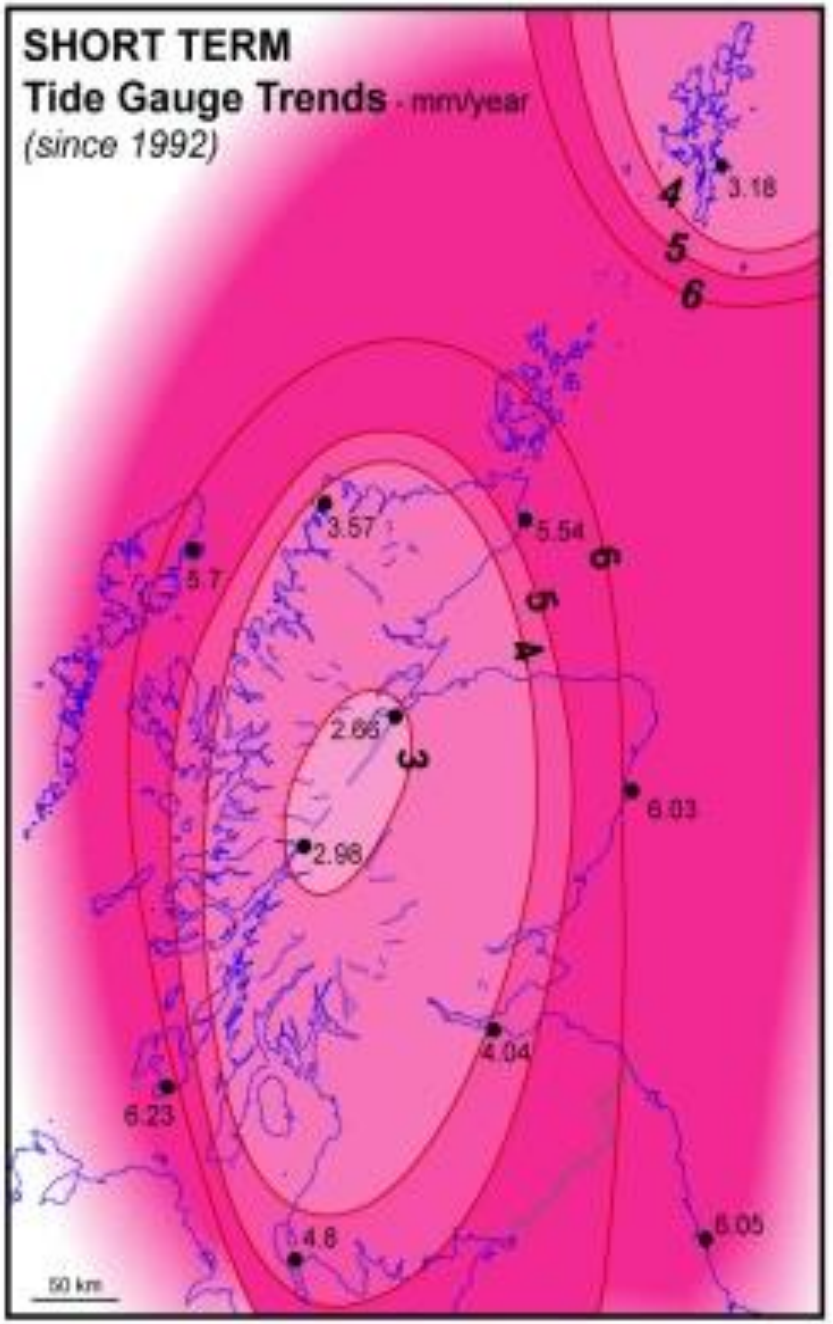
Coastal change

- How do you separate cyclical dynamism from trend?
- When does change become threat?
- How do you define threat?

Issue 1

- Relative Sea Level Rise (RSLR)





Source: Rennie & Hansom 2011

Threshold

"Such modern RSL rates also exceed the 3-4 mm/year thresholds identified as points beyond which widespread re-organisation of coastal landforms begins to be forced"

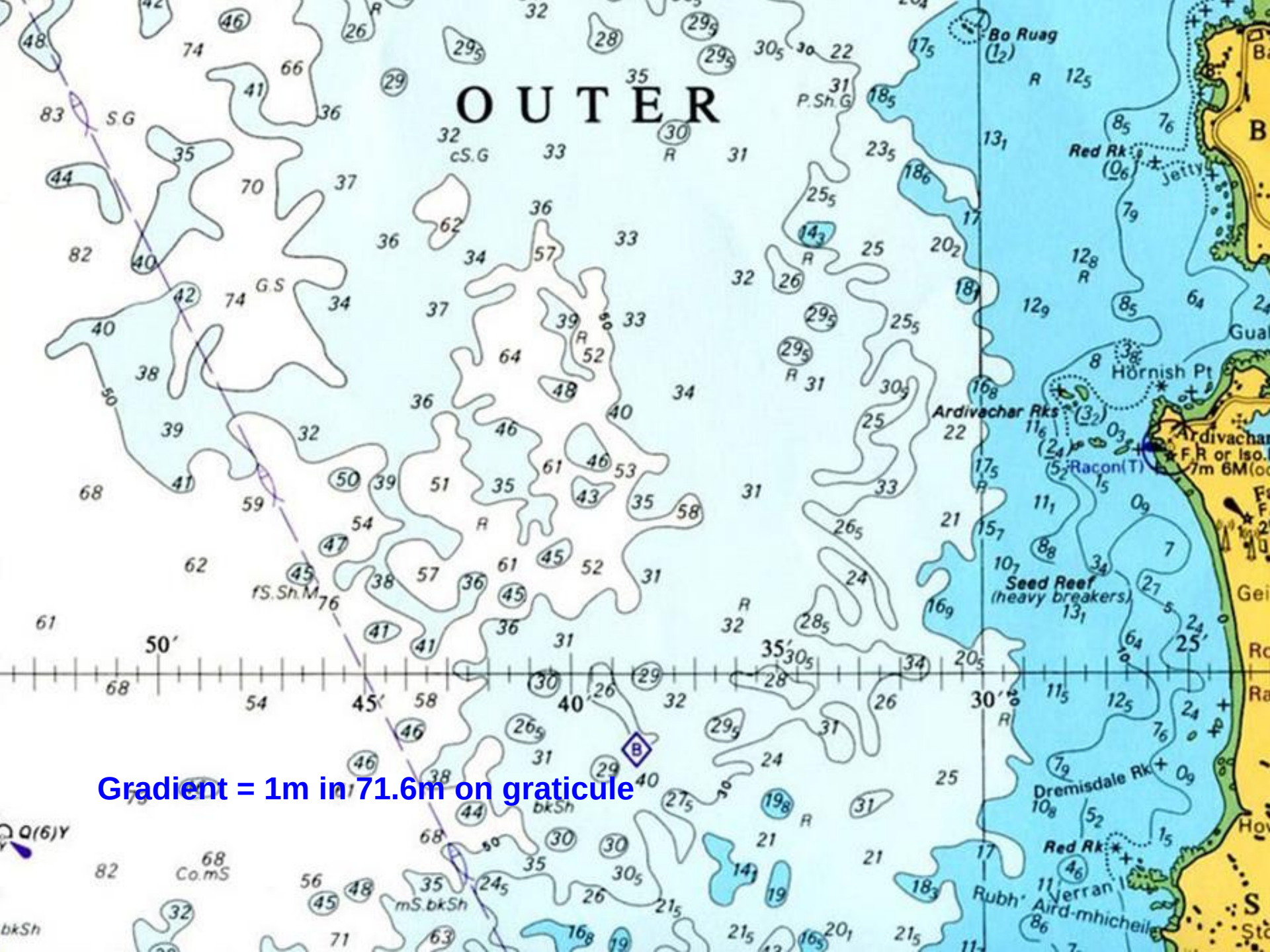
Rennie, A.F. & Hansom, J.D. 2011. Sea level trend reversal: land uplift outpaced by sea level rise on Scotland's coast. *Geomorphology*,125,193-202.

