Wungong Catchment Trial

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Hydrology for the Wungong Catchment Trial

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Summary

The hydrology component of the Wungong Catchment Trial focuses on the ecological sustainable principle of maintaining ecosystem health as described in the Forest Management Plan 2004-2013. The main criteria to achieve this principle being the conservation and maintenance of water and the maintenance of aquatic ecosystems.

Maintaining streamflow is critical to aquatic ecosystem health and also important in the provision of public drinking water. The forest ecosystem, also dependent on the availability of water, benefits through programs that channel funds in support of adaptive management.

From the late 1960's a high quality streamflow and catchment rainfall network was established for South West Western Australia. Also during the 1970's and 80's there was exceedingly valuable cooperative small catchment hydrologic research that provided the background knowledge for the Wungong Catchment Trial.

In 1998 operation of many stream gauging stations and pluviometers in this region ceased due to funding constraints. To support the Wungong Catchment Trial key stream gauging stations, pluviometers, and a groundwater monitoring network have been re-established. This network can now provide hydrologic information for areas being treated and for reference catchments to enable the Wungong Catchment Trial to be placed in context.

This hydrologic network together with gauged catchments being operated for Alcoa and the Department of Water is once again providing reliable information on the stream regime of the Northern Jarrah Forest.

These data show that streamflows in the 2000's are substantially less than the flows that were measured in the 1990's for the same rainfall. It is of great concern that the historically perennial Wungong Brook is now ceasing to flow for considerable periods each summer.

Current research by CSIRO should assist in quantifying the relationship between forest condition and this recent (post 1998) downturn in streamflow.

Streamflow quantity and quality monitoring of the first treated area (TA1) has shown no adverse impact on water quality. Also there is no apparent increase in runoff, which is not unexpected as it could require a further one or two winters before any additional water released into the soil and groundwater is observed in streamflow.

Sufficient hydrologic data has now been collected by the Wungong Trial to commence development of hydrologic sub-catchment models for Wungong Brook. This WEC-C modelling, planned for 2009, should better relate forest condition to groundwater and stream sustainability.

Introduction

In the mid 1970's a multi-agency research programme was commenced to investigate the water resource impacts of forest management strategies aimed at increasing both timber and water yields. Many of the small research catchments were in the Northern Jarrah Forest and they provided the knowledge that was utilized in developing the Wungong Catchment Trial. Although valuable this information is not representative of the forest hydrology of the 2000's nor the impact of operational scale forest thinning on streamflow.

For the Wungong Catchment Trial gauged catchments were needed to monitor both treated catchments and reference catchments to quantify impacts of the Trial on the quantity, quality and variability of streamflow. To meet the time demands of the trial it was critical that the majority of stations selected had significant years of earlier good quality data.

In addition, if at all possible, groundwater monitoring of bores with a previous record in the region to be treated need to be identified and reactivated.

To have creditability the hydrologic data collected must be of a high and known quality and be readily available to all.

Method

All stream gauging stations and pluviometers that have been operated in the Northern Jarrah Forest, with emphasis on stations in or near the Wungong catchment, were identified and the extent and quality of previous record studied. From this a desired hydrologic network to meet the needs of the Wungong trial was identified.

A wildfire in the Mundaring and Canning Catchments in January 2005 provided the opportunity to gain valuable information of the impact of a sharp and extreme vegetation change by re-opening gauging stations on the severely burnt Little Darkin catchment and the adjacent Pickering Brook (as an unburnt control catchment).

The required stations were re-activated progressively, being upgraded where necessary to provide high quality data. Pluviometer site exposure was inspected and where possible the desired clearance criteria (two horizontal to one vertical) was achieved with some tree removal where necessary. A new pluviometer was required and was established for the 31 Mile Brook control catchment.

One reason for selecting the Wungong catchment for the thinning trial was the presence of a high quality hydrologic network. The mainstream Vardi Road gauging station was upgraded by the addition of a pumping sampler to collect daily water quality samples to monitor salinity, colour, turbidity, sediment and pH daily. Water samples were also collected manually at field visits for major

ion analysis. In addition catchment rangers collect samples to monitor for potential pollutants including glyphosate.

The small Cobiac gauged catchment, with an extensive groundwater monitoring network, that had been operated from 1992 to 1998 was re-activated. Again water quality monitoring equipment was added and an analysis regime established.

To monitor the stream flowing out of the first area to be treated in the Wungong catchment (TA1), a new gauging station was established at a culvert on Chandler Road. A pumping sampler was installed and a water quality analysis programme established.

Operation of the gauging stations is of a high standard due to the competence of Hydrographic teams from HydroSMART and the Department of Water working jointly on this project. Records of streamflow and rainfall are collected and verified in line with Australian standards.

The processed flow and rainfall data in monthly form is on line for the public to access at the Department of Water web page:
http://kumina.water.wa.gov.au/waterinformation/wrdata/wrdata.cfm
On that page is guidance on how to request detailed data for any station of interest.

Archiving groundwater and water quality monitoring data to the Department of Water data base is proving technically challenging, and in the interim these data are available through the Wungong Trial project team.

To discuss special data requirements contact keith.barrett@iinet.net.au.

The following table shows the hydrologic network that is being analysed for the Wungong trial. Operation of some of these stations is funded by Alcoa (for bauxite research) and these are shown with an asterisk.

WUNGONG CATCHMENT TRIAL HYDROLOGY Gauged Catchments						
Stream gauging stations	Station Number	catchment area km²	Historic rainfall mm (PWD 1980)	Runoff 83-98ave mm	Gauging Station Record + still operating	Pluviometer Station Numbers
Wungong Brook Catchment						
Wungong Brook, Vardi Road	616041	80.84	1280-1000, 1170#	150	May 1981 - +	509269, 509273, 509576
Wungong Brook, Cobiac	616058	3.64	1110#		May1992 -June98, May 2005- +	509576
Wungong Chandler Road	616124		1200-1250, 1220#		May 2005 - +	509269
* Seldom Seen Creek, Travellers Arms	616021	7.21	1290-1260 1250	236	May 1966 - +	509269
* More Seldom Seen Creek, Ceriani Farm	616022	3.41	1300-1280 1275	211	April 1966 - +	509270
* Waterfall Gully, Mount Curtis control	616023	8.62	1320-1255 1275	275	April 1966 - +	509271 509269
Correlation and Regional Context						
31 Mile Brook, 31 Mile Road	616026	10.96	1230-1120 1180#	151	July1985 -April 99; April 2006 - +	509610
39 Mile Brook Jack Rocks	614031	55.36	1220-980, 1120#	101	May1981-April 99; April 2006 - +	509232, 509324
North Dandalup North Rd	614036	79.74	1320-1130, 1240#	96	March1983 -99; May 2006- +	509189, 509548, 509349
Canning River Glen Eagle	616065	520.00	850	25	June1950-May 99; May 2008 - +	509273, 509410, & Millars Rd
Canning River, Millars Road	616039	140.59	920-700, 800#	12	June1985-April 99; May 2008 - +	509422, 509423
* Big Brook O'Neil Rd	614037	148.99	1200-850, 1050#	34	April 1983 - +	509221, 509589,
Harvey River, Dingo Road	613002	147.21	1250	238	March 1970 - +	509119, *509223,4, 509116,7*
* Little Dandalup Trib, Bates,	614062	2.22	1300#		July 1988 - +	509579
Wildfire Impact (Jan 2005 wildfire)						
Little Darkin, Hairpin Bend	616010	37.82	980-850 900	23	May1969-May99; April 2005 - +	509159, 509155
Pickering Brook, Slavery Lane	616009	29.44	1160-980 1050	63	May1969-May99; April 2005 -+	509280, 509631

NOTE; Historic catchment rainfall average taken from "Streamflow Records of WA to 1982" (# or equivalent) shown as PWD 1980,.
Average annual runoff for 1983 to 1998 is provided for basic comparison of gauged catchments listed
Italics ; pluviometers currently not operated but valuable

Results

Data for all gauged catchments are readily available for up to and including the 2007/08 Water Year (1 April 07 to 31 March 08). Also data for stations operated specifically for the Wungong Trial have been extracted and processed to October 2008.

The hydrologic data for all stations indicate a further significant reduction in streamflow for recent years compared to the flows of the 1990's, even for the same rainfall. This downturn is so compelling that interested parties should carry out their own analysis and carefully consider the implications for their forest management accountabilities.

Streamflow
By way of an example the streamflow data collected on the Wungong Brook mainstream at Vardi Road is presented here and discussed is some detail.

The Vardi Road gauging station has a stable low crest concrete weir control and good facilities for flow rate verification measurement. It has been well operated since its establishment in May 1981 and provides a reliable and accurate flow record for its 80.84 km^2 catchment. There are records for the damsite (130km^2) going back to 1911 that provide a very relevant long term assessment of Wungong Brook flow regime.

The table below summarises the gauging record for the Vardi Road catchment.

The rainfall is taken from the Seldom Seen Gardens pluviometer which provides the most reliable long term record in the immediate area. Missing record for 1981 (18 days) and 1985, 1986 (267 days) was filled in from the nearby More Seldom Seen and Waterfall Gully pluviometers.

2001 and 2006 were abnormally dry years with the only recorded replicate being 1914.

If one excludes 2001 and 2006 as record outliers, the annual rainfall, number of raindays and rain per rainday for the Seldom Seen pluvio has remained generally unchanged over its entire record which commenced in June 1974.

For simple comparison purposes the 27 year record for Vardi Road has been considered as three 9 year data sets. The average runoff, expressed as a percentage of the average rainfall, for the 1990 to 1998 water years was marginally higher than the previous 9 years, possibly reflecting an influence of active bauxite mining.

