The eco-hydrology of wet dune slacks: experience from Winterton Dunes, Norfolk

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What are dune slacks?

- Damp or wet hollows left between dunes, where the groundwater reaches or approaches the surface of the sand
- Seasonally fluctuating water table, which usually reaches a maximum in winter and spring, and drops in summer
- Primary slacks originate from sandy beaches cut off from the influence of the sea by new foredunes, particularly in prograding systems
- Secondary slacks result from blowouts or the landward movement of dune ridges in eroding systems
- Some research on UK systems; knowledge depends heavily on the Netherlands/Wadden Sea area (see English Nature Research Report **696**)

Conservation importance

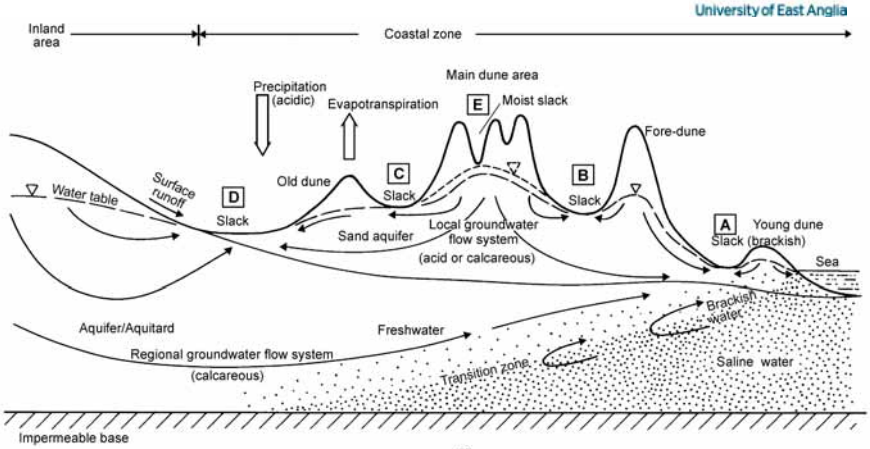
- EU Habitats Directive Annex 1 dune habitats that are sensitive to water abstraction. European habitat features 2190 'Humid dune slacks' and 2170 'Dunes with *Salix repens* ssp. *argentea,* or *Salicion arenariae*' (NVC SD13, 14, 15, 16, 17)
- Annex 2 protected species, particularly:
  - Natterjack toad (*Bufo calamita*),
  - Fen orchid (*Liparis loeselii* var. *ovata*)
  - Petalwort, thalloid liverwort (*Petallophyllum ralfsii*)

- Fewer than 1000 ha remain in England and Wales
- Threatened by water abstraction, afforestation, recreation (golf links, tourism) and atmospheric N deposition

Disturbance and species diversity

- Fluctuation in water table – alternating selection pressures of waterlogging and drought require opposite adaptations
- Physical disturbance of blowing sand (and tides in fore dunes)
- Successional changes to internal environment – decalcification and concomitant hydrochemistry, organic matter accumulation
- Changing successional mosaic of dune slack hydrological types
- Hence diversity is high, but few endemic species - many also occur in calcareous fens, fen meadows, and other wetlands

Hydrological controls on humid dune slack formation



A Seaward, young dune slack
B Rain-fed dune slack
C Flow-through dune slack
D Boundary dune slack
E Moist dune slack

Significance of the slack water table

- In coarsely textured, porous, sandy substrates, the depth of the dune water table has immediate consequences for plants
- About 28% by mass of water can be held against gravity in freshly blown sand. Substantial incorporation of organic matter can increase it to only about 50%
- Sand remains saturated 10-15 cm above the free water table and capillary action carries substantial amounts of water up to 45 cm above it
- The water table has little influence on the moisture content of sand 1 m above it
- Flooded soils become anoxic and reducing, requiring anatomical and metabolic adaptation in their species

Hydrochemistry of dune slacks

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Principal controls:

- pH of dune sand dependent on carbonate (shell) content giving acidic or calcareous conditions
- pH (alkalinity) of local and regional groundwater flow systems creating base-rich conditions
- Flux of anoxic and Fe-rich water important for vegetation succession
- Regular supply of mineral-rich groundwater to develop microbial/algal mats and stabilise longevity of pioneer stages
- Salinity distribution
- Expect spatial and temporal variations in hydrochemical conditions in response to fluctuating water levels