Charter of Inchaffrey 1389

Godfrey of the Isles, lord of Uist, makes known that he has given, granted, and confirmed for the weal of his soul, etc., and in Honour of the Holy Trinity and St Mary glorious virgin, to Inchaffrey, in pure and perpetual alms, the chapel of the Holy Trinity in Uist, and the whole of the land of Karynche, and four pennylands in Ylara between Hussaboste and Kanusorrath …

Sgeir Hussabost, Baile Sear – settlement disappeared 15th century?

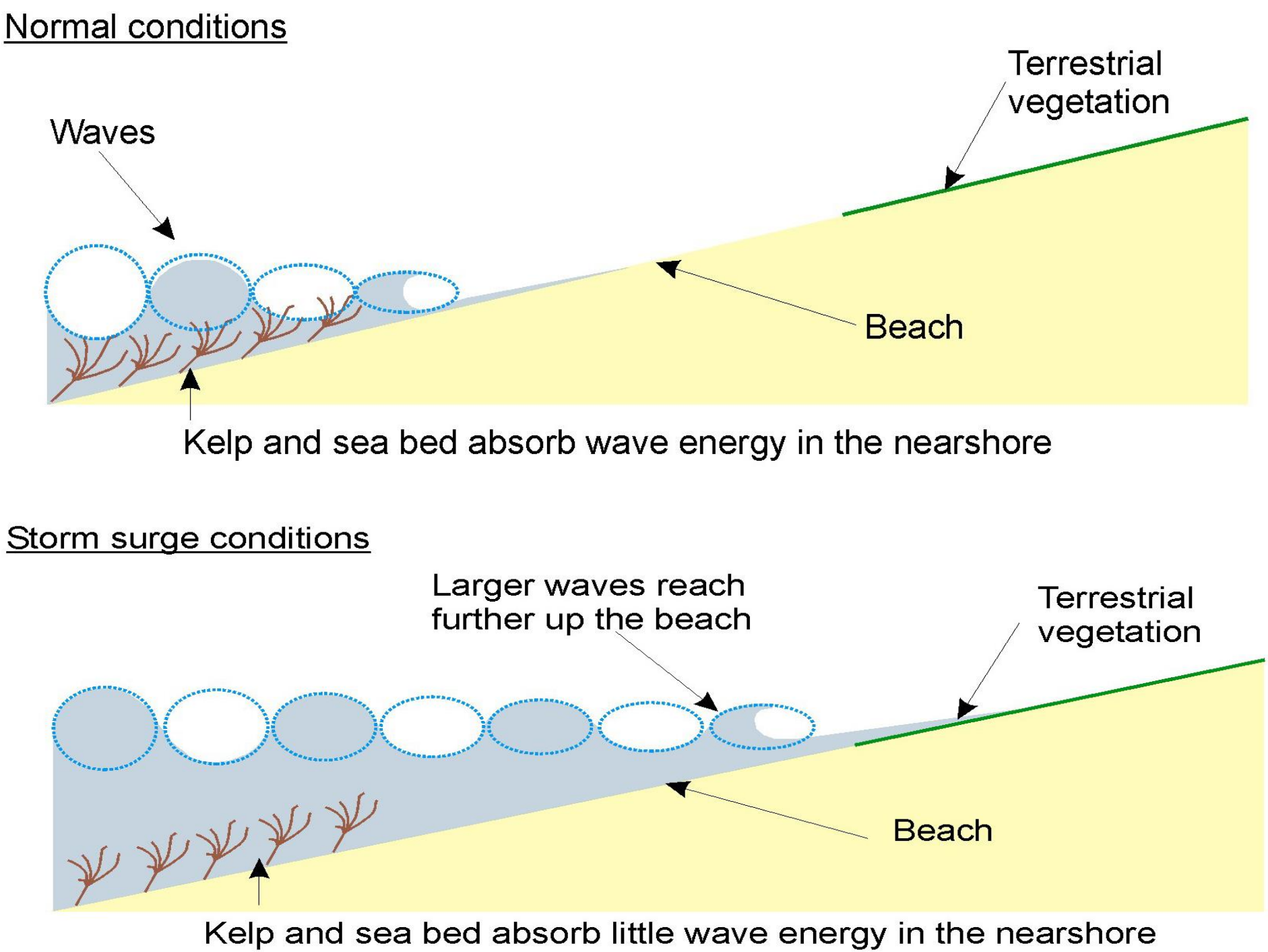
Baile Sear, North Uist


OUTER
Bo Ruag
(12)
Red Rk
(06)
Jetty
Hornish Pt
Ardivachar Rks
(32)
(24)
Racon(T)
Seed Reef
(heavy breakers)
Dremisdale Rk
Red Rk
Rubh' Aird-mhicheil
Verran I
50'
45'
40'
35'
30'
25'
Gradient = 1m in 71.6m on graticule

Kelp biodiversity

Kelp forests along temperate and polar coastlines represent some of most diverse and productive habitats on the Earth

Smale, D.A., Burrows, M.T., Moore, P., O'Connor, N. & Hawkins, S.J. 2013. Threats and knowledge gaps for ecosystem services provided by kelp forests: a northeast Atlantic perspective. *Ecology & Evolution,* 3 4016–4038.


Normal conditions
Terrestrial vegetation
Waves
Beach
Kelp and sea bed absorb wave energy in the nearshore
Storm surge conditions
Larger waves reach further up the beach
Terrestrial vegetation
Beach
Kelp and sea bed absorb little wave energy in the nearshore

Kelp

- With seabed, removes huge proportion of wave energy
- Progressive disengagement of wave base from seabed and kelp as sea level rises
- Light not a limiting factor in Uist – kelp need not grow to meet rising sea level
- Waves will hit coast with more energy
- Huge role in ecosystem function