The 1999 to 2007 period percentage average runoff was two thirds of the average for the 1980's.

A most compelling indication of change is the fact that when the 27 years of Vardi record were ranked on percentage runoff, the six poorest performing years all came from the last seven years of record (2001/02 to 2007/08).

WUNGONG RIVER — VARDI ROAD GAUGING STATION

Catchment Area 80.84 km²

Water Year	Gardens Pluvio RAINFALL mm	Rain Days	Rain/ raindays	Vardi 616041 RUNOFF mm	% RUNOFF	Average Runoff % Comparison	**Minimum Daily Flow litres/sec.**
1981/82	1325			211	15.9%		**19.4**
1982/83	812	155	5.15	90	11.1%		**11.5**
1983/84	1251	161	7.85	221	17.7%		**14.5**
1984/85	1332	169	7.88	178	13.4%		**15.2**
1985/86	1077			106	9.8%		**11.7**
1986/87	924			110	12.0%		**10.0**
1987/88	1026	113	8.97	99	9.7%		**5.8**
1988/89	1339	166	8.07	251	18.8%		**8.0**
1989/90	1201	168	7.15	129	10.8%		**30.2**
Average 81-89	**1143**	155	7.5	**155**	**13.6%**	1	
1990/91	941	152	6.19	158	16.8%		**18.8**
1991/92	1355	161	8.42	233	17.2%		**19.2**
1992/93	1147	147	7.80	215	18.8%		**34.8**
1993/94	849	135	6.29	110	13.0%		**17.4**
1994/95	893	123	7.26	106	11.9%		**8.1**
1995/96	1097	161	6.81	146	13.3%		**12.3**
1996/97	1334	152	8.78	226	16.9%		**14.2**
1997/98	966	135	7.16	114	11.8%		**7.5**
1998/99	1053	153	6.88	91	8.6%		**5.0**
Average 90-98	**1071**	147	7.3	**156**	**14.5%**	1.070	
1999/2000	1197	147	8.14	126	10.5%		**11.6**
2000/01	1056	128	8.25	187	17.7%		**5.7**
2001/02	758	125	6.07	43	5.7%		**2.5**
2002/03	1010	160	6.31	86	8.5%		**2.3**
2003/04	1153	148	7.80	128	11.1%		**2.0**
2004/05	1109	147	7.36	75	6.7%		**0.0**
2005/06	1112	160	7.05	85	7.6%		**0.9**
2006/07	679	130	5.32	23	3.5%		**0.0**
2007/08	1149	147	7.61	81	7.0%		**0.0**
Average 99-2007	**1025**	144	7.1	**93**	**9.0%**	0.67	
Excluding 2001 & 2006							
Average 99-2007	**1112**	148	7.5	**110**	**9.9%**	0.73	

A fairer comparison is possibly to exclude the very dry 2001 and 2006 Water Years from the 1999 to 2007 data set. When this is done the average rainfall is similar to the previous two sets of 9 years and the average runoff is about 70% of the pre 1999 runoff (73% of 1980's and 68% of 1990's).

From an aquatic ecosystem viewpoint the greater concern is the reducing minimum flow. Wungong Brook, which was previously a perennial stream, now ceases to flow each summer. It ceased to flow for the first time in March 2005 (14 days) and maintained a trickle in summer 2006. Following the poor 2006 winter it ceased to flow on 21 January 2007 for 99 days and the pools were bone dry.

The winter of 2007 had good winter rains through the Wungong Catchment and it was therefore very disappointing to observe the Brook again cease to flow in January 2008 for 83 days.

Streamflow quantity and quality for the first treated area (TA1) has been monitored at the Chandler Road gauging station. There is no apparent increase in runoff, which is not unexpected as it could require one or two further winters before any additional water released into the soil and groundwater was observed in streamflow. With the substantial area of untreatable stream reserves, Fauna Habitat Zones and informal reserves (mostly located low in the profile) there is no certainty that an increase will be observed.

The following table sets out the catchment runoff as measured at the stations associated with the Wungong Trial. These are provided for qualitative interest only. It is considered that one or two further years of record are required from the re-established stations with detailed rainfall runoff analysis to build up a reliable quantitative understanding of the change in flow regime that appears to have occurred recently.

GAUGED CATCHMENTS — STREAMFLOW EXPRESSED AS RUNOFF (mm)

Stream gauging stations	Catchment area	Average 1983-98	Water Years 2005 06	2006 07	2007 08	2008 to Oct 12
	Km²	mm	mm	mm	mm	mm
Wungong Brook Catchment						
Wungong Brook, Vardi Road	80.8	156	85	23	81	45
Wungong Brook, Cobiac	3.6		48	6	54	31
Wungong Chandler Road	17.0		131	43	131	68
Seldom Seen Creek	7.2	250	121	27	104	
More Seldom Seen Creek	3.4	234	75	16	51	
Waterfall Gully, Mount Curtis	8.6	276	201	92	167	
Correlation and Regional Context						
31 Mile Brook, 31 Mile Road	11.0	151		23	85	54
39 Mile Brook Jack Rocks	55.4	101		9	54	26
North Dandalup North Rd	79.7	96		27	68	29
Canning River Glen Eagle	520	25				9
Canning River, Millars Road	141	12				3
Big Brook O'Neil Rd	149	34	23	8		
Serpentine River, River Road	243	30				12
Harvey River, Dingo Road	147	243	195	83	198	
Little Dandalup Trib, Bates,	2.2		106	47	103	
Wildfire Impact (Jan 2005 wildfire)						
Little Darkin, Hairpin Bend	37.8	23	27	0.8	15	10
Pickering Brook, Slavery Lane	29.4	63	34	0.8	33	25

Note: 2008 record for Little Darkin & Pickering Bk is to Oct 1st.
Water Year starts on April 1st

Notably although the 2007-08 water year had slightly above average rainfall, the runoff for stations listed was only some 55% of the 1983-98 average.

There are interesting observations to be made from the gauged catchment records collected to date for Cobiac, Little Darkin and Pickering Brook and these are covered in separate Research Overview papers.

Although 2008/09 Water Year winter was non typical (dry August and wet November) the data collected for all of the stations listed in the Gauged Catchments table will be studied after the water year concludes on 31 March 2009.

Water Quality

The comprehensive water quality monitoring programme has provided detailed data sets for Wungong Brook at Vardi Road, Chandler Road and Cobiac and for Little Darkin River (impacted by wildfire).

The January 2005 Wildfire on the Little Darkin Catchment caused significant water quality issues clearly identified in the data collected. The impact of this fire is covered in The Effects on Wildfire paper in this update. A summary of some of the laboratory analysis results of the water samples collected at the Little Darkin gauging station is provided in the following table.

LITTLE DARKIN RIVER Water Quality Monitoring Results

			Turbidity				
		number of samples	**Average** NTU	10% NTU	Median NTU	90% NTU	98% NTU
Little Darkin Hair Pin Bend	2005	198	**5.8**	0.7	2.2	13.3	37.4
	2006	49	**4.5**	0.3	0.8	10.5	49.0
	2007	141	**4.4**	0.8	2.0	9.2	25.4
			Conductivity (25º C) Laboratory Analysis				
		number of samples	**Average** mS/m	10% mS/m	Median mS/m	90% mS/m	98% mS/m
Little Darkin Hair Pin Bend	2005	198	**46.1**	30.4	37.3	65.6	140.0
	2006	49	**28.6**	22.4	30.0	33.4	36.0
	2007	141	**28.5**	20.0	30.0	35.0	36.0
			Salinity measure - TFS from sum of major ion				
		number of samples	**Average** mg/l	10% mg/l	Median mg/l	90% mg/l	98% mg/l
Little Darkin Hair Pin Bend	2005	17	**469**	165	197	1448	1547
	2006	4	**163**	149	165	174	176
	2007	6	**145**	111	152	172	172

Note; A high percentage of the turbidity results exceed the guideline value of 5 NTU

The Wungong Trial forest thinning has concentrated on treatment area TA1 and the Cobiac small catchment. Streamflow quality and quantity for TA1 is monitored by the specially established gauging station (with pumping sampler) at Chandler Road. The Cobiac catchment is closely monitored by the re-opened Cobiac gauging station with the pumping sampler established in

2006, one year prior to any treatment. Pumping samplers are also operated at the Wungong Brook mainstream Vardi Road gauging station.

Turbidity and salinity are possibly the parameters of general interest so summary results for these parameters are presented in the following table.

