Research consultancies

This section contains a summary of non-uranium mining related research consultancies carried out by ***eriss*** during 2009–2010. Most of these reports are commercial-in-confidence and are not available for public release.

List of non-uranium mining related research consultancies

Boyden J 2010. Waterbirds data and related environmental datasets collated by SSD for the Northern Australia Water Futures Assessment (Ecological assets sub-project). March 2010.

Jones, DR, Humphrey C & van Dam R 2010. Review of water, sediment and biota data for Page and Lawn Hill Creeks. Commercial-in-Confidence Report for Metals and Mining Group – Century, February 2010.

Ryan B & Bradley F 2010. Preliminary report into the characterisation of groundwater at the Rum Jungle minesite: Consultancy report for Department of Resources, Energy and Tourism. Supervising Scientist, Darwin.

Ryan B, Bradley F & Bollhöfer A 2010. Final report into the characterisation of groundwater at the Rum Jungle minesite: Consultancy report for Department of Resources, Energy and Tourism. Supervising Scientist, Darwin.

Ecotoxicological assessments of discharge waters from Cosmo Howley, Pine Creek, Tom's Gully and Brocks Creek Project Areas

AJ Harford & RA van Dam

The Environmental Research Institute of the Supervising Scientist (***eriss***) conducts a limited amount of commercial work to provide scientific advice to commercial clients in northern Australia, including mining companies and government agencies. Over the 2009–10 wet season, a contract project was undertaken by the ***eriss*** Ecotoxicology Group for Crocodile Gold Australia Operations Pty Ltd (CGAO).

The objectives of the program were to:

1 derive discharge dilutions (trigger values; TVs) for mine waters from Pine Creek Mine (PCM), Tom's Gully Mine (TGM) and the Cosmo-Howley Project Area (CHPA), which can be used by CGAO to negotiate agreed discharge dilutions with the Northern Territory Government; and

2 assess the relative toxicities of ambient waters at strategic sites along Howley Creek, spanning a longitudinal gradient that receives discharges from both CHPA and the Brocks Creek Project Area (BCPA) located upstream of CHPA.

Five tropical freshwater species were used to assess the toxicities of the mine waters: a green alga (*Chlorella* sp), duckweed (*Lemna aequinoctialis*), cladoceran (*Moinodaphnia macleayi*), green hydra (*Hydra viridissima*) and fish (northern-trout gudgeon, *Mogurnda mogurnda*). The specific mine waters assessed for toxicity were: PCM – Pine Creek Process Water Dam (PCPWD) water; TGM – Evaporation Pond 2 (EP2) water; and CHPA – water from discharge site CHCK05. The toxicity of an undiluted sample of water from the Alligator Pit at BCPA was also assessed. The key outcomes from the water toxicity assessments for the three mines were the derivation of TVs and corresponding dilution ratios for each of the three mines' licensed discharges.

Ambient waters collected from five sites along Howley Creek were screened for toxicity using the above-mentioned five species. The sites were: 1. Howley Creek upstream of both mine project areas (CHCK01; upstream control); 2. BCPA tenement boundary/Alligator Pit discharge compliance point (BCSW20; influenced by discharges from BCPA and, to a lesser extent, CHPA); 3. Immediately downstream of the confluence of the main CHPA discharge point and Howley Creek (CHCK07); 4. CHPA downstream compliance point (CHCK06); and 5. ~7 km downstream of CHPA downstream compliance point (CHCK08). The results of the Howley Creek toxicity screening assessment were consistent with those from the CHPA discharge and Alligator Pit toxicity assessments, and provided additional information to CGAO on the potential effects of its operations on aquatic biota in Howley Creek.

A comparison of the Howley Creek toxicity screening results with those from the field macroinvertebrate survey undertaken in April 2010 is currently being conducted. A synthesis of the results could be used to refine and add weight to the dilution ratios derived from the laboratory ecotoxicological test work.