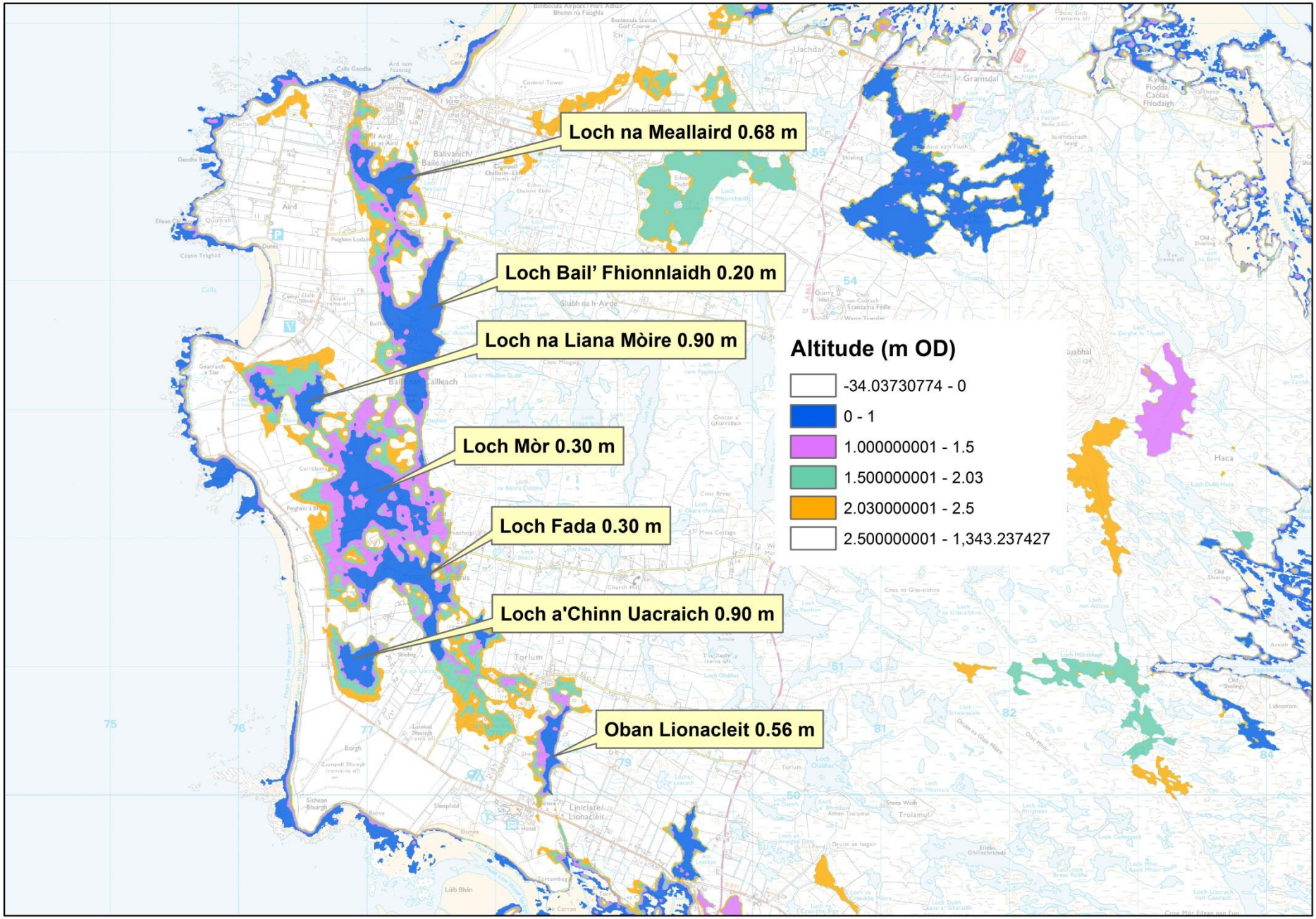
Issue 2

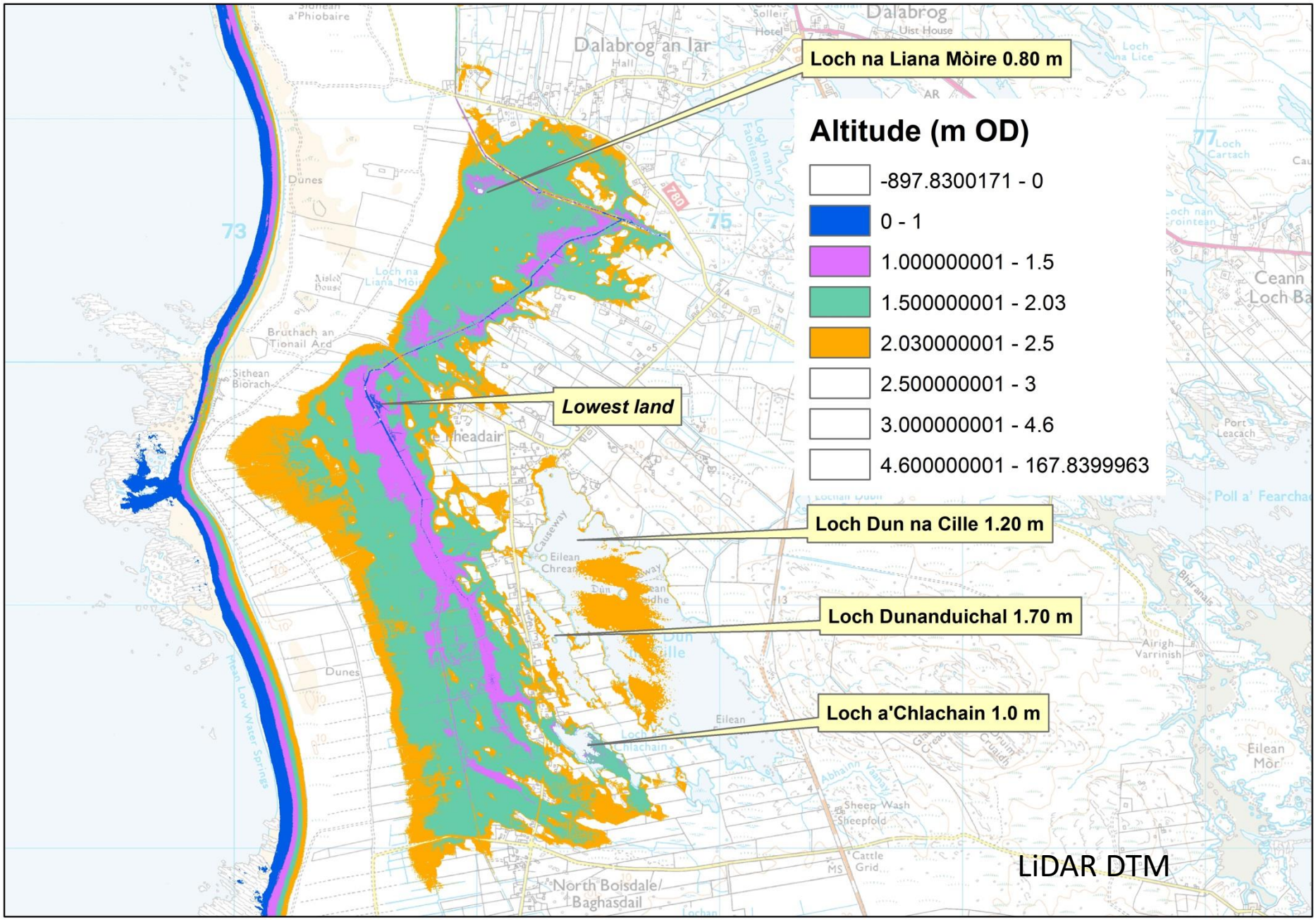
Low-lying land

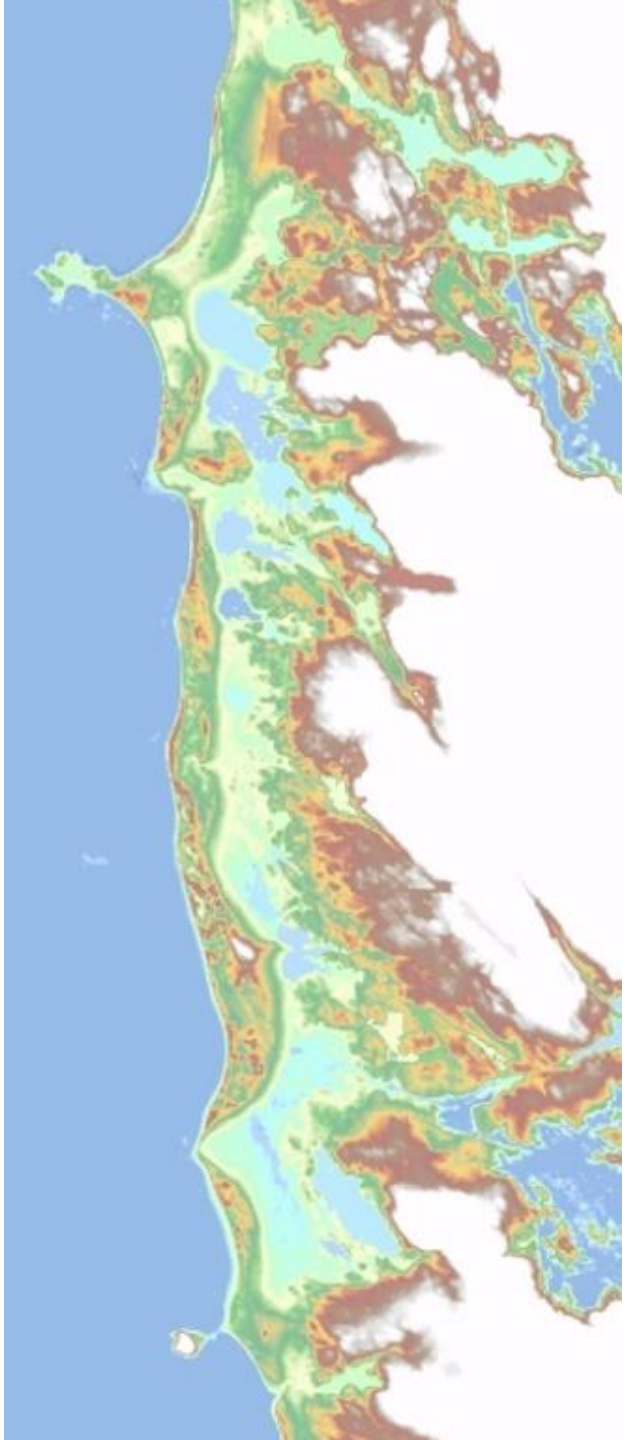
Mean High Water Spring (MHWS) in Uist around 2.07 m OD

