Indicator of reduction in soils (IRIS) for wetland identification in Queensland

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Abstract
A large proportion of Queensland's wetlands are seasonal and ephemeral in nature. Identifying these wetlands is complex as field indicators (such as soil features and hydrophytic vegetation) may only be present at times of saturation. The Indicator of Reduction in Soils or IRIS method was developed in the USA (Castenson and Rabenhorst 2006, Jenkinson and Franzmeier 2006, Rabenhorst and Burch 2006). The method uses synthetic iron oxides painted on PVC pipes to determine whether a soil is in a reduced state. Trials were conducted at 8 wetlands in Southeast Queensland to assess the applicability of the IRIS method in reflecting reduced conditions in soils, to assist in wetland identification. The zone of saturation in a soil profile was the most influencing factor in indicating reduced conditions through the removal of iron oxide paint. An area over the entire surface of PVC pipe which has 15% removal of iron oxide paint within 0.3 m of the soil surface is recommended as confirmation of reducing conditions, sufficient to support evidence of a wetland soil in Queensland. It is proposed that the IRIS method be utilised as an additional line of evidence to identify wetland soils at sites where soil features are lacking, or where evidence of a current hydrologic regime is required.

Key Words
IRIS, wetland soils, identification.

Introduction
Wetland legislative regimes in Queensland rely on the clear identification and delineation of wetlands to support management policies. Indicators that reflect hydrology, and are relatively unchanging once formed, are more useful for wetland identification. Direct observation of inundation or water table heights is the most accurate way to identify a wetland. This process however is not practical as it requires long periods of time to monitor accurate trends in water levels. Hydrophytic vegetation and soil features can reflect current hydrologic regimes and are used for wetland identification in Queensland currently.

Extensive ephemeral wetlands are present in the arid and semi-arid interior regions of Queensland and many wetlands in the tropical and sub-tropical climatic regions are only seasonally saturated. The definition of a wetland in Queensland (EPA 2005), was specifically tailored to capture the episodic nature of these wetlands, using terminology such as 'periodic' and 'intermittent' (EPA 1999). The periodic nature and variable extent of these wetlands affects their accurate mapping, as the boundaries can change from season to season or over several years. The problem with identifying these wetlands is that field indicators (such as soil features and hydrophytic vegetation) may only be present at times of saturation and change during drier times.

A wetland soil in Queensland is defined as having '*a substratum which is predominantly undrained soils that are saturated, flooded or ponded long enough to develop anaerobic conditions in the upper layers'* (EPA 2005). The *'upper layer'* depth is recommended to be 0.3 m (Bryant *et al*. 2008). In order to define whether a soil is a wetland soil there needs to be anaerobic conditions or indicators of anaerobic conditions present. An anaerobic environment can alter the chemistry of soil and this is reflected in soil morphological characteristics. Some characteristics conclusively identify a wetland soil (organic materials, acid sulphate soil material and gleyed soil matrix colours). Other features, like redox features (presence of mottles, segregations (iron and manganese), ferruginous root channel and pore linings, and decreasing matrix chroma), can be indicative of a wetland soil but not irrefutable (Bryant *et al.* 2008). Some soil features can form and persist in the environment which can be problematic as they may be relict features that do not reflect current hydrology. The identification of wetland soils is complex where soil indicators are not readily identifiable or where the interpretation of soil indicators requires evidence of a current hydrologic regime. This situation is commonly found within seasonal and ephemeral wetlands in Queensland.

The Indicator of Reduction in Soils or IRIS method was developed in the USA (Castenson and Rabenhorst 2006, Jenkinson and Franzmeier 2006, Rabenhorst and Burch 2006). The method is used to determine whether a soil is in a reduced state without relying on less conclusive visual soil indicators or using equipment which is time consuming and expensive. This method involves the use of synthetic iron oxides (predominantly ferrihydrite) to indicate the presence of reducing conditions in soils. PVC pipes are coated with a paint prepared from a synthetic iron oxide, and placed in the soil. Upon removal, the pipes are visually assessed for the loss of the iron oxide paint from the surface which indicates that reduced conditions are present. The objective of the study was to test the IRIS method and its interpretation procedures under Queensland conditions, to assess it's applicability in assisting with wetland identification. The IRIS method was trialled at 8 palustrine, seasonally inundated wetlands in Southeast Queensland in order to examine:

- the time necessary for this test to be conducted in periodically inundated wetlands to provide an accurate representation of reducing conditions
- the effect of different soils and soil conditions on the amount and pattern of reduction that occurs
- the level of reducing conditions required to determine the presence of a wetland soil in Queensland
- the applicability of the method across differing climatic regions and landscapes (as Queensland's wetlands and landscapes are much drier, variations on the method may be required for its use)

Methods

Site sampling

Transect sampling was used to assess the changes in paint removal from sites within the saturated zone of the wetland to sites considered external to the wetland. This method is the same employed by Bryant *et al*. (2008) when developing the methodology for wetland soil indicator use in Queensland. The three zones within the transect were categorised:

1) Saturated zone: The wettest lowest-lying area. For wetlands that were dry when sampled, this was the lowest part of the wetland that could be accessed. For wetlands that were inundated when sampled, this is the area at the water's edge.