Surface water quality monitoring at the Rum Jungle minesite, 2008–09 wet season

DR Jones & K Turner

Introduction

The former Rum Jungle minesite is located in the wet-dry tropics of the Northern Territory of Australia and is situated approximately 100 km south of Darwin. Extensive rehabilitation works were carried out in the mid-1980s using best practice methods of the day. In recent times it has become apparent that the performance some of the rehabilitation works associated with containment of the waste rock and tailings has begun to deteriorate.

This project was commissioned under the terms of a Memorandum of Understanding (MOU) funding agreement between SSD and the Australian Government Department of Resources, Energy and Tourism (DRET) to undertake a pilot study of deployment of continuous monitoring equipment to determine seasonal loads of solutes emanating from the site (gauging station GS8150200) and from the Dysons backfilled pit and overburden dump area.

The continuous monitoring of flow and EC was complemented by fortnightly grab samples for chemical analysis collected throughout the wet season from the GS8150200 and Dysons monitoring locations. Targeted grab sampling of flow and seepage lines around the Dysons pit area was done, prior to and at the end of the wet season, to characterise the composition of source waters from this vicinity. Several soil samples were also collected to provide additional information about levels of metals and radionuclides in surface soils and cover material on and downgradient of Dysons pit.

A synoptic grab sampling survey of water quality, at a number of strategic locations in flow lines across the site, was carried out during the recessional flow period at the end of the wet season. This was done out to identify the most important contributors to contaminant loads at this time.

Full details of this project are reported in Jones and Turner (2010).

Findings

Good grab sample coverage of water quality over the wet season at both the GS 8150200 and Dysons stations was obtained by the samples collected by staff from SSD and Compass Resources. For the first time the seasonal behaviour of run off and seepage downgradient of Dysons Pit and Overburden Heap was able to be assessed. The low pH and high concentrations of metals, including U, in the seepage downgradient from Dysons pit were of especial note. In particular there is little difference in concentrations measured at the end of the dry and at the end of the wet. This behaviour suggests that this seepage represents a chronic year-round source that does not exhibit a seasonal 'flush out' profile.

Apart from the start of the wet season the dissolved concentrations of all of the metals measured, except Cu, are very similar at both the GS8150200 and Dysons monitoring locations. In the case of Cu there is a systematically higher (almost double) concentration at GS8150200 for most of the wet season. Similar behaviour is displayed by the total (ie unfiltered) metals concentration data at both locations. It may not be possible to estimate copper load from continuous EC data owing to a substantial proportion of copper being present in particulate form during the majority of the wet season.

Surface water samples were collected in drainage lines across the site as part of a parallel groundwater characterisation project. The chemical analysis results showed that the 'primary' seepage from both the Whites overburden heap and Dysons Pit and overburden heap is very acidic and contains high concentrations of solutes (as evidenced by EC). However, the buffering capacity of the water coming from the upper catchment lines during the wet season appears to be sufficiently high to neutralise the bulk of acidity present in the seepage, as evidenced by the close to neutral pH values downstream of the seepage inputs. The EC data indicate that inputs of solutes from the Whites overburden heap were making the most substantial contribution in April 2009 to the solute load of water from the upper catchment as it flows through the site.

Several samples of soils, surface crusts and sediment were collected from around the Dysons pit area. Of especial note is the sample of stream sediment collected from the channel about 30m downstream of the Dysons station. It contained 571 mg/kg U and 2020 mg/kg Cu in the acid extractable fraction. The highest measured chemical concentration for U in the downstream channel sample is reflected in the ^{238}U activity value for this material. The very high ^{238}U to ^{226}Ra activity ratio suggests that the U in this material may have been sourced from uranium rich (and Ra-depleted) seepage water. It is conceivable that the source of the U is the uraniferous seepage water downgradient of Dysons pit. The U in solution would likely be adsorbed on the Fe-rich soils in the catchment and then transported downstream and deposited in the slackwater location from which the sample was collected.