Note that this is a mean, not an upper limit. Much land in Benbecula and South Uist below 2.07 m, lowest land at 0.97 m (Cille Pheadair)

Low gradients with negative slope


Loch na Meallaird 0.68 m
Loch Bail' Fhionnlaidh 0.20 m
Loch na Liana Mòire 0.90 m
Loch Mòr 0.30 m
Loch Fada 0.30 m
Loch a'Chinn Uacraich 0.90 m
Oban Lionacleit 0.56 m
Altitude (m OD)
-34.03730774 - 0
0 - 1
1.000000001 - 1.5
1.500000001 - 2.03
2.030000001 - 2.5
2.500000001 - 1,343.237427

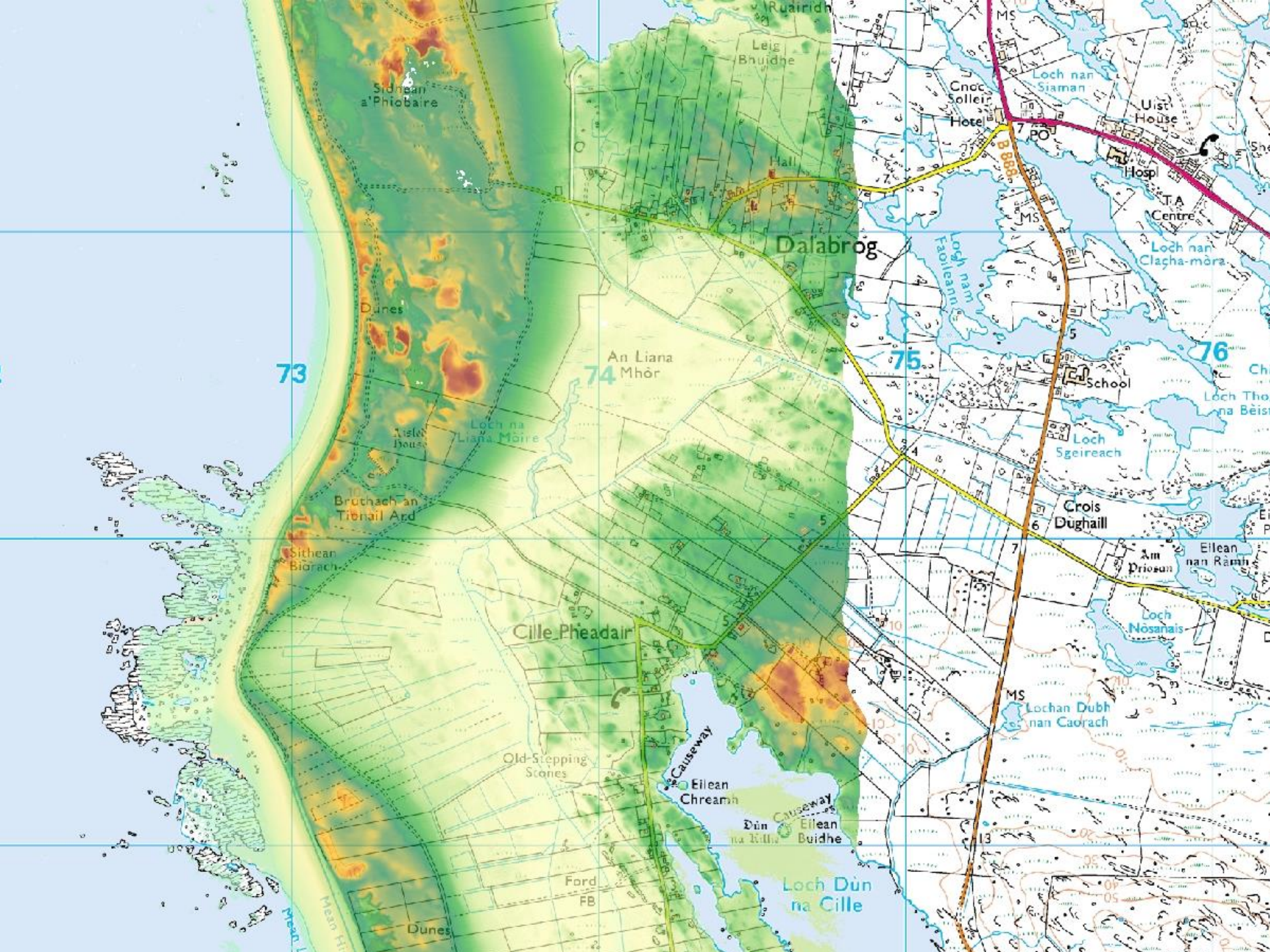

Loch na Liana Mòire 0.80 m
Altitude (m OD)
-897.8300171 - 0
0 - 1
1.000000001 - 1.5
1.500000001 - 2.03
2.030000001 - 2.5
2.500000001 - 3
3.000000001 - 4.6
4.600000001 - 167.8399963
Lowest land
Loch Dun na Cille 1.20 m
Loch Dunanduichal 1.70 m
Loch a'Chlachain 1.0 m
LiDAR DTM