2) Transition zone: This area appeared to be inundated intermittently or seasonally, with evidence of saturation through vegetation or landform features.

3) Outer zone: Above the high-water mark, no evidence of inundation at any time.

Soils were described at each site (or zone) to a depth of 1.0 m where possible and laboratory analysis was conducted for each soil profile with samples taken at 0.0-0.1 m and 0.2-0.3 m. Descriptions of microrelief, surface characteristics and water table heights were recorded. Each soil sample was analysed for pH, electrical conductivity (EC), nitrate (NO^{3-}), chloride (Cl^{-}), total carbon (TC) and total nitrogen (TN).

Pipe preparation

PVC pipes were cleaned first with acetone to remove any ink and then sanded with fine sandpaper (100 grit). Pipes were then cut to 600 mm lengths with the lower 500 mm painted with ferrihydrite paint. Pipes were painted with 2 coats with the first coat left to dry overnight. The paint was then tested for durability by trying to wipe the paint off with a finger (Jenkinson and Franzmeir 2006).

A method was devised to minimise paint loss from the surface of the pipes upon installation and removal. An unpainted pipe of the same length and width was first placed in the soil, removed and replaced by a painted pipe, in one movement attempting not to rotate the pipe (Bryant *et al*. 2008).

Up to 7 pipes were installed at each site to 0.5 m deep (where possible) in a random layout across an area approximately 1 m^2. To assess the length of time necessary for the IRIS method to provide an accurate representation of the redox status of a wetland, trials were run over 2 different periods (14 days and 28 days). Upon removal each pipe was washed down with water to remove any loose soil and then allowed to dry. Pipes were photographed by rotating them 120^0 to obtain 3 images which covered the entire surface. Photographs of the pipes were put together in Adobe Photoshop CS2 to form a single image (Jenkinson and Franzmeir 2006). A visual estimate of the percentage of paint removed was undertaken using standard charts (Castenson and Rabenhorst 2006). Two people independently assessed the percentage of paint removed and these figures were averaged for each pipe and site.

Results

A larger percentage of paint was removed from sites in the saturated zone compared with sites in the transition or outer zone across all 8 wetlands (figure 1). Sites which had a considerable amount of paint removed (>60% within the surface 0.3 m) were in areas which were inundated at some stage during the trials. The water table, at all wetlands, dropped during the trials. For several wetlands this had an effect on the zone of saturation within 0.3 m of the soil profile. Wetlands that were inundated or had water tables remain at or within 0.3 m of the surface had the largest amount of paint removed.

At sites where there was less than 2% of paint removed the water table had dropped below 0.3 m after 28 days. There was no distinct trend in the percentage removal of paint between the 14 or 28 day trial durations. The largest difference was at sites that were inundated throughout the trial. These pipes had a larger percentage of paint removed after 28 days.