As result of a combination of deployment and initial equipment reliability issues, critical early wet season data were not obtained from either the Dysons or GS8150200 stations. Hence it was not possible to derive solute loads for the whole 2008/09 wet season. This is especially the case for the Dysons station where the late start (mid-February) of acquisition of continuous data was coupled with an abnormally early end to the wet season. However, it can concluded from the available water quality and stream flow data that the area upstream of the Dysons monitoring station contributes a minor proportion of the total solute lead reporting to GS8150200.

A correlation plot between EC and sulfate concentration established using grab samples can potentially be used to infer sulfate load throughout the season (by combining sulfate concentrations derived by using the EC-SO4 correlation from grab sampling with measured flow data). This will enable the period when most SO4 (conservative solute and primary metal sulfide oxidation product) is being exported from the site. However, caution should be exercised in applying this approach. Owing to changing ionic composition with pH (especially for pH below 4.5) it will likely be necessary to use separate correlation plots for early, middle and late wet season.

Recommendations for future work

1 Contracts for future monitoring deployments should be in place well in advance of wet season to ensure that system is able to be installed and debugged prior to the start of the first rains. This is especially critical to capture data pertaining to the first flush of very poor quality water.

2 The low pH and high concentrations of metals, including U, in the seepage downgradient from Dysons pit are of especial note. In particular there is little difference in concentrations

measured at the end of the dry and at the end of the wet. This behaviour suggests that this may be a chronic year-round source that does not exhibit a seasonal 'flush out' profile. Additional work needs to be done to identify the source of this seepage.

3 Synoptic scans of water quality along the site flowlines should be made several times during the wet season to identify primary locations of solute inputs.

4 Event controlled autosampling should be used to provide a primary estimate of metal loads and thence to assess the possibility of being able to use the continuous EC data to infer metal loads (especially copper) during subsequent wet seasons.

At least two complete wet seasons of continuous monitoring data will be needed to characterise the seasonal elution profile for solutes from the site.

References

Jones DR & Turner K 2010. Surface water quality monitoring at the Rum Jungle minesite, 2008–09 wet season. Internal Report 578, June, Supervising Scientist, Darwin.

Characterisation of groundwater at the Rum Jungle minesite

B Ryan, F Bradley & A Bollhöfer

Introduction

This project was undertaken as a consultancy for the Commonwealth Department of Resources, Energy and Tourism to provide a better understanding of the groundwater regime at the former Rum Jungle minesite 100 km south of Darwin in Australia's Northern Territory. Two field sampling campaigns were conducted in October 2008 (end of 2008 dry season) and April 2009 (end of 2008–09 wet season) by staff from the Supervising Scientist Division (SSD) and the Northern Territory Department of Regional Development, Primary Industry, Fisheries and Resources (DRDPIFR). Water quality parameters, dissolved metal concentrations and radionuclide levels were analysed for 24 groundwater bores and eleven surface water sites. The aims were:

- provide a contemporary snapshot of groundwater quality across the site
- delineate locations of possible contaminated groundwater plumes
- provide insight into water flow and solute transport between shallow aquifers and surface water to investigate whether groundwater adjacent to waste rock dumps contributes to solute loads from the site.

Findings

There are elevated levels of contaminants, at some locations, in both the shallow and deeper aquifers at Rum Jungle. These contaminants are being transferred from the remnant mining structures which include Whites, Intermediate and Dyson overburden heaps and Dysons Pit. The relative contribution of how much contaminant is flowing from each of these sources into the east Finniss River needs further investigation.

It would be advantageous to establish if there is any contaminant movement out of Whites and Intermediate pits as well as the tailings dam. Although the water in Whites and Intermediate pits is relatively uncontaminated it would still be prudent to sample groundwater moving from these structures as higher levels of metals are present in water at the bottom of these pits. There may also be other as yet unidentified sources (for example, dispersed amounts of fill material) contributing to the contaminant load.

Inferred directions of flow pathways for shallow groundwater, based on head levels, are based on few points and hence interpretations based on this representation of the data should be treated with some caution.

An important finding from Principle Component Analysis is that there is little seasonal influence on the quality of water in the deeper aquifers and that there is connection between the shallow aquifer and surface water.