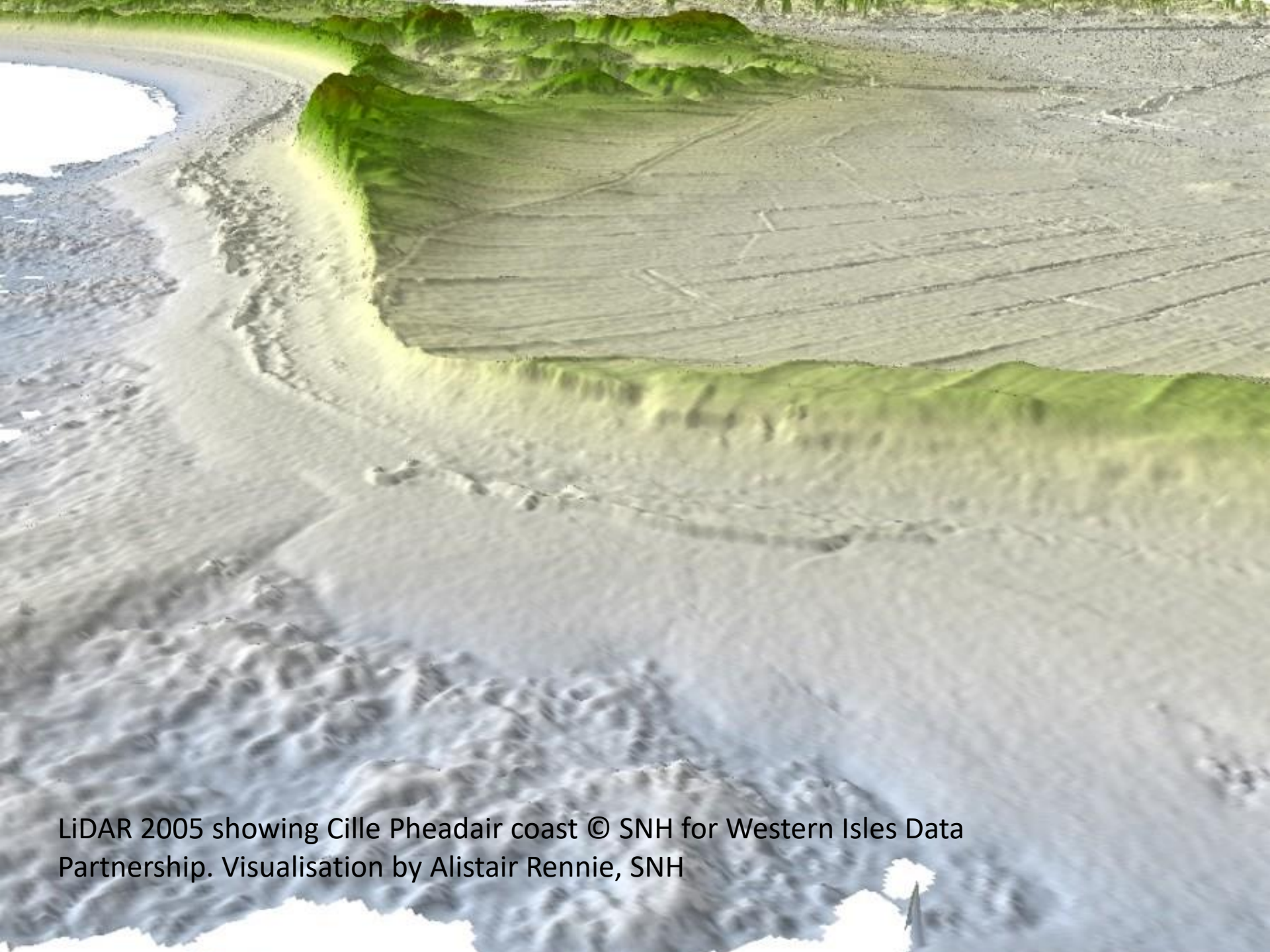


Loch Dalbrog

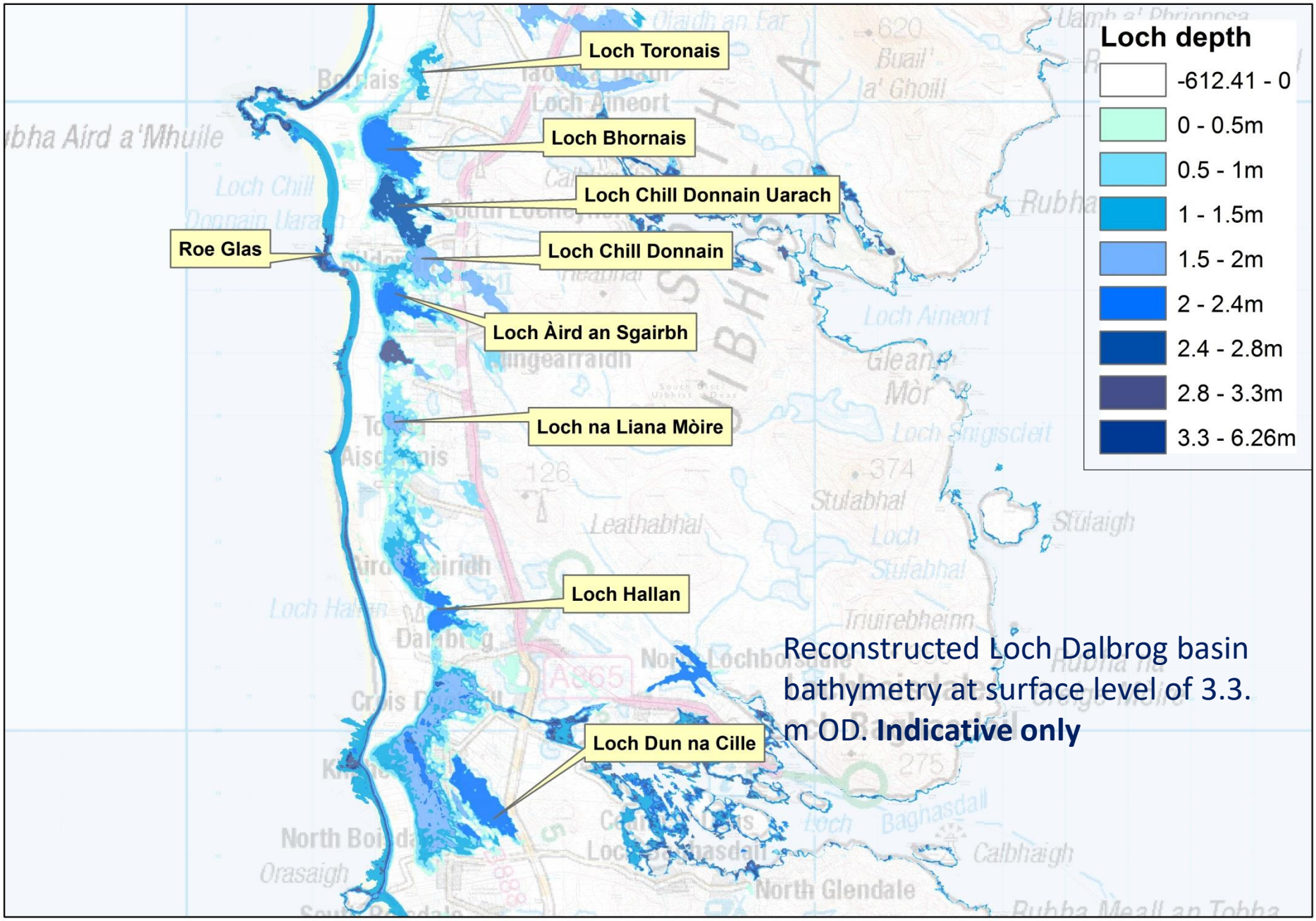
Connections from Boisdale to Loch Toronais

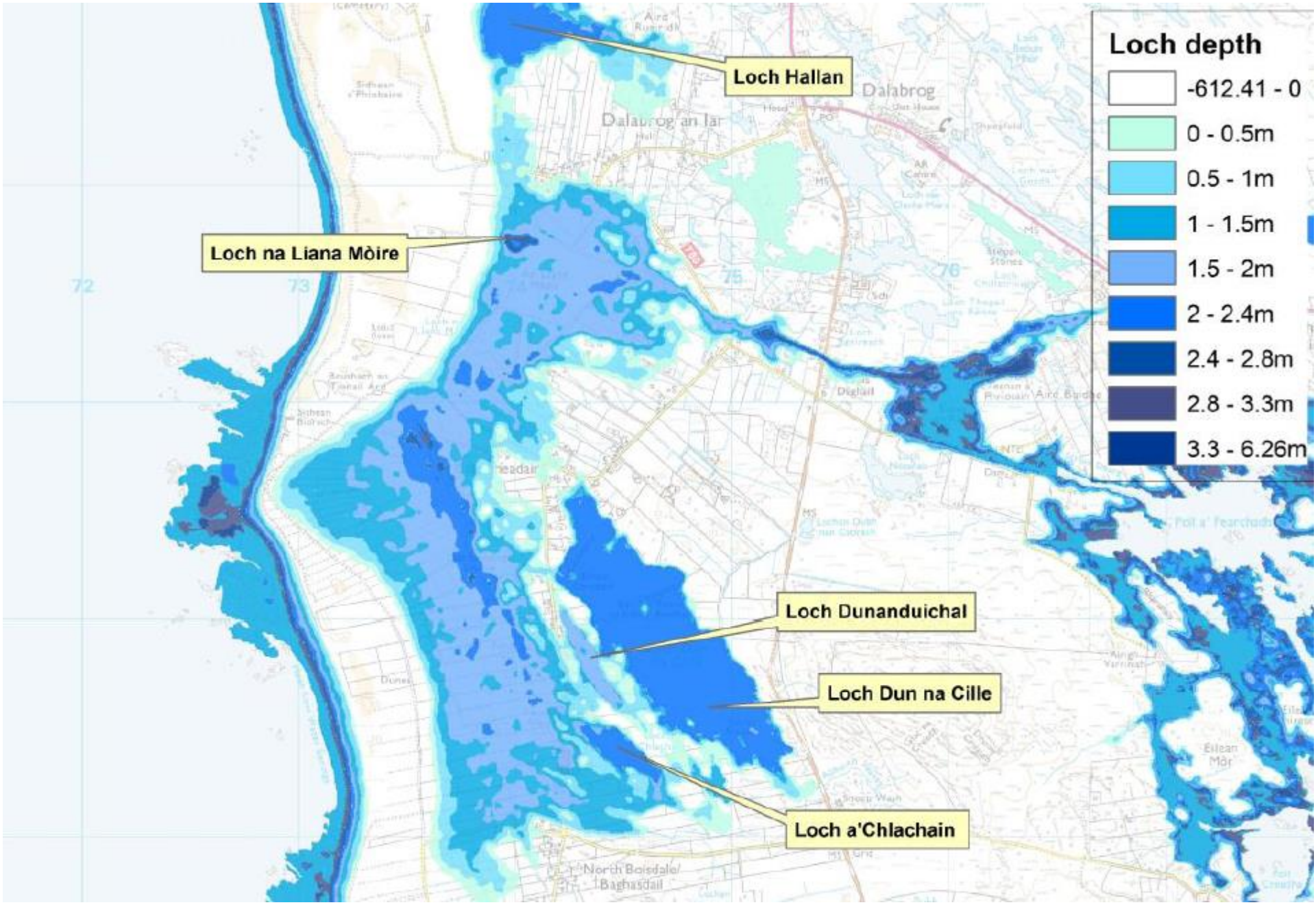
Loch Dalbrog itself was large loch at south end – now mostly gone due to drainage