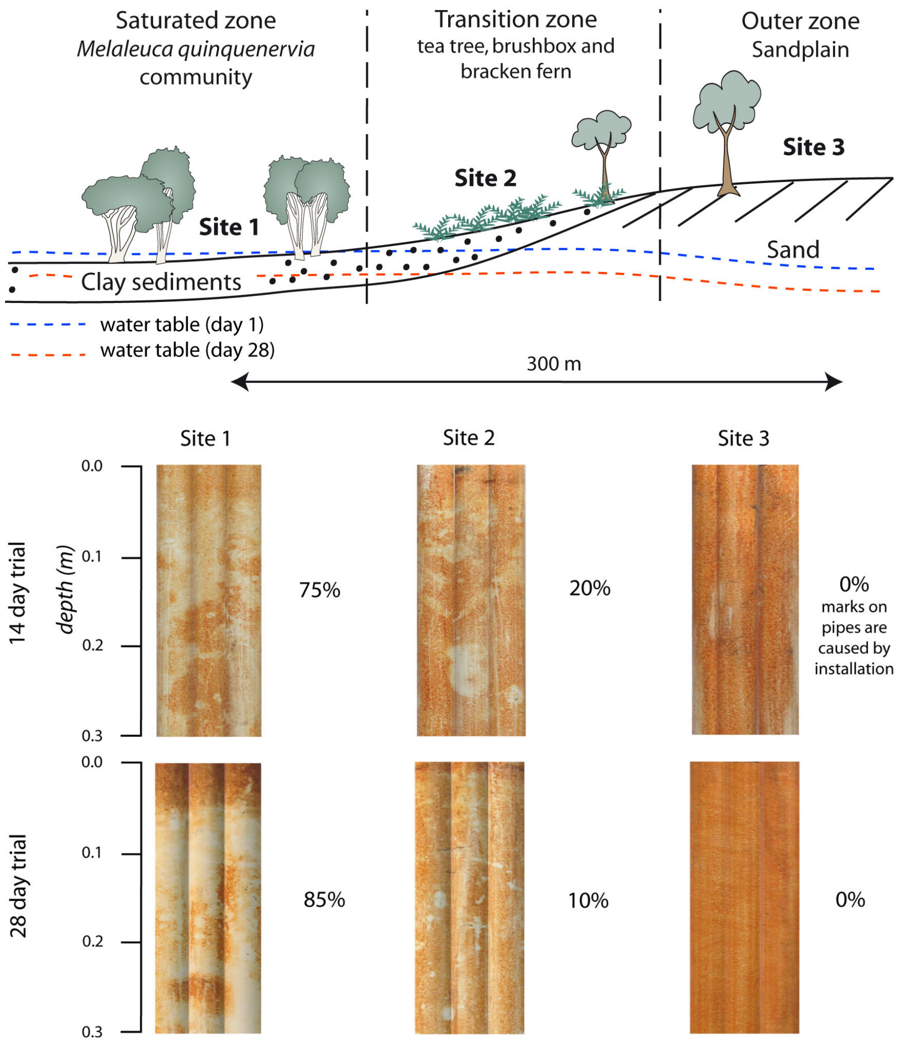

Figure 5. Example of one trial site, Bribie Island (Southeast Queensland): Average percentages of iron oxide paint removed from sites along transect.

The different soils types (sands, clays and organic dominated soils) do not appear to directly influence the removal of paint from the IRIS pipes. There were similar percentages of paint removed across differing soil types.

Organic carbon levels in the current trials ranged between 20.6% to 0.83% (in the surface 0.1 m) and 8.4% to 0.5% (in the subsurface 0.2-0.3 m). Where paint was removed from pipes organic carbon levels remained above 3.5%. This was however only at sites where there were also sufficient saturation levels for reducing conditions to occur. Soil temperatures were monitored at two trial sites and not fall below 13 C (at a depth of approximately 0.7 m) throughout the course of the trials, which is sufficient for microbial activity (Tiner 1999). It is therefore expected that microbial activity was not limited by temperature at any of the sites as they were located in a similar climatic region (sub-tropical).

Conclusion

The study has demonstrated that the IRIS method can indicate that soils are reducing and that this may assist with wetland identification in Queensland. Presently the method is not recommended to be utilised on it's own as a tool for wetland identification, but as an additional line of evidence to identify a wetland soil in the following situations.

1) Sites where wetland soil features are lacking. This may occur in transitional areas where soil indicators start to drop of the soil profile or in areas where soils are naturally lacking in minerals (particularly iron rich minerals) which form wetland soil features.
2) Sites where soil indicators described still require evidence of a current hydrologic regime, particularly to support the use of redox features in identifying wetland soils.

The most influencing factor in the percentage of paint removed was the zone of saturation within the soil profile. Soils that were completely saturated or were saturated in parts of the profile had the largest removal of paint. Soils which were moist but not saturated had no or very little removal of paint. Conducting this test at a time in which the wetland is not likely to be saturated will not accurately reflect the extent of reduced conditions.

Soil types appear to have minimal direct effect on the IRIS method. They do however influence the rate of transmission of water through a soil. In clay dominated soils water is transmitted slower and may allow water to pool and stagnate. In organic and sand dominated wetlands water movement is faster which may influence the level of aerated water that flows through a wetland and hence the time is takes for iron to become reduced.

A soil may be waterlogged but not become reduced for a long period of time if there is too little organic material (Vepraskas 1998). There are implications to applying the IRIS method in wetlands in the semi-arid and arid regions of Queensland. These wetlands have a lower soil carbon levels than others in Queensland, which would require longer periods of time to become reduced.

An area over the entire surface of PVC pipe which has 15% removal of ferrihydrite paint within 0.3 m of the soil surface (the average of at least 4 pipes installed at any one site) is recommended as confirmation of reducing conditions, sufficient to support evidence of a wetland soil in Queensland.

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