Successional change

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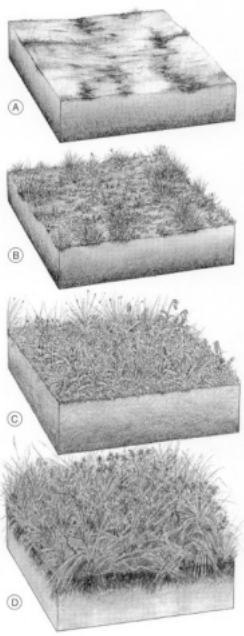

(A) Pioneer phase - small pioneer species establish on an almost bare soil, covered with a thin layer of green algae and laminated microbial mats

(B) Higher plants adapted to very low nutrient availability colonize

(C) Moss layer of pleurocarpous bryophytes develops, and typical dune-slack species become established

(D) Rapid accumulation of organic matter, increase of tall grasses and shrubs appear, which leads to the decline of many typical dune-slack species

(drawing by Rob Beentjes)

Location of Winterton Dunes

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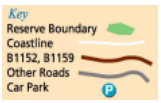

Landscape

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Winterton Dunes, Norfolk

Type B rain-fed dune slack

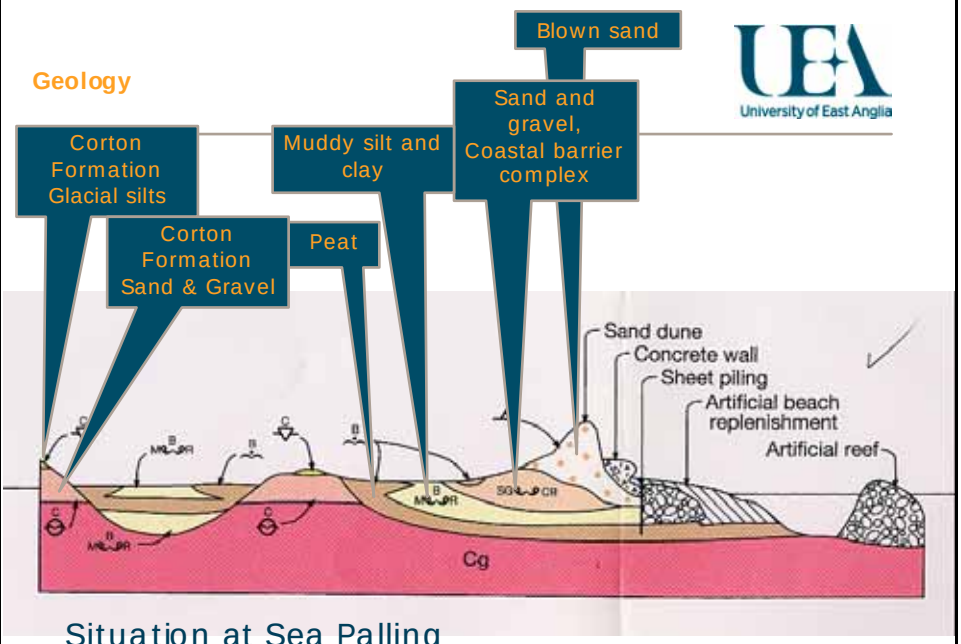
Horsey Dunes, Norfolk

Type D boundary dune slack

Winterton Dunes

Type E moist dune slack

Geology



Situation at Sea Palling

Construction of concrete sea defence post-1953

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Current morphology

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Topography

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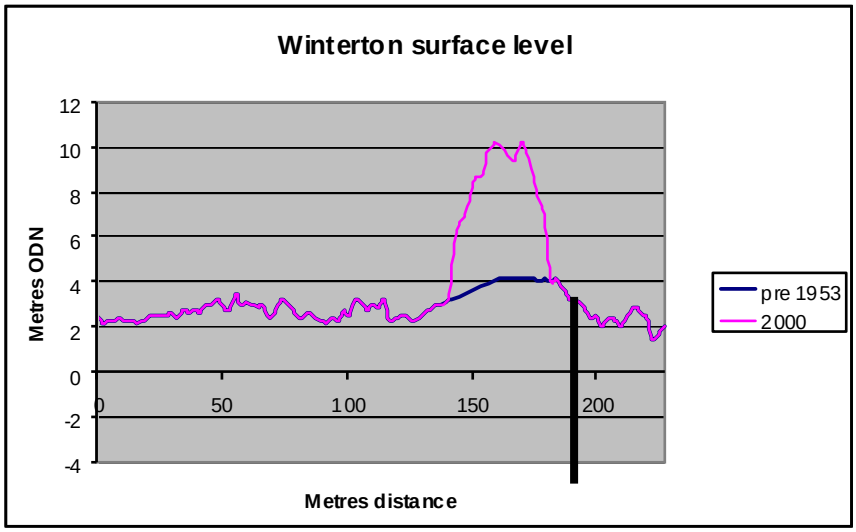
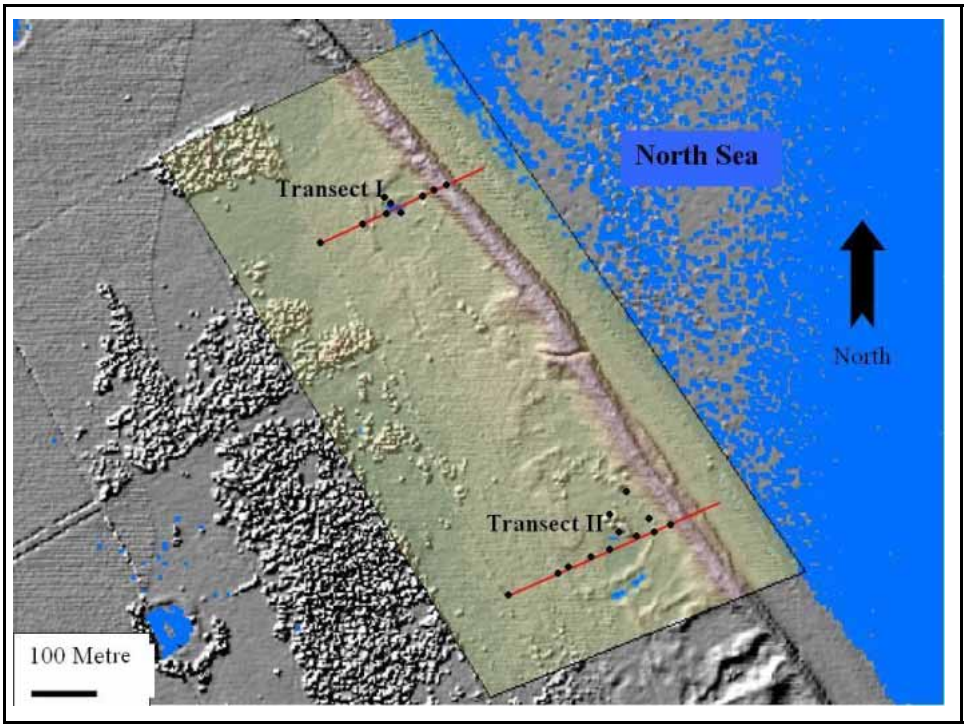
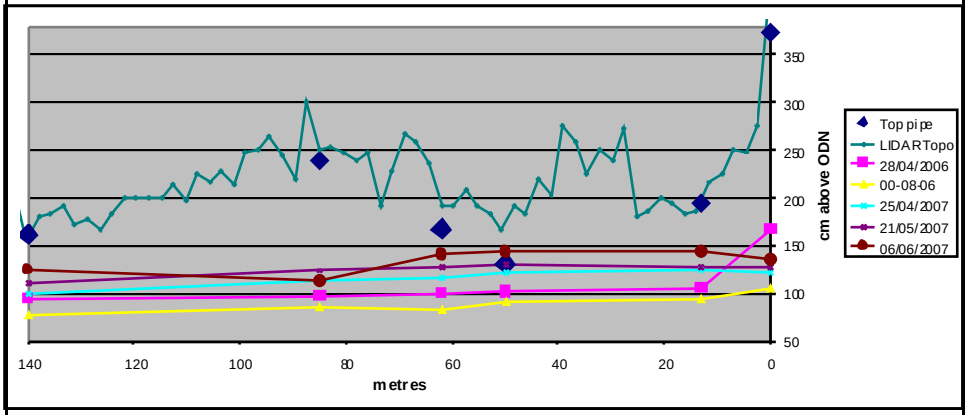
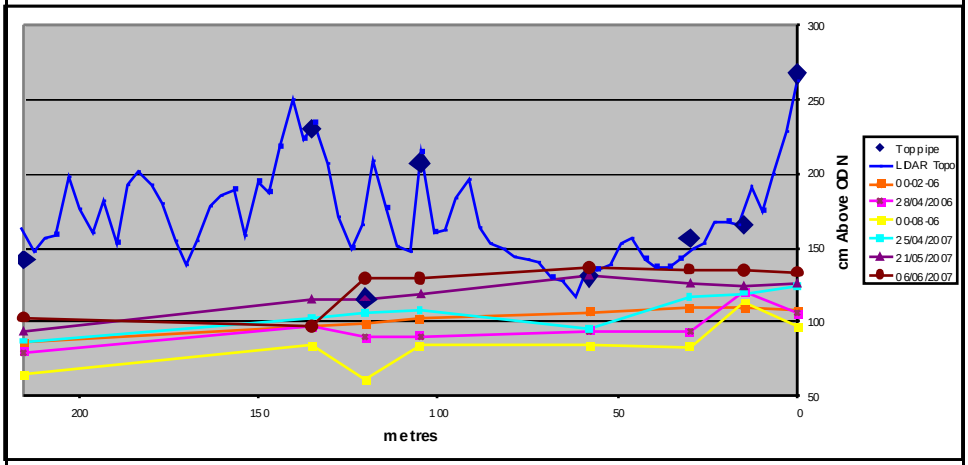