WUNGONG GAUGED CATCHMENTS Water Quality Monitoring Results

Turbidity

		number of Samples	**Average** NTU	10% NTU	median NTU	90% NTU	98% NTU
Vardi Road	2005	295	**0.8**	0.3	0.5	1.6	2.8
	2006	219	**0.6**	0.3	0.4	1.0	2.0
	2007	236	**0.6**	0.3	0.5	1.1	1.6
Chandler	2005	275	**0.6**	0.2	0.4	0.9	4.3
	2006	193	**0.6**	0.3	0.4	1.0	2.9
	2007	179	**0.4**	0.2	0.3	0.5	1.0
Cobiac	2005	6	**0.9**	0.2	0.3	2.1	3.5
	2006	60	**0.6**	0.3	0.4	0.6	2.9
	2007	99	**0.7**	0.3	0.5	1.2	2.0

Conductivity (25º C) Laboratory Analysis

		number of Samples	**Average** mS/m	10% mS/m	median mS/m	90% mS/m	98% mS/m
Vardi Road	2005	294	**33.4**	29.4	33.5	37.2	38.4
	2006	205	**32.8**	29.0	34.0	36.0	37.0
	2007	236	**29.7**	25.0	29.0	34.0	35.0
Chandler	2005	276	**28.6**	24.5	28.3	34.0	36.7
	2006	193	**29.2**	23.0	29.0	34.0	37.0
	2007	184	**26.0**	23.0	25.0	30.0	33.3
Cobiac	2005	6	**30.2**	24.7	31.6	34.3	34.3
	2006	60	**31.7**	27.7	32.0	37.1	38.8
	2007	99	**24.4**	22.0	24.0	28.0	30.0

Salinity measure - TFS from sum of major ion

		number of Samples	**Average** mg/l	10% mg/l	median mg/l	90% mg/l	98% mg/l
Vardi Road	2005	17	**169**	155	167	182	187
	2006	33	**163**	151	162	177	186
	2007	11	**158**	142	159	173	178
Chandler	2005	18	**138**	126	139	151	156
	2006	15	**149**	140	145	159	164
	2007	15	**133**	118	132	147	164
Cobiac	2005	6	**149**	126	154	168	168
	2006	4	**156**	136	157	174	180
	2007	8	**127**	113	128	142	146

Salinity, as measured by conductivity (mS/m) at 25º C, if multiplied by 5 will give an indicative mg/l salinity value. The more precise and time consuming TFS analysis was carried out on the manually collected water samples.

Sampling by catchment management rangers for glyphosate, (during times of notching) have not identified the presence of this herbicide in Wungong Brook.

A comprehensive set of water quality data are now available for detailed analysis. The 2008 water quality data are available to researchers and will be compiled for general release at the end of first quarter 2009.

Discussion

The Wungong Trial needs to be assessed in the context of the forest hydrology changes that now appear to be occurring across the entire Northern Jarrah Forest. Although a key stakeholder, the Water Corporation is not the forest manager. And the Wungong Trial is not tasked with studying the sustainability of the forest and aquatic ecosystems of the entire Northern Jarrah Forest.

The Wungong Trial was established to assess the feasibility of increasing flows to streams. The recently collected hydrologic data suggests that the objective should now be couched in terms of increasing flows "relative to the do nothing different" state. The declining flows from both regrowth and bauxite mining rehabilitated forests highlights the importance of the Wungong Trial with respect to the future of terrestrial and aquatic ecosystems and flowing streams in the Northern Jarrah Forest.

Conclusion

The network of stream gauging stations, water quality monitoring and pluviometers required to assess the hydrologic impact of the Wungong Trial has been established and is being operated to provide reliable and accurate data.

A further two years of streamflow record from Chandler Road and Cobiac stream gauging stations will be required to assess if the level of silvicultural treatment approved for TA1 (above Chandler Road) and the Cobiac catchment results in a rise in the shallow groundwater table and improved runoff to streams.

Recommendation

Continue the operation of the hydrologic network detailed in this report and continue with analysis of the data collected.

Undertake detailed modelling (WEC-C) to develop estimates of streamflow responses to the approved silvicultural treatment of Cobiac and Chandler Road catchments.

With this modelling, assess the impact that stream reserves, Fauna Habitat Zones and other informal reserves are having on streamflow.

Achieve installation of a recording class A evaporation pan and climate station to improve hydrologic modelling.

Continue with the development of protocols and computer systems to have all ground water level and water quality data readily available through the Department of Water Hydstra data base.

Acknowledgements

The high level of dedication and professionalism of the hydrographic teams from Hydro-SMART and the Department of Water is greatly appreciated. Special thanks to Kelvin Baldock and Rebecca James of Hydro-SMART and Kim Richardson, Glenn Biggins, Paul Rakich and other members of the Swan Avon Hydrographic Team, Department of Water.

The ready assistance of officers of the Water Information Branch, Department of Water is acknowledged with thanks.

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Groundwater responses of the Cobiac hydrological research catchment

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Summary

The Cobiac research catchment has an extensive groundwater monitoring network, and continuous rainfall and streamflow information. It was initiated in the early 1990s and was operated up until 1998 as part of Alcoa's hydrological research programme. In 2005 it was re-opened by the Water Corporation as part of the Wungong Catchment Trial.

Forest treatment in the catchment involved a commercial harvest followed by non-commercial notching, which was completed in the first half of 2008. It is still too early to see a groundwater or streamflow response from the treatment, although we expect to see the start of the response over the next couple of years. Monitoring will continue, but in the meantime we will be undertaking detailed catchment modelling to determine the likely response to the treatment.

Assessment of groundwater levels with all available data shows that groundwater levels have fallen 4-6m across much of the middle and upper parts of the catchment since the 1990s. In the streamzones and lower slopes, the reduction has been in the order of 1-2m. This reduction has had a critical impact on the streamflow in that groundwater appears to no longer intersect the stream. Also, the swampy areas surrounding the stream used to have groundwater levels at or near the surface, but these areas are now 1-2m below the surface which means that they are no longer 'wetting up' in winter, and no longer able contribute direct runoff to the stream throughout winter and spring.

Introduction

Cobiac is one of a series of research-scale catchments located within the drinking water supply catchment for Wungong Dam. It is located at the south-eastern portion of the Wungong catchment, along the upper reaches of the Wungong Brook, see Figure 1, and is 364 ha in size. It is part of the larger Vardi Road catchment.

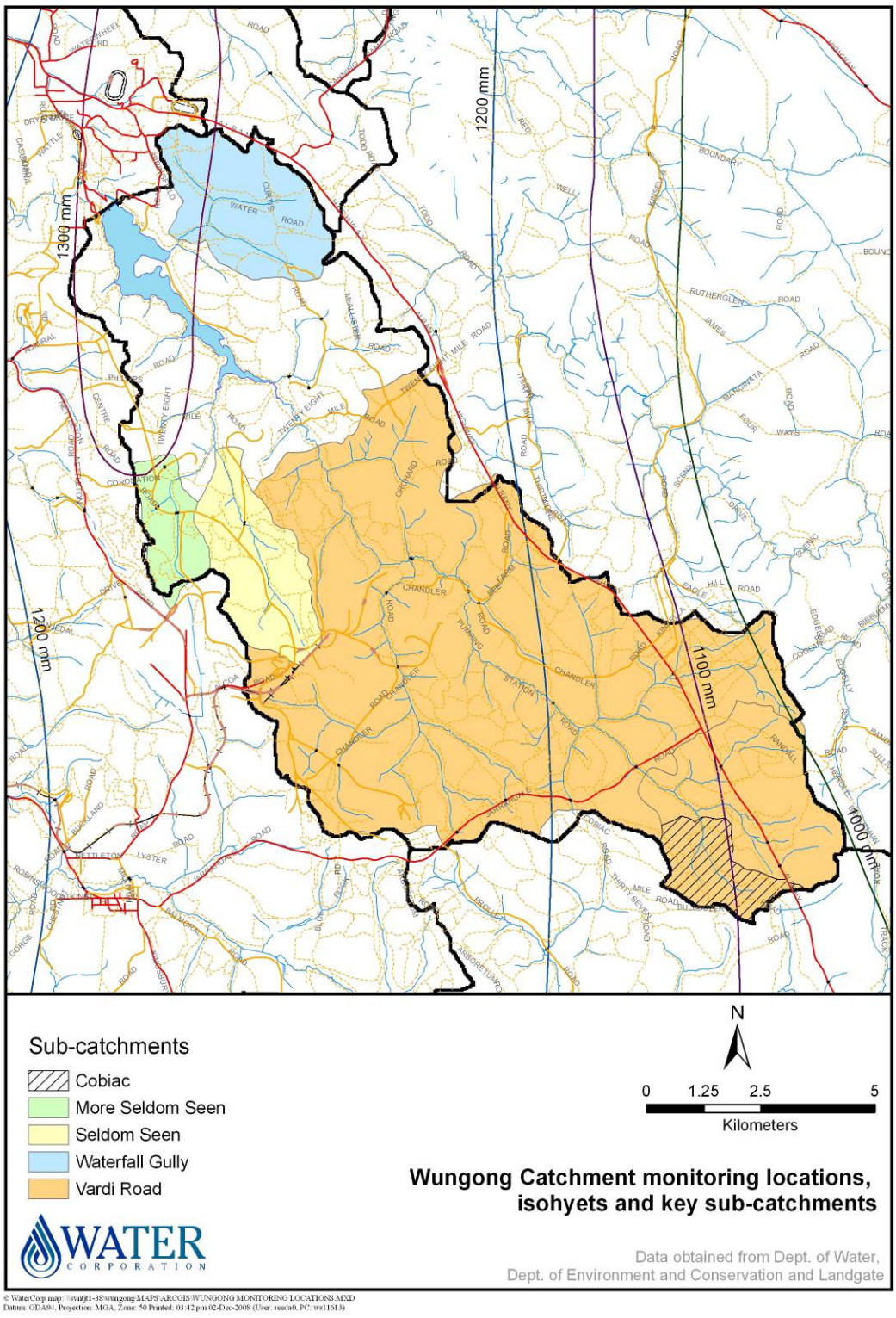

Figure 1 Location of the Cobiac research catchment within the Wungong catchment.

Cobiac was originally installed as part of the multi-agency hydrological research programme associated with Alcoa's mining activities and as such it had an extensive bore network installed in the early 1990s. However, Alcoa's decision to close the Jarrahdale mine site meant that Cobiac never became a critical mining research catchment and the site was mothballed in 1998. It was re-established by the Water Corporation in 2005 as part of the Wungong Catchment Trial.