The extent of connection between the shallow and deeper aquifer systems is still unknown. However, in this context it is noted that early studies state the deeper aquifer is confined in nature. A better understanding of the hydraulic properties of the aquifers and the effect of the complex geological structures on facilitating connections between the aquifers is needed. Extended monitoring of some of the deeper bores with electrical conductivity and water level probes may provide some insight into the dynamics of contaminant plume movement through the aquifers and additional information on hydraulic properties. . It is recommended that this monitoring be started as soon as possible so that time series level data can be obtained over at least two seasonal cycles.

A number of the bores sampled have shown some improvement in water quality over the last three decades. However, although there may have been some improvement the levels of contaminants in many of these bores are still high compared to relevant water quality guidelines. There are also some bores that have shown deterioration in water quality over the same period. The question arises as to what has caused this degradation and whether this provides evidence for an advancing contaminant plume.

Full details of the project and its findings are reported Ryan et al (2010).

Recommendations for future work

The key knowledge need for understanding changes in EC, pH and metals concentrations through time and space is an understanding of the variables that can impact these, including the strength of the source terms, location of aquifers, the lithology through which the ground water flows, and its acid buffering capacity. In order to adequately address these issues much greater definition of the physical conformations of the geological structures is needed than available from historical drill logs.

Measuring radon in surface water along the East Finniss would identify if significant amounts of deeper groundwater are expressing at the surface and contributing to the load of metals leaving the site.

It is recommended that a Stage 2 broadly-based hydrogeological characterisation program be commissioned to further analyse the material that has been presented in this report to identify locations for the installation of additional groundwater monitoring bores and to obtain additional characterisation information about aquifer properties. The additional information produced by this assessment would provide the necessary detail to develop a conceptual, and ultimately numeric, hydrogeological model for the site.

References

Ryan B, Bradley F & Bollhöfer A 2010. Final report into the characterisation of groundwater at the Rum Jungle minesite: Consultancy report for Department of Resources, Energy and Tourism. Internal Report 571, February, Supervising Scientist, Darwin. Unpublished paper.

Flood inundation mapping: Daly and Mitchell river catchments

R Bartolo, D Ward[1] & DR Jones

Introduction

The Tropical Rivers and Coastal Knowledge (TRaCK) research hub headquartered at Charles Darwin University in Darwin is one of the major components of the CERF program that was managed by DEWHA. ***eriss*** was a collaborator in the Theme 4 (Material Budgets) Project 4.1: Catchment water budgets and water resource assessment. The specific engagement was with a task focused on flood inundation mapping for the Daly and Mitchell River catchments using a combination of radar and optical satellite imagery analysis. Defining the extent of wet season inundation in floodplain and riverine environments is an important component of the annual catchment surface and groundwater budgeting process.

The aims of this sub-project were to:

1 Map the maximum inundation limit (extent) for both the Daly River and Mitchell River catchments;

2 Map the minimum inundation limit (extent) for both the Daly River and Mitchell River catchments; and

3 Provide information on the persistence of flooding in these catchments.

Determining the extent of flooding in tropical catchments using remote sensing is dependent on a number of factors: local conditions at the time of image acquisition (for example, cloud cover and flooding under vegetation); sensor selection (Optical or Synthetic Aperture Radar [SAR]); and definition of flood extent (interannual and intrannual analysis). There are a number of challenges to using remotely sensed data for such a task as mapping tropical floodplain inundation extent. In the tropics, atmospheric attenuation or interference resulting from cloud cover during the 'wet' season, and smoke from fires during the 'dry' season (Schultz & Engman 2000) are limiting factors for the use of optical sensors.