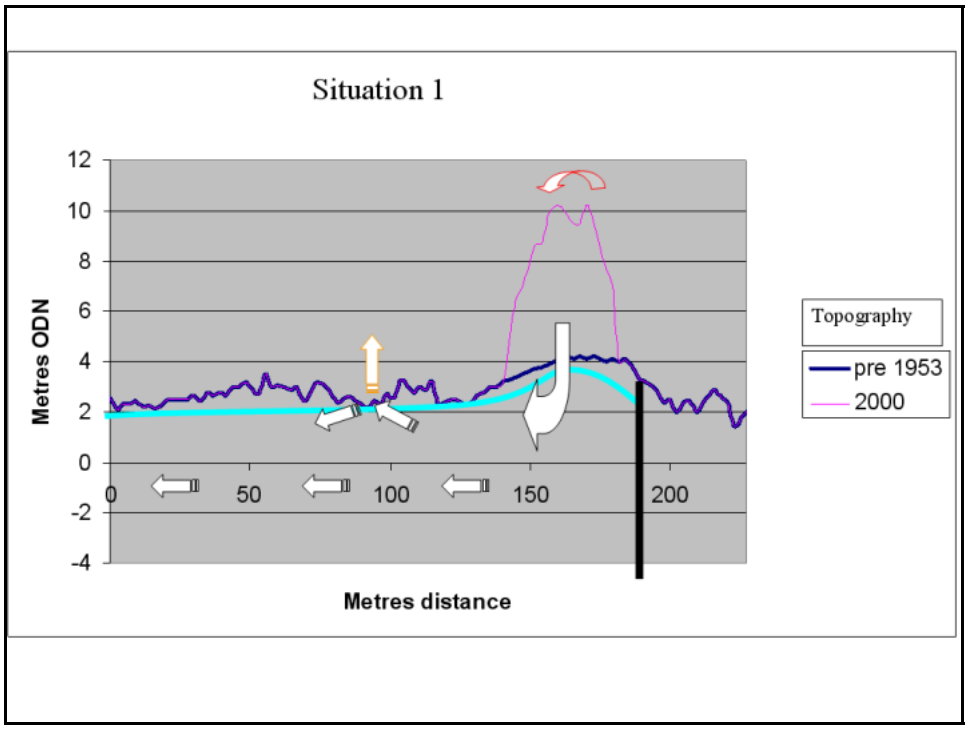


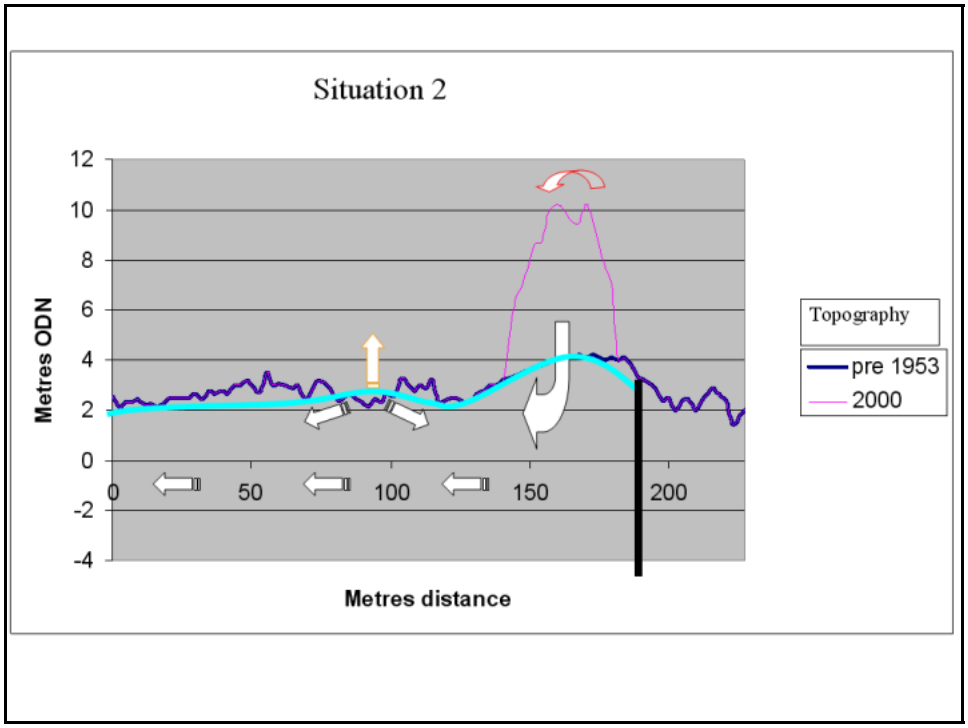
Transect I

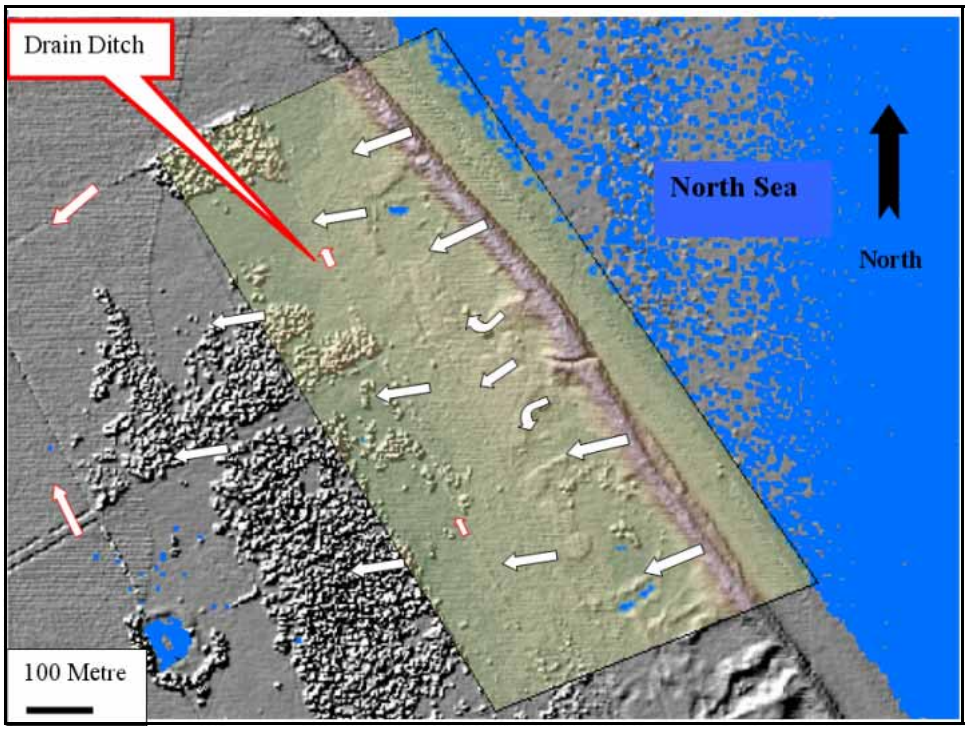


Transect II




Situation 1
12
10
8
6
4
2
0
-2
-4
Metres ODN
0
50
100
150
200
Metres distance
Topography
pre 1953
2000