Sidhean a'Phiobaire
Leig Bhuidhe
Cnoc Solleir
Hotel
Loch nan Siaman
Uist House
PO
Hall
Hospl
T A Centre
Dalabrog
Loch nan Clacha-mora
Loch nam Faoileann
Dunes
73
An Liana Mhor
74
75
76
School
Loch Sgeireach
Loch na Liana Moire
Bruthach an Tionail Ard
Crois Dughaill
Sithean Biorach
Eilean nan Ramh
Loch Nosanais
Cille Pheadair
Lochan Dubh nan Caorach
Causeway
Old Stepping Stones
Eilean Chreamh
Dun na Killie
Eilean Buidhe
Ford
FB
Loch Dun na Cille
Dunes



LiDAR 2005 showing Cille Pheadair coast © SNH for Western Isles Data Partnership. Visualisation by Alistair Rennie, SNH


Loch Toronais
Loch Bhornais
Loch Chill Donnain Uarach
Roe Glas
Loch Chill Donnain
Loch Àird an Sgairbh
Loch na Liana Mòire
Loch Hallan
Loch Dun na Cille
Loch depth
-612.41 - 0
0 - 0.5m
0.5 - 1m
1 - 1.5m
1.5 - 2m
2 - 2.4m
2.4 - 2.8m
2.8 - 3.3m
3.3 - 6.26m
Reconstructed Loch Dalbrog basin bathymetry at surface level of 3.3. m OD. **Indicative only**


Loch depth
-612.41 - 0
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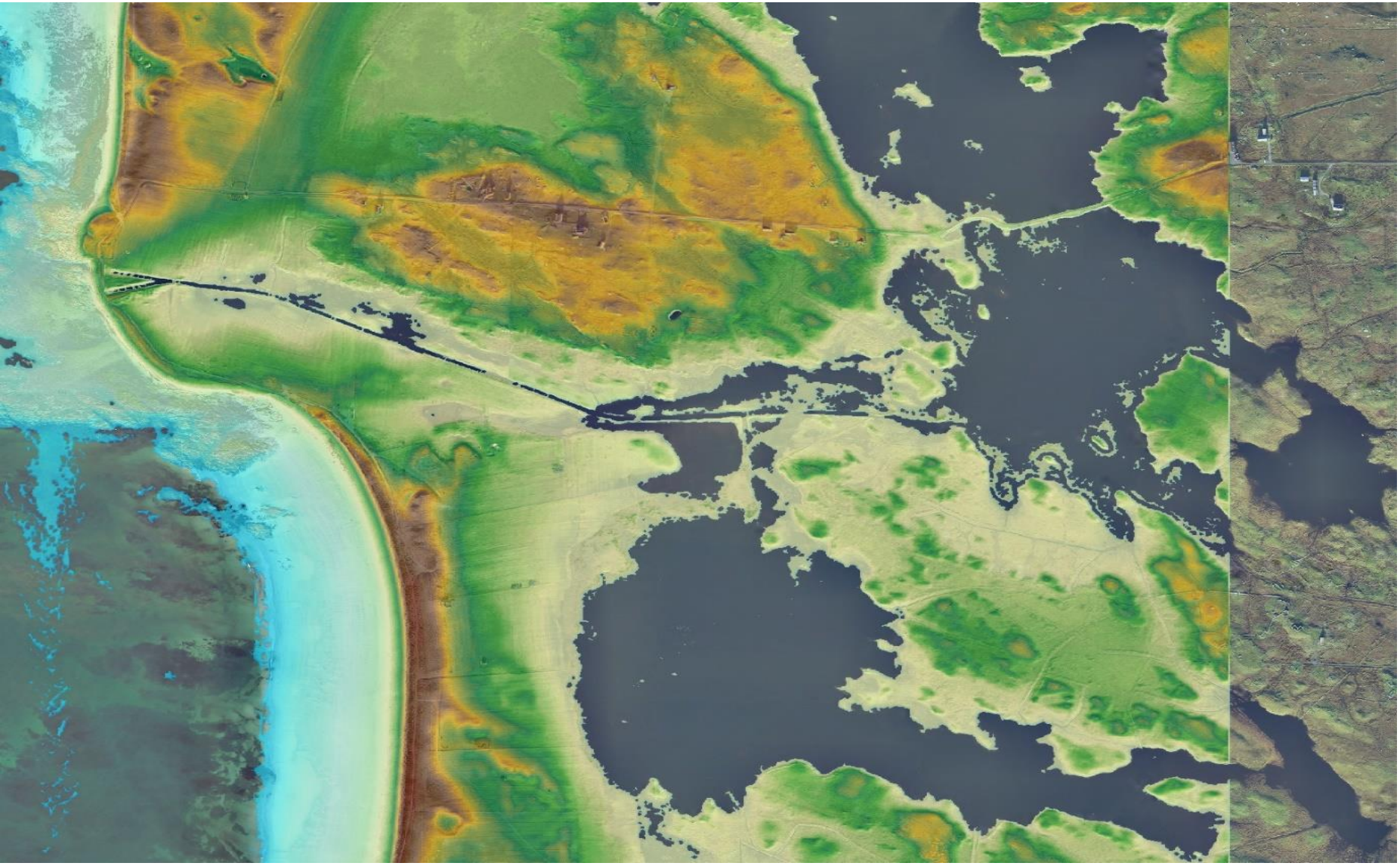
2.4 - 2.8m
2.8 - 3.3m
3.3 - 6.26m
Loch Hallan
Loch na Liana Mòire
Loch Dunanduichal
Loch Dun na Cille
Loch a'Chlachain
Dalabrog
Dalabrog an Iar
North Boisdale/
Bagh a Deas



Lochs and people

- Lochs originally used for navigation
- Navigability enhanced by canals
- Lochs later drained for agriculture
- Crofts set out on drained loch beds

Issue 2

Low-lying land – up to 1 m below MHWS

Mean High Water Spring (MHWS) in Uist around 2.07 m OD

If land is lower than the sea when the tide comes in, you **have** to have a barrier. That barrier is the dune ridge.

Issue 3

Low-lying land separated from sea by dune ridge

If the sea gets in, it will introduce salt water to the lochs and water table. If an organism is not already adapted to this, the salt water is toxic – to wildlife and crops.

Issue 3

Sea water already gets past the dune barrier – at Baile Sear, Howmore, Loch Bi and all saline lagoons.