Identification of 'wettest' and 'driest' wet seasons

The wet seasons that received the highest and lowest rainfall were identified using Foley's precipitation deficit index (Foley 1957), and this analysis provided the basis for locating the years corresponding to the likely maximum and minimum interannual inundation extents of the selected catchments. Foley's precipitation deficit index is the standardized monthly mean annual precipitation over a specified lag period relative to the long-term mean annual precipitation. Fensham and Holman (1999) found that 3 years is a significant lag period for precipitation deficit to influence vegetation dynamics in Australia's tropical savannas. Hence, we calculated Foley's precipitation deficit index for a 3 year lag period. The year that matched the satellite record and data availability for both optical and L-band SAR data for mapping maximum

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inundation extent in both catchments was identified to be 2009. The year that matched the satellite record for optical data for mapping minimum inundation extent was identified to be 2005 and 2004 for the Daly River and Mitchell River catchments respectively (there were no L-band SAR data available for years that fell into the lowest rainfall wet season range).

Satellite data and image processing

Both optical (Landsat 5 TM) and Synthetic Aperture Radar (SAR – ALOS PALSAR ScanSAR) data were combined to map maximum inundation extent during the wettest wet season (2009) in the Daly River catchment floodplain complex. Landsat 5 TM data were utilised for mapping the minimum inundation extent for the driest wet season (2005) in the Daly River catchment (SAR data were not available for that particular year and time). A time series consisting of 5 images were used to assess persistence in the Daly River catchment (which is considered more important than duration of flooding for the work undertaken under Theme 5) of flooding in 2009. Floods in the Mitchell river catchment are ‘flashy’ and inundation lasts in the order of 8 to 10 weeks. In order to capture the floods on the Mitchell it was necessary to use a satellite with a return interval greater than Landsat (16 days) because of issues of occlusion due to cloud cover. The USGS Terra MODIS satellite has a daily return interval but has relatively low resolution (250 m pixels). Consequently, MODIS optical imagery was used for mapping the maximum and minimum inundation limit for the Mitchell River catchment.

A Geographic Object Based Image Analysis (GEOBIA) approach (Benz et al 2004) was used to classify the Landsat 5 TM and PALSAR ScanSAR data using Definiens Developer 8.0. Multi-resolution segmentation was conducted.

Two band ratios, based on published literature on techniques to extract water coverage from optical satellite imagery, were used to highlight open water (flooding) in the Landsat 5 TM data. The first of these band ratios, the Normalised Difference Water Index (NDWI), was developed to delineate open water in satellite imagery (McFeeters 1996). The second ratio, the Modified Normalised Difference Index (MNDWI), is based upon the principle of the NDWI but further suppresses the signal from built up areas (Xu 2006) and cleared regions in the imagery by substituting the NIR with the MIR band. For MODIS, the two highest resolution bands are the Red and NIR bands, allowing calculation of NDVI. Using measurements obtained from a combination of depth loggers and temperatures sensors located on the Mitchell floodplain for the 2009 wet season, a comparison was made between density slicing of NIR and NDVI for delineating water. NDVI performed the best and was subsequently used to delineate maximum and minimum inundation extents for the Mitchell catchment.

Results

The full range of results is not reported here. Examples of some results are provided to indicate how the data can be used for environmental management.

Daly River floodplain

Maximum inundation extent for the Daly River Floodplain Complex was mapped using both Landsat 5 TM and PALSAR ScanSAR imagery. Three flood classes were produced: open water; flooded Melaleuca; and flooded grasses and sedges. Maximum inundation extent is shown by the mapping product displayed in Figure 1. A summary of the areal extent of the flooded classes over three months during the 2009 wet season is shown in Figure 2. It should be noted that the open water class includes the near shore environment as the data used to subset imagery was the GEODATA TOPO 250K subject to inundation with a 2km buffer. Therefore, the open water class using this method is not entirely confined to the floodplain proper.