Situation 2
12
10
8
6
4
2
0
-2
-4
Metres ODN
0
50
100
150
200
Metres distance
Topography
pre 1953
2000



Hydrochemistry

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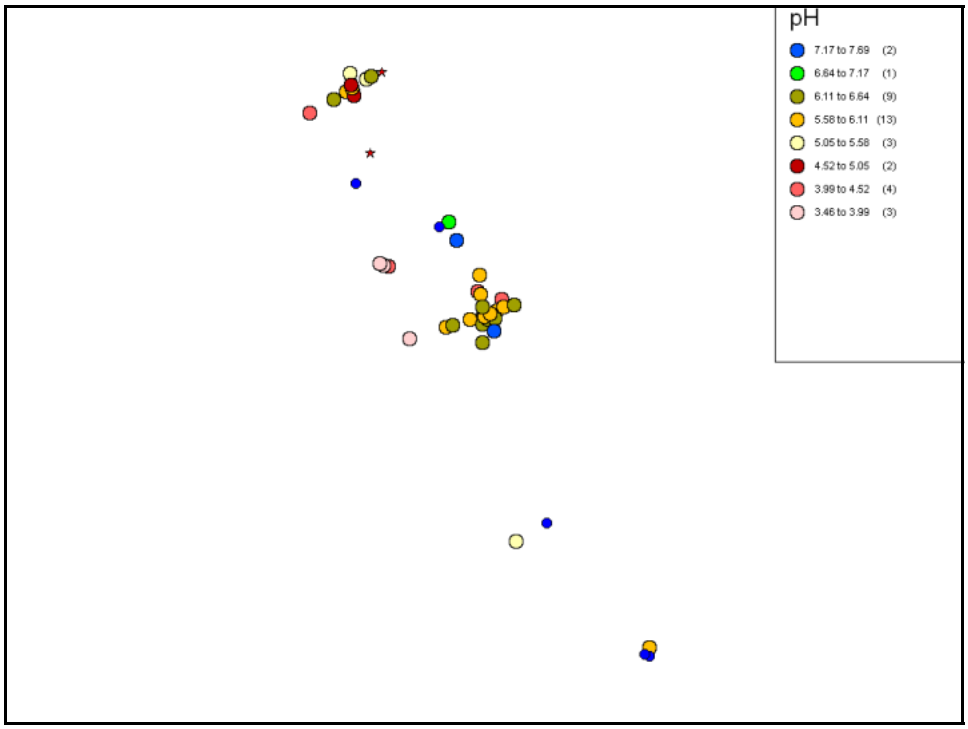
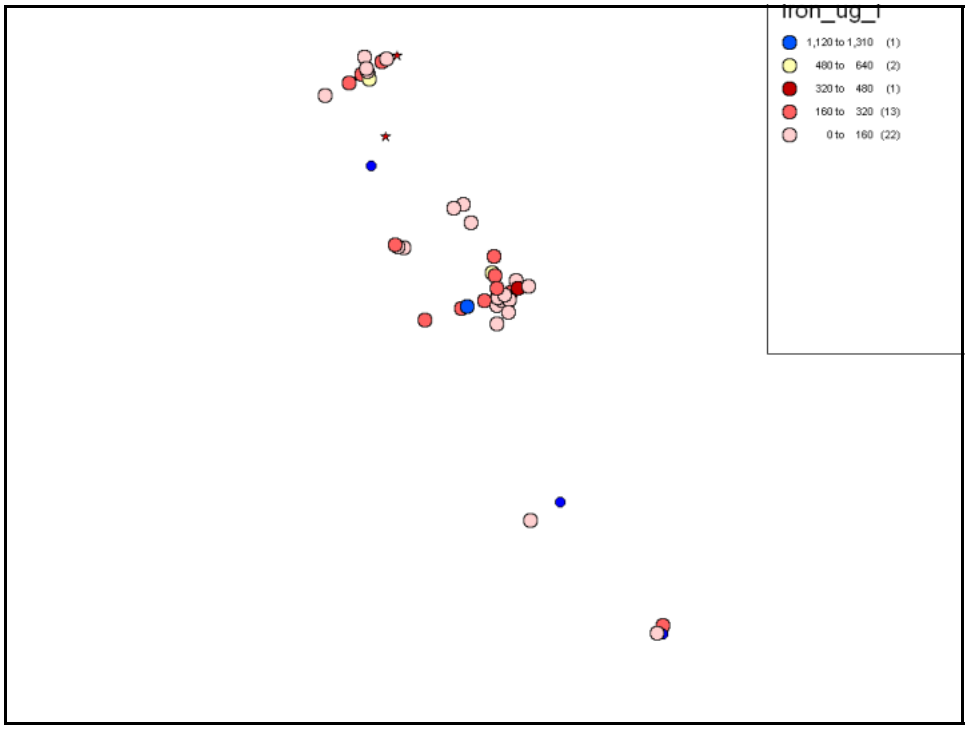
September 2005