Cobiac is also integrated into CSIRO's Premier's Water Foundation-funded project, 'Vegetation dynamics and water yield under changing climate and management' (referred to throughout this paper as 'the PWF project'). As part of the PWF project additional shallow piezometers[1] and soil moisture monitoring holes were installed by CSIRO in 2008 along hillslope transects to supplement the existing piezometer network.

The extensive piezometer network in Cobiac (see Figure 2) will be useful in determining how the groundwater system reacts to the approved forest treatment prescriptions. It will also provide detailed groundwater level information for input into catchment models, which will mean those models will be better able to predict the likely groundwater and streamflow reactions to various forest treatment scenarios.

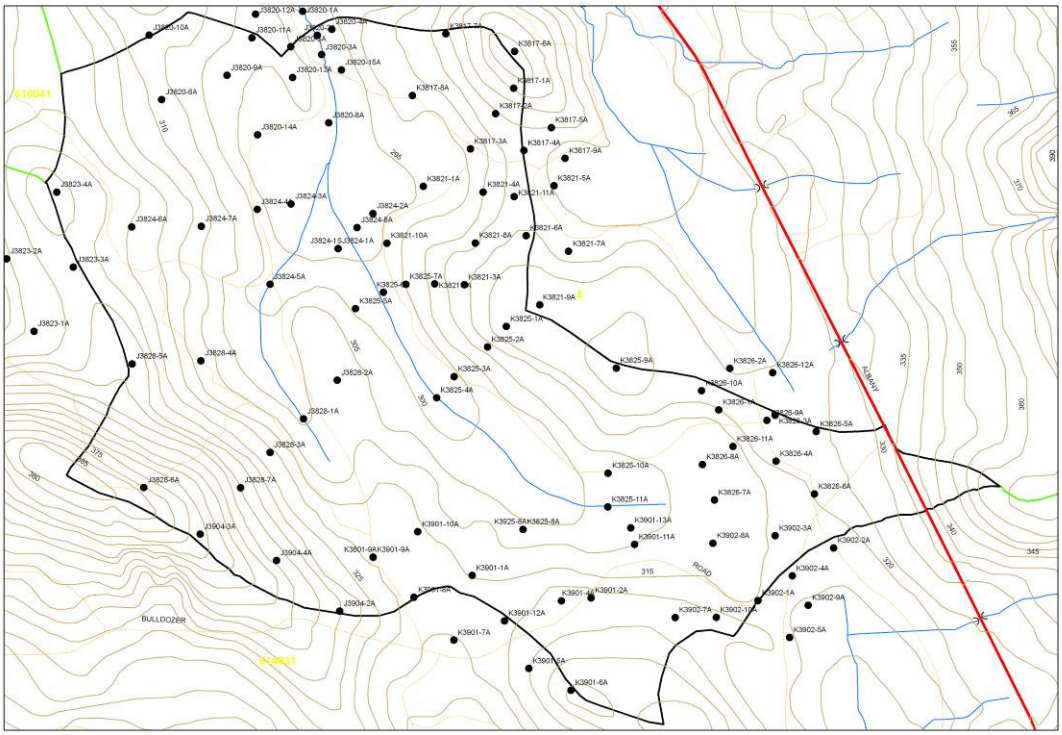

Figure 2 Piezometer network installed by Alcoa in the Cobiac catchment

Before treating this catchment, the Water Corporation proposed prescriptions that were designed to provide more hydrologic impact than those already approved for the Wungong Catchment Trial. However, this proposal was not accepted by the Conservation Commission.

Method

As part of the multi-agency research programme associated with Alcoa's mining activities, rainfall and streamflow monitoring was initiated in 1992 by the then Water and Rivers Commission (now Department of Water). A drilling program was undertaken by Alcoa from 1991 to 1994 to install the piezometer network. Rainfall, streamflow and groundwater were monitored until 1998.

[1] A piezometer is a bore installed for the purposes of groundwater monitoring.

In 2005 the rainfall, streamflow and groundwater monitoring was reactivated by Water Corporation in anticipation of the proposed forest treatments, and is planned to continue throughout the life of the Wungong Catchment Trial.

The rainfall and streamflow monitoring methodology is discussed in the Hydrology paper and will not be duplicated here.

Groundwater monitoring in the Cobiac catchment was originally undertaken by Alcoa by manually dipping each piezometer to record depth to water levels on a monthly basis. Selected sites were also sampled to provide water quality information. Since the monitoring has been re-established in 2005, the monitoring has been undertaken on a quarterly basis, which is sufficient to pick the peaks and troughs in depth to water. Regular bore maintenance has not been undertaken to date as part of latter monitoring period.

To maximise the likelihood of a hydrologic impact a request was made for Cobiac and a 200 metre extension beyond its catchment boundary to be thinned to a heavier prescription than that which applies elsewhere. The requested prescription was to retain 10 m^2/ha total basal area (7-8 m^2/ha growing stock plus 5 habitat trees per hectare). This request also proposed that the retained trees be representative of all size classes with a strong emphasis on retaining larger trees where a choice exists. Approval for this proposal was not achieved and instead the "Interim Guideline for Silvicultural Practice in the Jarrah Forest of the Wungong Catchment – SFM Interim Guideline No. 1, 2007", was adopted for treating the Cobiac catchment. This allows the forest to be thinned to a target basal area of 12-15m^2/ha, with 5 habitat trees per hectare retained.

Results

Forest treatments

Figure 3 is a map of the forest treatments for the harvesting coupe containing the Cobiac catchment.

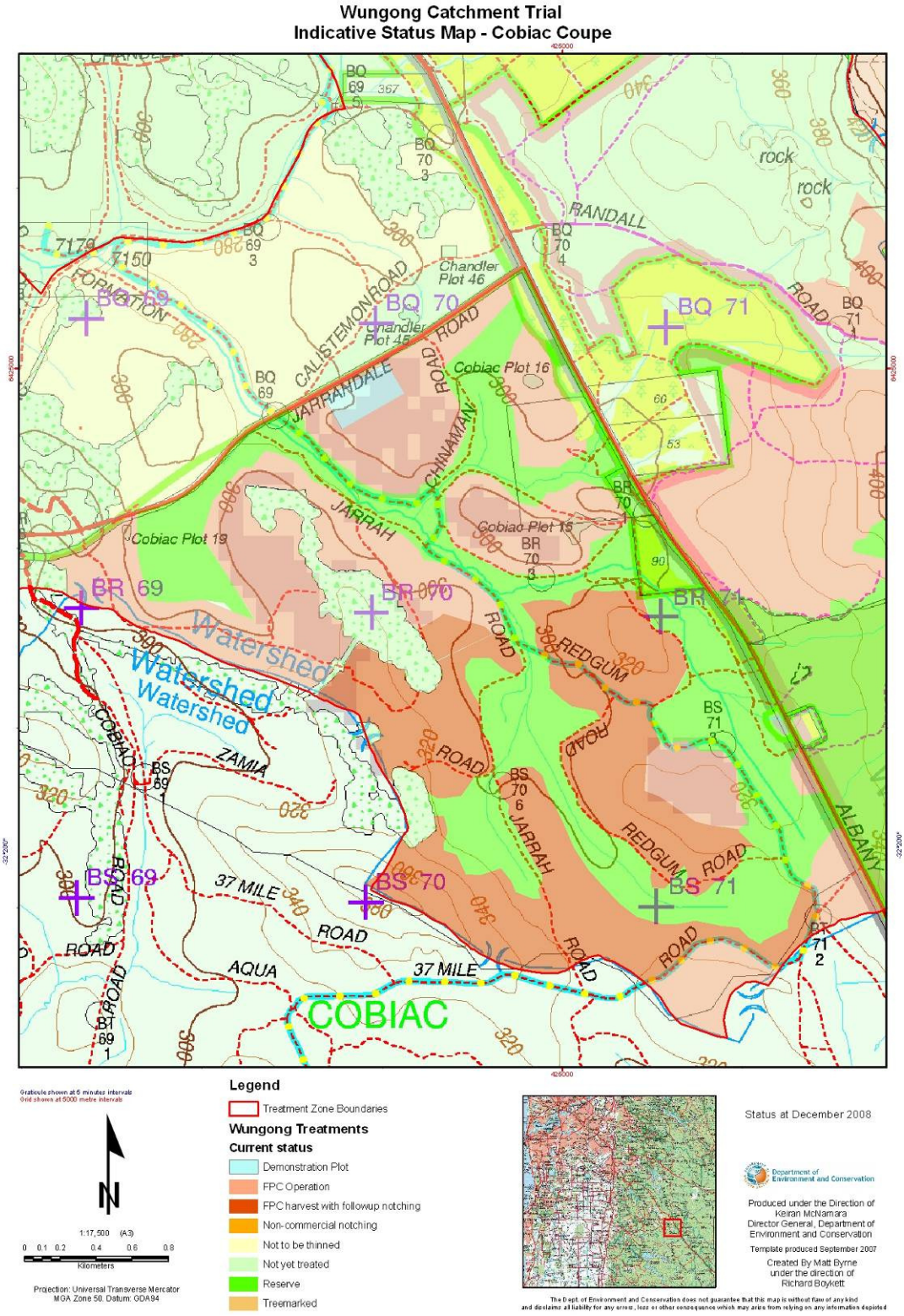

Figure 3 Forest treatment map for the harvesting coupe (inc Cobiac catchment).