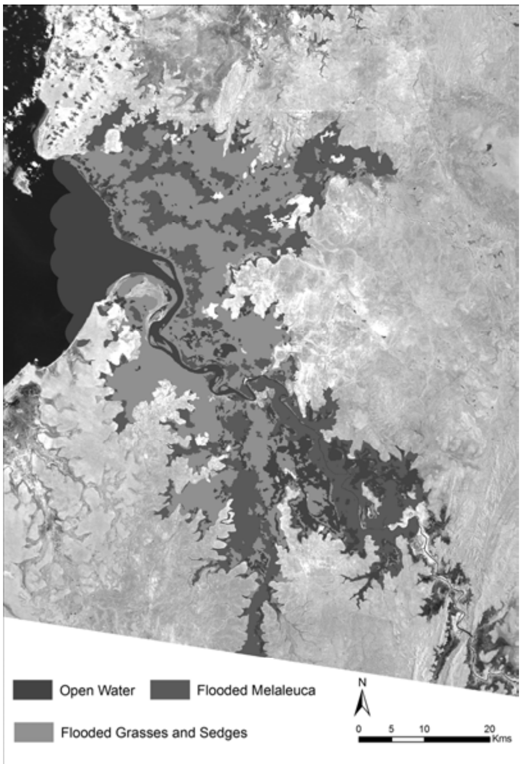

Figure 1 Maximum inundation extent during March 2009 for the Daly River Floodplain Complex

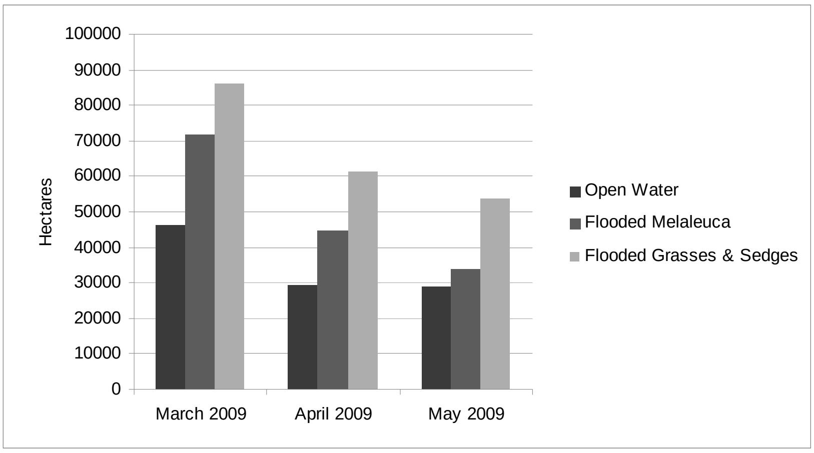

Figure 2 Summary of the areal extent of flooded classes during March–April 2009 for the Daly River floodplain complex

Mitchell River catchment

The majority of vegetation on the Mitchell river floodplain has less than 30% canopy density (Foliage Projective Cover), allowing water to be relatively easily detected using MODIS NDVI. Areas with canopy density greater than 30% were limited largely to the main river channel and subsidiary channel levees, and flood inundation was not mapped in these areas. A summary of the areal extent of flood inundation over 2 months during the 2009 wet season is shown in Figure 3.

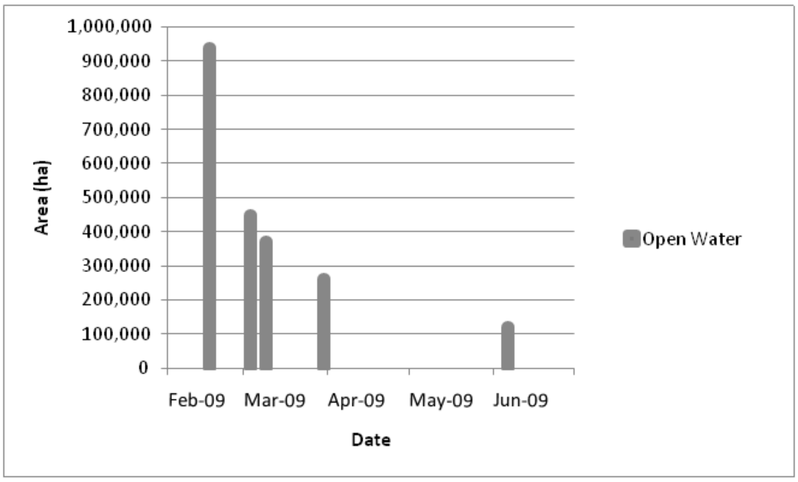

Figure 3 Summary of the areal extent of flood inundation for the 2009 wet season (with additional Landsat 5 TM water extent for June 2009) for the Mitchell River floodplain