Sometimes there is no dune ridge

As sea level rises, the amount of salt water getting in will increase

Lochs in North Uist

Water table

Seasonal lochs behind dunes seldom have inflow or outflow

Clearly surplus water table, and believed to interact with subsoil water table, so salinity equalises

Excellent adaptation to short-term marine flood, but problematic for prolonged marine flood

Meta-ecosytem + Legacy

- Extensive old loch and canal network
- Possible old links between catchments
- The loch basins are where modern flood water will accumulate
- Possible that almost all of western South Uist is connected at water table level – we do not know how that water table functions

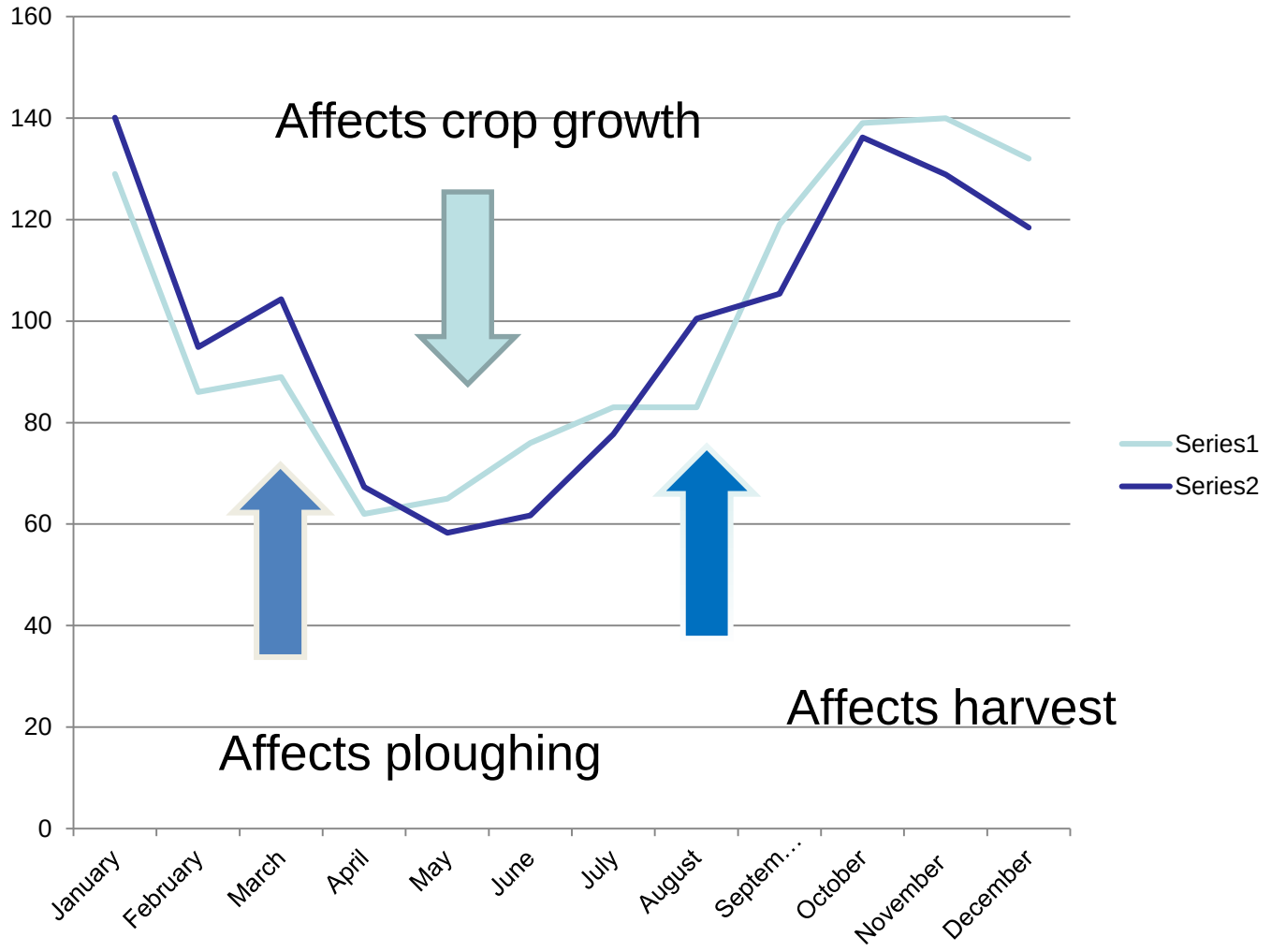
Issue 4

Getting rid of rainfall

Water

- Has more than just level
- Velocity
- Suspended sediment (velocity-related)
- Chemistry – pH and salinity
- Biota

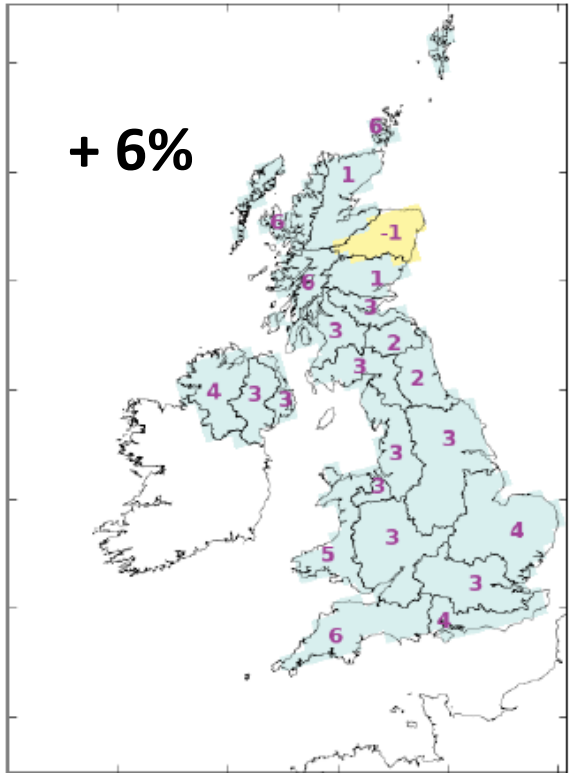
Benbecula & S Uist precipitation

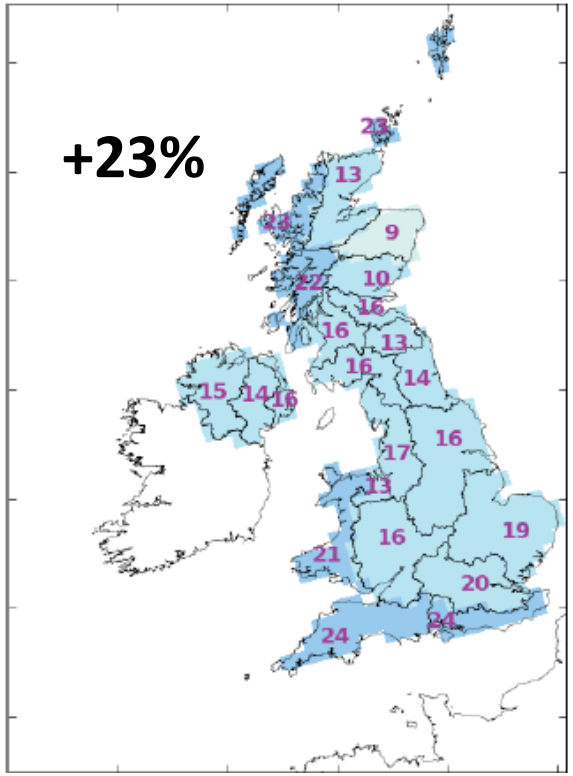


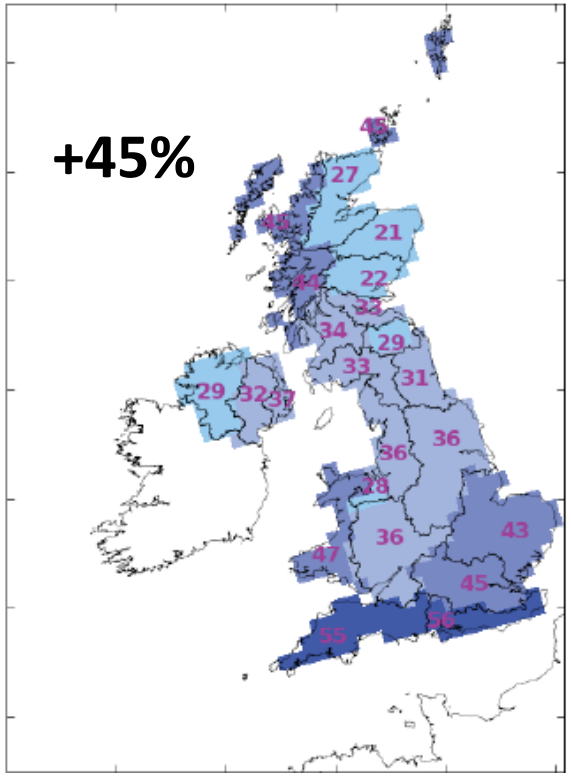
1951-1980 1203 mm

1981-2010 1194 mm

UKCP09 estimates of the percentage change in winter mean precipitation, for the 2080s under the Medium emissions scenario, at 3 probability levels







10%

50%

90%

Source: Kay *et al.* 2011

2005 storm

Little impact damage on natural heritage

Major damage to infrastructure, 5 fatalities

4.6 m marine flood (MHWS 2.07 m)

Marine flood interaction with water table

No rainfall

Issue 4

Ability of drains to discharge has been compromised since their construction as low tides are not as low as they used to be. There will also be less time during the tidal cycle for water discharge to the sea. This problem will become worse as Relative Sea Level Rise progresses.