Cobiac is part of a commercial harvesting coupe undertaken by Forest Products Commission (FPC) in the 2007/08 summer season. The area was generally identified by FPC and treemarked as a 'selective cut in dieback' with some areas of 'shelterwood' in the upslope areas. Harvesting was undertaken in early 2008 and completed by April 2008.

Notching was undertaken by Western Forest Management, operating under contract to Water Corporation, in June 2008.

Pre-treatment basal area's sat around 25-30 m^2/ha. After harvesting this was reduced to 15-25 m^2/ha with cull trees still standing. Analysis of the post-notching field surveys has not yet been completed for this area. The Water Corporation also has pre- and post-treatment remote sensing data, which will be used to calculate the reduction in canopy density due to these operations.

Prescribed burning was last undertaken in 2002/03. The next burn is planned around 2010.

Streamflow

While it is too early to pick up any groundwater or streamflow responses to the treatment that has occurred so far, there are some clear hydrological changes that have occurred between the two periods of record (1992-1998 and 2005-2008).

The table below gives a summary of the streamflow and rainfall analysis for the full period of record in the Cobiac catchment.

Year	Days of flow	Rain prior to start of flow (mm)	Runoff (mm)	Total rainfall (mm)	Runoff as a percentage of rainfall
1992	184	233	142	1071	13.3%
1993	136	260	46	753	6.1%
1994	134	266	56	798	7.0%
1995	174	233	91	1026	8.9%
1996	179	222	143	1309	10.9%
1997	164	228	52	839	6.2%
1992-1997 average	**162**	**240**	**88**	**966**	**9.1%**
2005	160	339	48	980	5.0%
2006	63	316	6	683	0.9%
2007	117	294	54	1021	5.1%
2005-2007 average	**113**	**327**	**36**	**902**	**4.0%**

Table 1 Streamflow and rainfall analysis for Cobiac, reported as a water year (from 1st April to 31st March).

Critical points to note from this are:

- runoff as a percentage of rainfall has halved; and
- it now takes almost 100mm more rainfall to initiate flow in Cobiac catchment.

Detailed rainfall analysis, such as comparisons of rain days, rain per rain day and rainfall intensities has not been undertaken for the data collected at Cobiac. This should be assessed within the broader context of rainfall patterns and changes across the Darling Plateau.

Groundwater

There have been reductions in groundwater levels recorded in the 2005-2008 period compared with the 1992-1998 period across the Cobiac catchment. Average groundwater levels on the mid- and upper-slopes have dropped 4-6m, while streamzone and lower-slope groundwater levels have dropped around 2m.

Figure 4 shows the depth to water readings for a mid-slope piezometer, installed in 1991. A depth to water reading of 0m indicates that that groundwater is at the ground surface, a reading of 5m means that groundwater is 5m below the ground surface, etc.

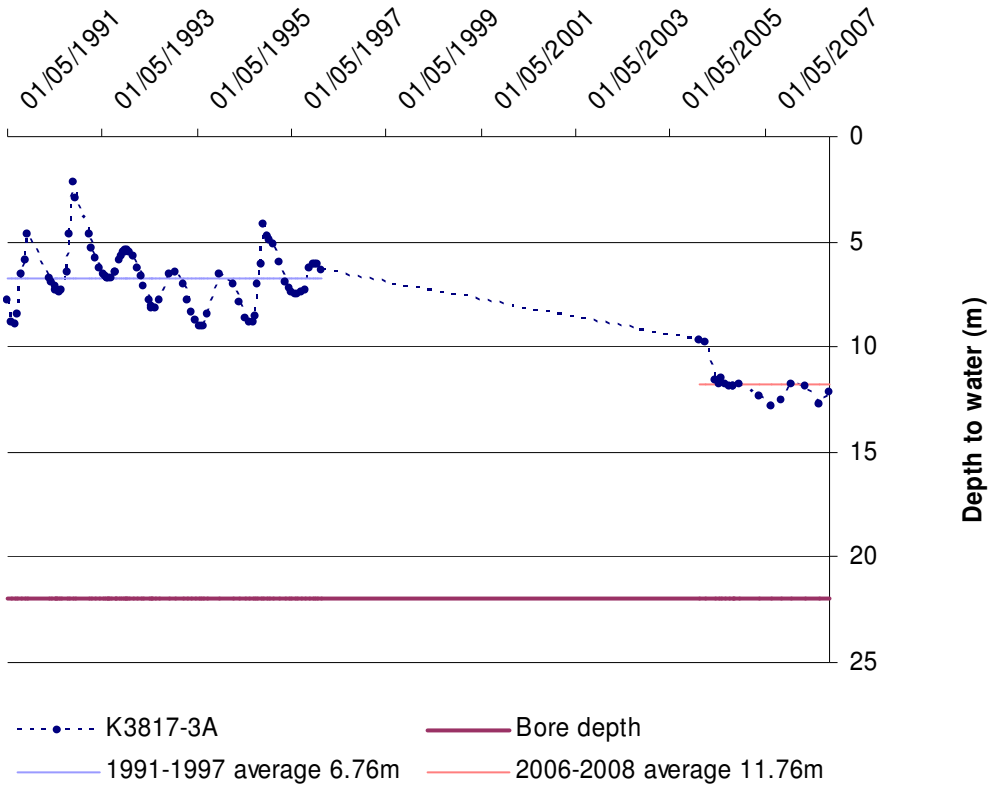

Figure 4 Depth to groundwater levels for a typical piezometer located mid-slope in Cobiac catchment

Typically, groundwater levels demonstrate a lag effect relative to the rainfall season in that the highest levels are recorded throughout spring and early summer (in this case between October and December), and the lowest levels in winter (June and July here).

An interesting point to note about the record for this piezometer is that groundwater levels did not appear to recover at all following the 2006 winter – a particularly poor rainfall year across the Northern Jarrah Forest. In fact, in this location, it appears that the 'trough' following the 2005 summer becomes the 'peak' following the 2006 winter, indicating there was no groundwater recharge during that season.

Figure 5 shows the depth to water record for a piezometer located in the streamzone near the Cobiac streamflow gauging station.

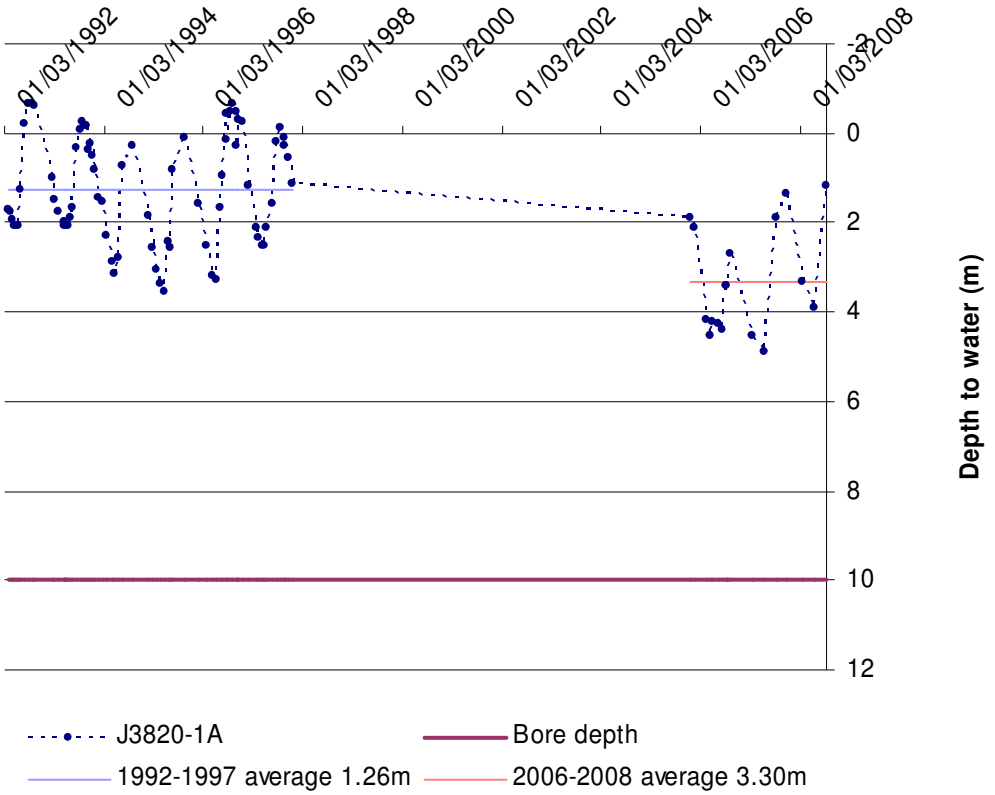

Figure 5 Depth to groundwater levels for a streamzone piezometer, located near the Cobiac streamflow gauging station

During the earlier period, groundwater frequently intersected the surface (and therefore the stream) for an average of 2 months each year. The latter period of record shows that groundwater is no longer intersecting the surface, and even at its highest levels is over a metre below the ground. Not only does this mean that groundwater is no longer contributing to streamflow at the gauging station, it also means that the streamzone and lower slope area that used to saturate no longer does so. It is this saturated area around the streams that allows direct runoff to occur. The conclusion from this is that there is now a deficit in both a groundwater contribution and a direct runoff contribution to streamflow.

It is worth noting that the groundwater recharge in the streamzone and lower slope piezometers following the winter of 2006 is poor but does exist, unlike many of the mid- and upper-slope bores.

Figure 6 shows an upper-slope piezometer record that appears to be "bucking the trend" established throughout the rest of the catchment by having a groundwater *increase* of around 2m during the latter period of record.