Findings

The methodology for reliable and robust flood inundation mapping in Australia, and in particular northern Australia, is still in its developmental phase. The type of satellite sensors used are critical for mapping flood classes in northern Australia, due to ubiquitous cloud cover during the wet season, coverage of floodplains by grasses and aquatic plants etc following rain, followed by fire and associated smoke in the dry season. The effect of cloud cover and smoke in optical imagery is not the only limiting factor. Fire scars from early dry season burning (as early as May) can result in class confusion with flooded classes, in particular flooded vegetation (even with the inclusion of SAR data).

The findings from this project are that combining L-band SAR data with optical data substantially improves the ability to map flooded classes during the wet season. Flooded *Melaleuca* swamp areas are particularly well distinguished in the SAR data. The MNDWI data analysis method was found to be particularly useful in mapping open water. Combining the SRTM DEM data into the classification process may further improve classification results and this is an area for further investigation for mapping flooded classes. For optimal data classification results it is recommended that the optical and SAR data are acquired concurrently. Unfortunately with limitations in availability of satellite L-band SAR, and the available frequency of image acquisition by the SAR-capable platforms, this is not often possible.

Depending on the environmental management question to be answered, combining the three flooded classes into one flooded class for the Daly may be useful. From the isotope tracing food web work for TRaCK Theme 5.3 it was found that 30–40% of the biomass of barramundi caught in the Mitchell is coming from food sources on the floodplain during the wet season. There is evidence that this is true for other fish species as well. This indicates the importance of inundated floodplains for the maintenance of aquatic food webs. One approach to using the flood inundation mapping for management is to identify those areas of the flood plain that have the longest flood duration and that are most connected to the drainage network. In the absence of an exact inundation time series that allow estimation of inundation duration, flood inundation frequency could be used as a surrogate. Flood inundation frequency is calculated by combing all flood event captures (over any number of years) and adding them such that the frequency of flood occurrence can be determined for any point in the landscape.

Recommendations for future work

The L-band SAR imagery used in this study was the Map 1.5-G product which is provided with a level of pre-processing. The use of the Level 1.0 (raw data) would enable the Cloude Decomposition to be implemented. The Cloude Decomposition method results in data showing single, double and multiple bounce interactions with targets. The resulting data can indicate the presence of water and flooding under vegetation. However, the Level 1.0 raw data requires specialised processing software such as RAT (Radar Tools- which is open source software), available from: http://radartools.berlios.de/. There are two polarimetric images that were acquired for the Daly River floodplain which can be used to test the Cloude Decomposition method. Further investigation will also be conducted on the Fine Beam Double imagery as the cross-polarised channel (H-V) may be useful in mapping some of the flooded classes.

While cloud cover is a limitation for the optical remote sensing of floods in northern Australia it can applied to map the dynamics of water following flood events. A characteristic feature of the wet-dry tropics of northern Australia is the relative absence of cloud following the wet season. Landsat 5 TM is free and readily available and can be effectively applied to map the seasonal dynamics of water bodies following floods. One of the key advantages of optical remote sensing over microwave remote sensing is the capacity to map the constituents of the water bodies such as turbidity which has a significant influence on aquatic primary productivity.

Validation of flood mapping

The Daly River mapping is currently unvalidated, and it is recommended that ground-truthing and validation be conducted at the time of image acquisition to provide a level of accuracy (or uncertainty) on the classification results. Accuracy assessment of the MODIS food inundation mapping for the Mitchell was undertaken using data obtained from a combination of depth loggers and temperatures sensors deployed on the Mitchell floodplain over the 2009 wet season. A total of 8 depth loggers (pressure transducers) and 33 temperature sensors were deployed. Accuracy of the MODIS flood mapping ranged from 78% to 86% based on the number of correctly classified sites divided by the total number of sites.

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