Historical legacy

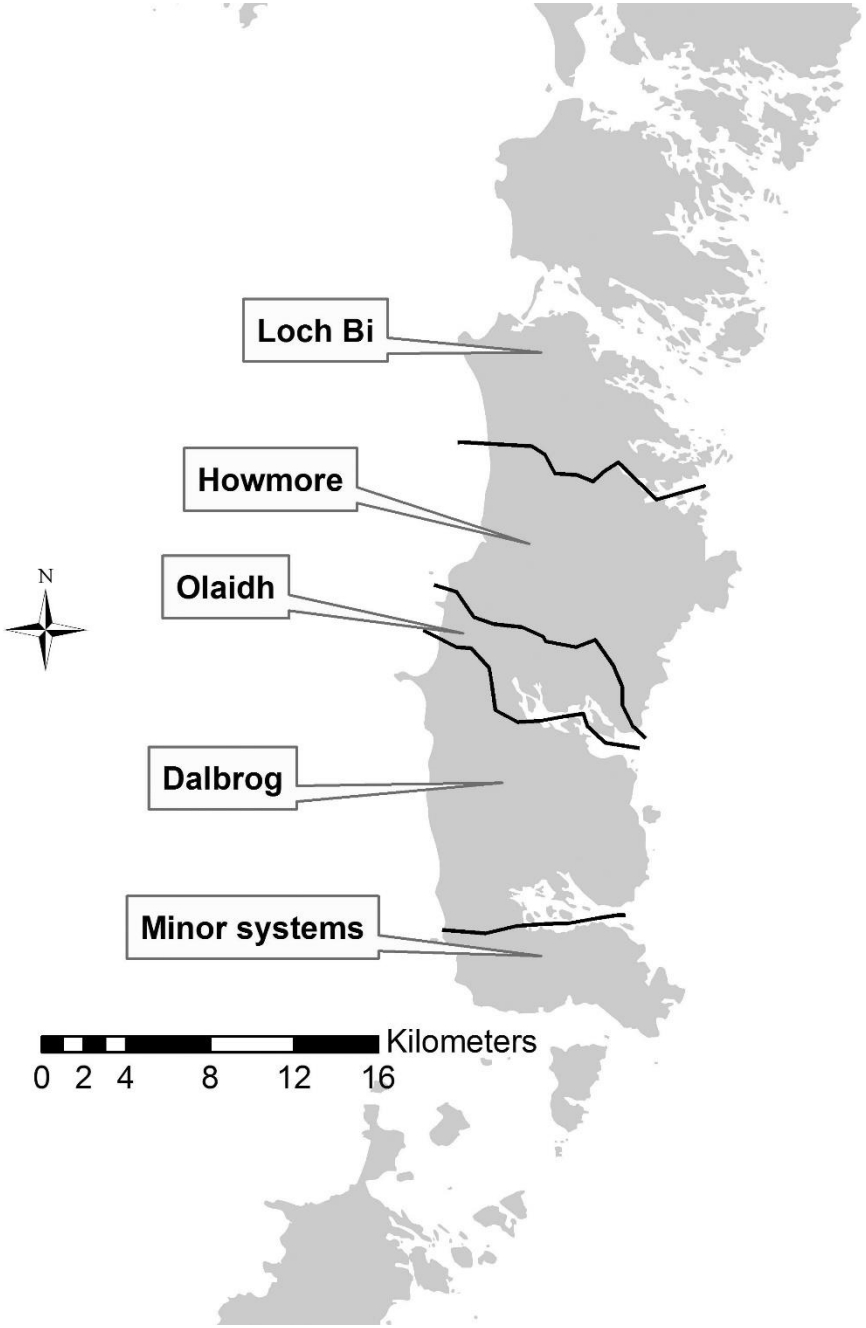
- Need to maintain drains and take heed of reducing effectiveness with RSLR and increased precipitation
- Need to appreciate importance of drain structure in maintenance
- To inform future planning for water and climate change, we have to understand the past

Inland lochs?

11 lake/loch types in UK

All 11 occur between Sound of Harris and Sound of Barra

9 of the 11 occur below 5m OD


Loch Bi
Howmore
Olaidh
Dalbrog
Minor systems
N
Kilometers
0 2 4 8 12 16

Uist connectivity

- Habitats connected in west-east transition
- Kelp beds protect coasts and drive inshore ecosystems, beach-cast kelp enhances littoral productivity. Kelp used as fertiliser on crops
- Water connects all low-lying habitats, both on surface and within water table
- Amount of water and its salinity critical to ecosystem function and socio-economic factors

Canals and drains

- Artificial networks of drains link lochs to each other, and old canals link water tables of adjacent basins – massive aquatic connectivity
- Lochs linked to sea via drains, rivers and saline lagoons
- Huge potential for water table salination in South Uist as sea level rises – will affect machair crofting and machair biodiversity – and lagoons

Uist meta-ecosystem

- High rural population density
- Complex of habitats, all with high nature conservation importance
- Artificially established and maintained landscape
- Low-lying, often negative gradient
- High (often surplus) winter water table
- Loch and water table levels held low by elaborate drainage network

Uist connectivity

- Meta-ecosystem is where interacting nearshore, shore, dune, marsh and freshwater components and processes must be considered together, sometimes in conjunction with interactions with contiguous inland habitats – geographical connectivity
- Uist adds a socio-economic element (crofting) and, in the form of the legacy of canals and drains – historical connectivity
- Uist: beyond the meta-ecosystem?

Uist connectivity

- Meta-ecosystem is where interacting nearshore, littoral, dune and freshwater components and processes must be considered together, sometimes in conjunction with interactions with contiguous inland habitats – spatial connectivity
- Uists add a socio-economic element and, in the form of the legacy of canals and drains, a temporal one
- Uists: beyond the meta-ecosystem?

Terrestrial, freshwater & marine habitats, climate, history, archaeology, socio-economics, culture

History will determine future

Climate change has huge implications for Uist

To know where we are going we need to know where we have been

Environmental linkage and human linkage are extreme in Uist

Everything is connected

Uist adaptation

- Most habitats can roll back (but will they?)
- But people cannot roll back their land holding – this is fixed
- People can accept ideas if they have some role in their development
- Even a population that accepts principle of adaptation might have no choice but to resist
- Resistance generates new problems

The coast at risk

- Habitats can adapt
- Human adaptation needs to be very well planned as it is expensive
- Ill-planned adaptation to climate change could be more of a problem on the coast than the climate change itself
- Planning needs **information** and **expert advice**

Future Uist

- Natural environment will adjust …. naturally
- A lot of this environment is not natural, and is the result of centuries of human intervention
- Human interaction with this environment is at risk, meaning the environment is at risk
- By working in partnership, we can optimise the resilience of the environment and those who live and work in it

Beyond the meta-ecosystem?

- Terrestrial habitat connectivity
- Marine ecosystem + terrestrial
- Inland aquatic links to these
- Historical legacy – canals and drains
- Crofting socio-economics

All interact

We need to understand this connectivity to plan effective adaptation and enhancement of resilience