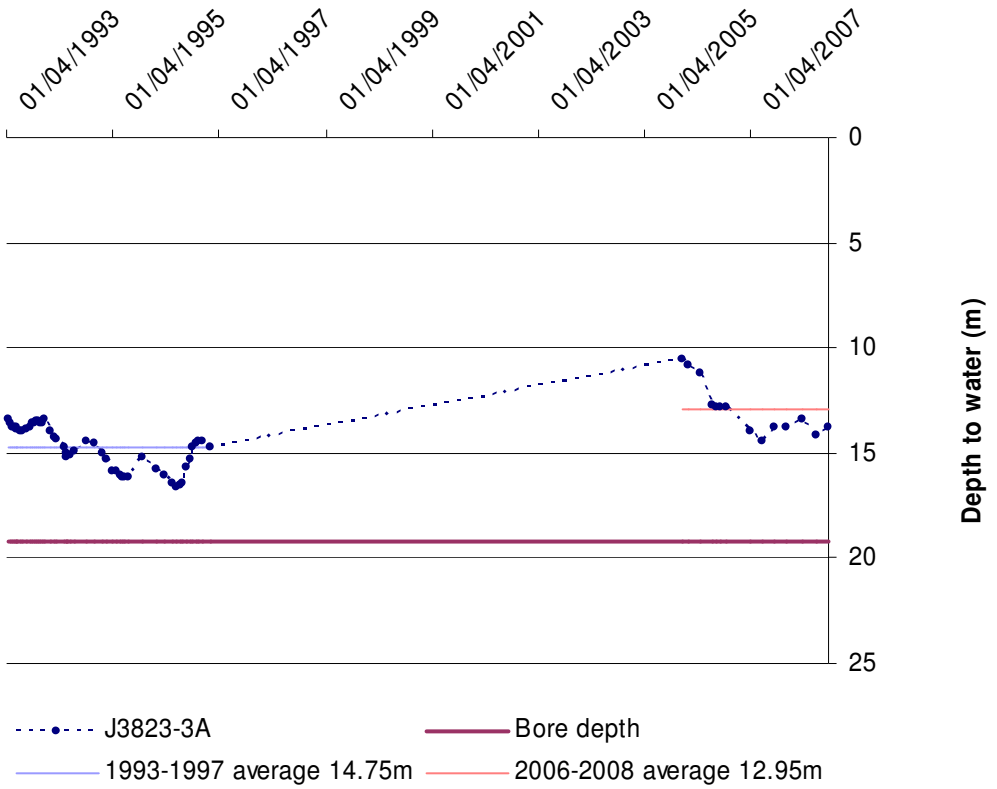

Figure 6 Depth to groundwater levels for an upper-slope piezometer, located adjacent to a rehabilitated bauxite mining pit in Cobiac catchment

This piezometer is actually located next to a rehabilitated bauxite mining pit, which was cleared in 1998 and rehabilitated in 2001. Unfortunately the piezometer was not monitored during this period, or the years immediately following rehabilitation, so it is unknown exactly how high the groundwater level peak would have been. However, this does indicate that significant groundwater level responses to treatment can still be achieved in the current hydrological regime, although the treatment in this case is rather severe.

Discussion

These results suggest that the groundwater and streamflow systems in Cobiac have not yet reached a new steady state following the rainfall downturn in the mid-1970's. Rather, they are indicative of a long-term and continuing drying trend, which is exacerbated by extreme years such as 2006.

At this stage it is unknown whether these reductions in streamflow and groundwater levels are related to any recovery in forest cover since the 1990s. It may be possible to relate remote sensing data and any information collected in the field during the 1990s to the data being collected as part of the Wungong Catchment Trial.

Given that future groundwater responses to the treatment within the catchment could be small in magnitude and duration in comparison with the overall reductions in depth to water level observed to date, the current quarterly monitoring of all piezometers is unlikely to provide the level of detail needed.

Despite the falling groundwater levels, the depth to water results for the area surrounding the rehabilitated bauxite mining pit do indicate that significant and sustained groundwater recharge is still possible from clearing. However, the longevity of that response following revegetation is unknown.

Conclusion

Cobiac catchment is a critical hydrological research catchment to assess the ability of the approved treatments in improving water yield. Continued monitoring of rainfall, streamflow and groundwater levels is crucial.

Undertaking detailed, physically based modelling of the catchment is also an important tool in understanding the groundwater and streamflow responses to the treatment that has been undertaken, in comparison with a 'do-nothing' scenario, and other potential treatment scenarios. These comparisons will be valuable tools in the decision making process associated with potential forest treatment options for water yield purposes, especially in the altered hydrological regime we are currently observing.

Recommendations

We now have a picture of the groundwater level fluctuations throughout the catchment. The next stage of assessment will be to determine what impact the forest treatments have had on groundwater, and as such we need to concentrate the monitoring effort by targeting streamzones and lower slope areas, and key piezometers on the mid- and upper-slopes on a monthly basis, rather than quarterly. We will also identify if any bores are suitable for monitoring on a sub-monthly interval.

Maintenance of these priority piezometers, a process known as bore development, is currently underway. This is necessary to ensure the continued accuracy of the level data recorded. This maintenance should be incorporated as a key component of the future groundwater monitoring programme.

A detailed physically based model (WEC-C) of the Cobiac catchment will need to be produced to assess the differences in streamflow and groundwater levels resulting from the proposed treatment compared to what actually happened. This model can also be used to run other treatment scenarios, the results of which will be valuable to decision-makers in assessing potential forest management options and their implications to water yield.

An understanding of the rainfall patterns and changes that have occurred across the Darling Plateau would be useful in assessing streamflow and groundwater level changes. This should be an item of consideration for the data assessment section of the PWF project.

Methods of determining what, if any, changes to forest cover between the two monitoring periods have occurred should be assessed. A quantitative assessment of this nature may help reduce the uncertainty surrounding the cause(s) of streamflow and groundwater level declines in Cobiac.

Acknowledgements

Many thanks to Keith Barrett, Frank Batini and Richard Boykett for their valuable contribution to this paper. The ready assistance from Alcoa World Alumina Australia in providing their groundwater monitoring data, and for re-establishing the groundwater monitoring programme during the early days of the Wungong Catchment Trial are greatly appreciated. Finally, the continuing efforts, dedication and professionalism of Dacre Allen of ND Mine Services in ensuring that the groundwater data collected is of high quality is acknowledged with many thanks.

The effects of wildfire on water quality, quantity, forest health and some measures of biodiversity

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Summary

The effects of the 28 000 ha, 2005 wildfire in the Helena catchment are being monitored by two gauged catchments, Pickering Brook (mostly unburnt) and Little Darkin (mostly burnt). Data show a substantial increase (2.2 times) in the first year following the fire, but with substantial erosion and loss of water quality. Between 1.5 and 2.5 million trees were killed by the fire. The terrestrial invertebrate biodiversity was reduced after the wildfire. Monitoring of water and forest recovery will continue for another 5-8 years.

Introduction

The trials are located in the Helena catchment, Pickering Brook and Little Darkin sub-catchments. The aim is to monitor water and forest values, the damage caused by the wildfire and recovery processes and times.

Method

The work relies on data collected from gauging stations, pluviometers, water quality sampling, remote sensing of foliar damage and recovery and ground plot data that assesses tree damage and recovery.

Results

Data show a substantial increase in water yield (2.2 times) over the control catchment in the first year following the fire, but with substantial erosion and loss of water quality. Five hundred tonnes of soil and organic matter had to be removed to keep the gauging station operational. By the third year, the difference in flow was minimal and there was little further erosion. Between 1.5 and 2.5 million trees were estimated to have been killed by the fire. Many were large habitat trees. Following the fire, the diversity of terrestrial invertebrates was reduced. Monitoring of water and forest recovery is expected to continue for another 5-8 years.

Discussion

The data show that wildfire can severely and detrimentally affect water quality, the stream-bed, pools, invertebrate diversity and forest health. In comparison, milder, more frequent prescribed fire, as occurred in the control catchment, is a tried and tested method of protecting all these values.

Conclusion

Water catchments should be prescribed burnt on a regular (5–7 years) timeframe so as to enhance water yield and minimise the size of wildfire.

Recommendations

Monitoring should continue for a further 5-8 years.
Results should be made widely available to politicians, the public, water and forest managers.

Published Reports/ Papers

The Forester vol 6 no 3 2007
Wungong Whispers Vol 5 2008
Jackson C (2006) Honours Thesis UWA

Acknowledgements

K Baldock, Hydrosmart

Forest perceptions project

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Summary

The Water Corporation's Wungong Catchment Trial is assessing the potential for tree thinning to increase run-off in a water supply catchment (Water Corporation 2005). If the Wungong Trial proves successful, the preferred thinning techniques may be implemented in other drinking water catchments.

Studies overseas and in Australia have demonstrated that modifications to forest management techniques can change perceptions of aesthetic appeal and recreation value. As with many drinking water catchments, the Wungong Catchment is a resource for non-water contact nature-based recreational activities. Most notably, a segment of the Munda Biddi Trail (i.e. a regional scale off-road cycling route) traverses the Catchment. Originating near the now tourist town of Jarrahdale, several bushwalking trails also pass through portions of the Catchment.

The first phase of the experiment is to use photo simulations of forest thinning options to measure perceptions of recreational value and ecosystem health for each option. These photo simulations will be presented in the form of a web-based survey.

Participants will be drawn from three target populations: a) off-road cyclists, b) bushwalkers, and c) forest managers. The web-based survey will be followed up with face-to-face in-depth interviews with some of the survey respondents to increase the richness of the data.