(note development of ferruginous algal growth)

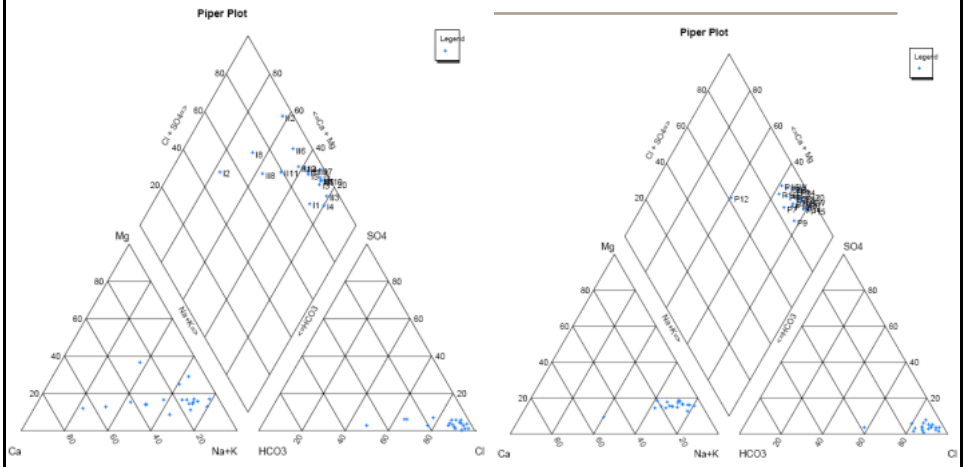
November 2005

(note generally fresher conditions)


pH
7.17 to 7.69 (2)
6.64 to 7.17 (1)
6.11 to 6.64 (9)
5.58 to 6.11 (13)
5.05 to 5.58 (3)
4.52 to 5.05 (2)
3.99 to 4.52 (4)
3.46 to 3.99 (3)


1,120 to 1,310 (1)
480 to 640 (2)
320 to 480 (1)
160 to 320 (13)
0 to 160 (22)

Piper diagram for transects and ponds



Conclusions

- Dune slacks are part of a larger, successional, eco-hydrological system, with a hydrological catchment
- Nutrient enrichment of infiltrating waters or groundwaters will accelerate successional development
- Slacks of most conservation interest are early successional stages that depend upon periodic disturbance for renewal
- They depend on interplay between infiltrating water and anoxic, calcareous groundwater. Lowering of groundwater can cause decalcification that has damaging hydrochemical consequences
- Dutch experience shows that the critical communities that include rare species such as *Liparis loeselii* have virtually no tolerance of a decrease in groundwater

Acknowledgements & References

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Davy, A.J., Grootjans, A.P., Hiscock, K. and Petersen, J. (2006) *Development of eco-hydrological guidelines for dune habitats – Phase 1*. English Nature Research Report No. 696, 80 pp.

Coulet, W.C.E. (2007) *Managing Winterton for Natterjack Toads. Internal Report*. Natural England, 73 pp.