A technical report on the study methodology and findings will be published. Results from the first year of the study will feed into the Year 2 study, which will evaluate the effect of information on perceptions of the forest thinning treatments.

Introduction

The Wungong Catchment Research Project is assessing the potential for tree thinning to increase run-off in a water supply catchment. As with many drinking water catchments, the Wungong Catchment is also a resource for non-water contact nature-based recreational activities. Our social science research project will evaluate the impact of alternative thinning treatments on perceptions of (a) recreational value and (b) ecosystem health. The knowledge gained from this research project will assist the Water Corporation in selecting forest thinning techniques that strike the best balance between increasing catchment runoff and social impacts on recreational use.

Method

Photo simulations for each of the selected forest thinning options are being developed with the input of forest management experts. Each scenario will be presented in a longitudinal sequence to represent the appearance of the forest over time (i.e. at 1, 5, 25, 50 and 70 years post the initial forest thinning treatment). Five options or scenarios will be tested, including a "no treatment" option. The treatment scenarios selected by the Water Corporation and the researchers are listed in Table 1.

Table 1. Treatment options for the photo simulations

Option	Treatment
1	No treatment (active regrowth forest)
2	15 m^2/ha (12 + 3 m^2/ha habitat trees) – cut stump
3	15 m^2/ha (12 + 3 m^2/ha habitat trees) – notching
4	10 m^2/ha (8 + 2 m^2/ha habitat trees) – notching leaving large trees - allow dense understorey
5	10 m^2/ha (8 + 2 m^2/ha habitat trees) – notching leaving large trees - active control of understorey

Participants will be drawn from three target populations: a) off-road cyclists, b) bushwalkers, and c) forest managers. The web-based survey will be followed up with face-to-face in-depth interviews with some of the survey respondents to increase the richness of the data. In the web-based survey, photo simulations for each of the selected forest management scenarios will be presented. Questions will be designed to gather data on:

- Perceptions of the acceptability of the various forest thinning treatments on (a) recreation values and (b) ecosystem health.
- The use, non-use and intrinsic values respondents associated with natural areas.
- Beliefs about the effects or consequences of the various forest thinning treatments.

The survey will apply the Natural Area Value Scale (Winter 2002) developed in Australia to measure the use, non-use and intrinsic values study participants hold for the natural environment. Preliminary field studies with each population will contribute to survey development. The survey will also be pre-tested and modified, as necessary, prior to final distribution via email (or organisational websites) to each of the target populations. Finally, data gathered through the web-based survey will be supplemented with data gathered in the in-depth interviews.

Timeline

The proposed timeline for Year 1 of the study is presented in Table 2.

Table 2. Proposed timeline for Year 1 of the Forest Perceptions Project

Activity	Month								
	1	2	3	4	5	6	7	8	9
Preliminary field studies	X	X							
Murdoch University ethics application	X	X	X						
Preparation of photo simulations	X	X	X	X					
Expert review of simulations		X		X					
Questionnaire design		X	X	X					
Web-based interface				X					
Survey instrument pre-test				X					
Administration of survey					X				
Follow-up interviews						X	X		
Statistical analysis						X	X	X	
Technical report preparation									X

Results

Not applicable (study has not been completed).

Discussion

Not applicable (study has not been completed).

Conclusion

Not applicable (study has not been completed).

Recommendations

Not applicable (study has not been completed).

Acknowledgements

The funding and support of the Water Corporation are appreciated. We extend a special thank you to Water Corporation employees Michael Loh, Bishnu Devkota, and Marg Wilke for their assistance with this study. The authors would also like to thank Frank Batini for providing his expert knowledge and insights to this study. In addition, we would like to acknowledge the work of Martin Randall, who prepared the photo simulations.

This study draws on work done both in Australia and overseas. The work conducted by Kathryn Williams, University of Melbourne and Caroline Winter, La Trobe University, on perceptions of forest management techniques significantly contributed to the design of this study.

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Winter, C. 2002. Measuring intrinsic and instrumental values of nature: Development of a generic survey instrument. Charles Sturt University: Albury.

Ecosystem response to forest thinning in the Wungong Catchment

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Summary

This project, funded by the ARC and the Water Corporation, aims to assess ecosystem response to forest thinning in the Wungong Catchment.

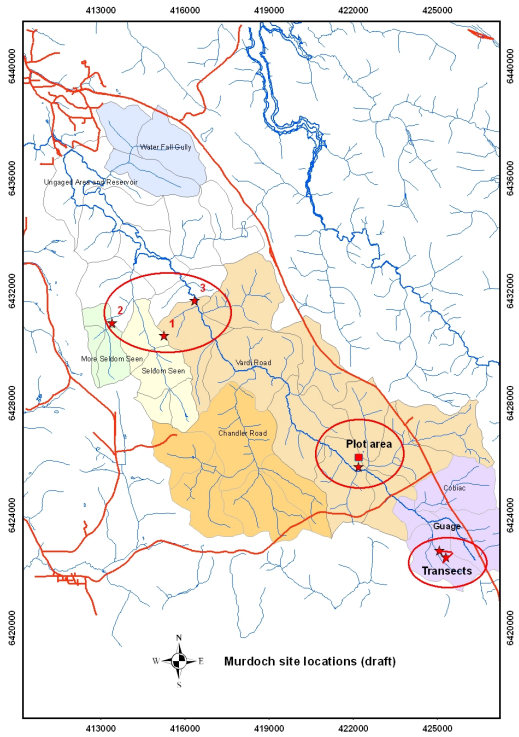
Field study commenced in late 2007 with research sites set up in three major sub-catchments. In Seldom Seen and More Seldom Seen sub-catchments, a thinned and burnt site, a burnt but not thinned site, and a natural forest site (control) were studied; thinning at this site occurred in 2005. A replicated experiment was set up in a high-quality jarrah forest site in the Vardi Road sub-catchment, to examine the anticipated changes in microclimate and the concurrent changes in vegetation properties and soil nutrient conditions.

Weather stations and soil moisture loggers were installed in the research plots to continuously monitor rainfall, temperature (soil and ambient), soil moisture, light and wind. Litter traps were set up to assess forest litter production, and the nutrients cycled though litter turnover, enabling further comparison with nutrient turnover following the thinning treatment.

A thinned and unthinned (control) transect in the upper stream of Cobiac subcatchment was monitored for nutrient export potential from the thinning residue. Field measurements and sampling of soil and vegetation were carried out monthly for soil, litter and vegetation, and the concurrent nutrient dynamics monitored from the forest floor.

In the experimental plots one year of baseline data has been collected and selected plots will be subject to two different thinning operations in late summer 2009.

The response to prescribed thinning will be measured though a number of biotic and abiotic indicators, which would help us to understand the effect of thinning, including changes in forest microclimate, residue turnover and plant nutrient- and water-stress that underlie the resources provision for forest health, tree regeneration and regrowth, as well as the successional pathways of the thinned forest.



Introduction

The Wungong Catchment, an important drinking water resource for Perth, Western Australia, receives 1000–1300 mm annual rainfall, but only 13% of the rainfall is converted to streamflow. The forested catchment is covered by young regrowth jarrah with dense undergrowth and a significant area replanted after bauxite mining. Decreased streamflow in recent years was associated with a period of low average annual rainfall and exacerbated by high tree transpiration loss. The Wungong Catchment thinning trial is being carried out by the Water Corporation starting in 2005 to recover 4–6 gigalitres of run-off water annually at an expected cost of about 25 cents per thousand litres.

Understanding ecosystem responses at relevant spatial- and time-scales in the Wungong catchment is challenging, but it is important to be addressed as it is a major community concern and critical to ensuring the after-thinning forest ecosystem develops along an acceptable successional pathway. The present study focuses on ecosystem response to thinning, using changes in the forest environment such as light, water and nutrients as underlying threads linking vegetation and ecosystem responses to the prescribed thinning intervention.

Methods/Approach

The study sites were selected according to a set of criteria considering forest properties and past interventions. These sites were paired or grouped by research purposes, and each group or pair has one site as an unthinned 'control'. For example, Group A include 3 sites, Site 1 (S1, thinned and burnt); Site 2 (S2, a natural forest, control); Site 3 (S3, burnt only) in Seldom Seen and More Seldom Seen sub-catchments. In the Vardi Road sub-catchment, a field plot (5.7 ha) with a randomised complete block design was installed, which consists of 9 individual plots (each of 90 x 70 m) with two types thinning treatments and one control, each replicated three times. In the Cobiac sub-catchment, two paired-sites were selected within two research transects, and one transect was thinned by commercial thinning plus notching (site X) and the other was used as the 'control' (site W), to study the effect of thinning on soil nutrient status, and the potential off-site movement of nutrients to the downstream water.

Scheduled measurements and sampling were carried out monthly or seasonally in selected sites to understand forest microclimate conditions, soil and vegetation properties, stand features and nutrient cycling and litter turnover (Table 1).

Table 1. Ongoing sampling and measurement in selected sites

Items	Sampling	Analysis
Microclimate		
2 x Met stations	rainfall wind direction/velosity photosynthetic active light humidity soil moisture, temperature air temperature	data download monthly
6 x G-Bugs (4 sensors each)	soil moisture 10, 20, 30, 50 cm	data download monthly
TDR (surface water content)	VWC%	field measurement monthly
Soil properties	debris 0-5 cm, 5-10 cm, 10-20 cm,. 0-50 cm profile (10 cm interval)	labile carbon, nutrients, water content litter depth and coverage
Physical		soil density, particale size and fraction
Nutirent dynamics	Resin N/P	in-situ captured resin N, P
Tree properties		
Green Leaf	young regrowth old growth	$\delta^{13}C$, nutrients, relative water content
Tree coring	tree stem	
Seedling growth	3 quadats/plot	height and other properties
Stand properties	9 plots	height, DBH, basal area, canopy density
Litter cycling		
Litterfall	18 litter traps	water content/weight/nutrients
Litter decomposition	litter bags	weight/elemental
Ground litter	surface litter degraded debris	weight/coverage/nutrients
Water quality		
Bore level and sampling Shallow piezo monitoring	Bores at trasect W, X	water properties and nutrients

Results

The baseline forest microclimate conditions were recorded through two weather stations installed in the research plots, and the recorded parameters include light, wind, rainfall, temperature and soil moisture (30 cm depth).

Soil carbon and nutrient status were recorded for surface soils in all the sites. Gravel and large particles (>2 mm) accounted for over 2/3rd of the total soil weight. Similar to other parts of WA, the soil carbon and nutrients in all sites were typically concentrated near the soil surface, and markedly decreased with depth in the soil profile. Soil microbial biomass on the forest floor was measured using substrate induced respiration and fumigation-extraction methods, and showed similar microbial activity in the selected sites on the three sub-catchments. Microbial biomass was also concentrated in surface soils.

Nutrient content of tree leaves and twigs were measured for young and old growth. Sapwood cores were taken from tree stems for examination of carbon isotopic discrimination, to assess tree response to anticipated changes in water and nutrient stress after thinning. Properties of jarrah forest, including canopy density, basal area, DBH, and tree height were measured in the selected sites. Stand properties including above ground biomass were quantified in the research plot. Data are used to further estimate nutrient compartments for the research plot, facilitating a nutrient balance approach to gain insight into the effect of thinning on resource provision for the thinned ecosystem.

Large numbers of soil and vegetation samples were collected for further laboratory study and analysis.

Discussion

Previous work in the WA jarrah forest has provided useful background on jarrah forest properties, but the possible ecosystem responses to forest thinning intervention remain unclear. A detailed monitoring and field experiment programme has been established to understand thinning effects, the project is still in an early phase of data collection.

The forest baseline conditions in the study area, however, are emerging from research conducted to date. The nutrient pools in surface soils are being estimated, along with those in litterfall, and in the case of thinned forest, the pool of nutrient produced by thinning residue. While there were intermittent rainfall events between November and March 2008, soil drying appeared to be the predominant process prevailing in the forest floor until the end of March. The shallow soil moisture (30 cm depth) increased dramatically from early April, following the onset of the rainy season, which provided sufficient soil water for shallow-rooted plants, especially important for the short recovery of seedlings and understorey species.

The jarrah forest is a nutrient-poor ecosystem. Our preliminary data suggest that, the proportion of nutrients stored in thinned residue biomass can be large compared with the available nutrients in surface soils. In such forest systems, soil nutrients are concentrated in the surface but little is in plant available form. Since forest thinning is expected to increase nutrient availability through residue turnover, an effect on vegetation dynamics may be expected. The magnitude of these effects relative to that of burning may also need examination.

Over the next two years, our research will examine the links between thinning induced canopy-reduction and potential changes in the energy (light) and mass (water and nutrients) flow, starting from altered microclimate and nutrient turnover, which are expected to underlie vegetation responses in the thinned forest ecosystem.

Birds of the Wungong Catchment, Bedfordale Western Australia

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Summary

The aim of this project is to provide information on the distribution, status, relative abundance, habitat preferences, breeding and migration and movements of all species of birds inhabiting or visiting the Wungong Catchment. A paper titled *Birds of the Wungong Dam Catchment* Bedfordale, Western Australia has been completed and was submitted to the Water Corporation in July 2008.

Introduction

This work covers the entire catchment and adjacent areas and will provide baseline data for future reference. It will help interpret historical changes in the avifauna and enable comparisons between neighbouring catchments.

Method

Data was compiled from historical records broad-scale surveys and transects. We made over 1500 visits to the catchment from the early 1990s to 2008.

Results

Publish the Birds of the Wungong Dam Catchment in WA Museum Records or Water Corporation publication.

Discussion

Total of 124 species recorded for Wungong Catchment with 12 exotic species and one local extinction.

Conclusion

This is a very important catchment at both a regional and national level.

Recommendations

Need to continue this study during the thinning process using both transect and broad-scale surveys. Possibly expand the study to include Canning and Serpentine catchments and Bungendore Park.

Future direction

Continue to monitor bird populations in the catchment. While we have continued with this study our funding from the Water Corporation ceased in June 2008. This work could be linked with our ongoing study on black cockatoos.

Black Cockatoos in the Wungong Catchment Bedfordale, Western Australia

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Summary

The aim of this project is to monitor the current distribution, status, habitat preferences, breeding season and diet for Carnaby's, Baudin's and the Forest Red-tailed Black Cockatoos in the Wungong Catchment and surrounding areas.

Introduction

For over 8 years we have been monitoring black cockatoos in this region. We have collected data on feeding, breeding and roosting sites, breeding behaviour and success, clutch size, incubation period, fledging period and movements. We also have been monitoring the impact of hollow competitors.

Method

Data was compiled from historical records broad-scale surveys and transects. Nest sites are located during the breeding season. Trees are marked and measured and mapped using GPS. Chicks are banded. Food data is collected opportunistically. Birds are regularly counted at roost sites.

Results

A paper dealing with the distribution, status, social organisation, movements and conservation of Baudin's Cockatoo *Calyptorhynchus baudinii* in South-west Western Australia has been completed and published in the WA Museum records (vol 25:107-118).

Discussion

The Wungong Catchment contains the largest known breeding population of the Forest Red-tailed black Cockatoo in the south-west, a large traditional roost site for Baudin's Cockatoo and a small breeding population of Carnaby's Cockatoo.

Conclusion

This is a very important catchment for black cockatoos at both a regional and national level.

Recommendations

Continue to monitor black cockatoo feeding, breeding and roosting sites within the catchment at least for the duration of the thinning programme. Continue searching and mapping potential nest trees in the catchment. Continue mapping the expansion of Carnaby's into this area.

Future direction

We have continued this study in the catchment but funding ceased in June 2008.

Fauna monitoring — 2006 pre treatment results

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Summary

Six plots were established prior to catchment forest thinning treatments to provide baseline data from which fauna change may be measured. Two plots each were established in areas that would under go one of two of the major forestry thinning treatments for the Wungong Project – non commercial thinning and commercial thinning and two were established as controls where only ordinary forestry treatments for conservation forested areas would be undertaken. Each plot consists of two 50-m apart parallel 250 metres transects (3000 m in total) with measurements made each 20 metres (150 sample points)

Fauna surveyed included mammals, birds, reptiles, ants and some other invertebrates. Data on the vegetation characteristics of each of the sampling points were collected by E. Mattiske and Associates..

An attempt was made to select sites that were similar, though it was not possible to match the logging and fire histories exactly in all sites. In addition, which of the two thinning treatments that was used, depended upon the structure of the forest.

Plots 1 and 2 (within the area where non commercial thinning will be undertaken) show differences to the other transects in both vegetation structural characteristics and faunal assemblages. These two plots are within the bauxite mining envelop when mining occurred in the area and, under the forest management plans for bauxite mining in the Darling Range, the forest within the envelop was heavily logged about 20 years ago and then left un burnt. In contrast, plots 3 and 4 (within the area to be commercially thinned) and 5 and 6 (the control plots) were selectively logged well over 50 years ago and have been prescribed burnt within the past 4 to 6 years.

Analyses show that time since the last burn is positively correlated with a number of fauna groups and negatively correlated with others.

Introduction

The Water Corporation is undertaking a catchment thinning program for the Wungong Catchment. As part of the approvals, the Water Corporation is obligated to carry out various monitoring programs including fauna monitoring (Water Corporation 2005). Lacking long term fauna monitoring in the area, the Water Corporation has obtained copies of Alcoa's monitoring data for the catchment carried out as part of Alcoa's Long Term Fauna Monitoring Program. Alcoa's 8 plots in the catchment are located in its rehabilitation (2), dieback effected forest (2), stream zone (2) and in upland Jarrah forest (2). The Water Corporation has initiated it own monitoring using the same techniques as those used by Alcoa so as to be able in integrate its monitoring

into that of Alcoa's and so establish a long term pre catchment thinning base line to monitor its catchment thinning treatments on. The Water Corporation plots are placed in each of the proposed two catchment treatments plus control plot where none of these treatments will be undertaken.

This report documents the setting up of the Water Corporation fauna monitoring plots and the pre catchment thinning monitoring results.

The Water Corporation has developed two types of catchment thinning programs (Water Corporation 2005) that are aimed at reducing the catchment basal area to 15 - 18 m^2/ha

- A non commercial thinning and
- A commercial logging followed by a non commercial thinning

In both prescriptions all trees and logs on the ground to be retained up to the basal area are marked. All other trees are treated. The areas are dieback demarcated as well so that dieback hygiene practices can be implemented during treatments. After the treatments have been applied a prescribed burn is carried out in the treated areas the following year.

The non commercial thinning involves the use of stem injection confined to the culling of trees to produce the required basal area. Herbicide injection is carried out in the non summer months. Soil compaction is minimal. Forest structure is retained and there is no physical fragmentation of habitat.

The commercial logging involves such silvercultural practices as thinning, single tree selection, shelterwood and the creation of gaps for regeneration. Habitat trees are retained as are protection of a representation of the larger key understorey such as banksia, sheoak and balga. A follow up non commercial thinning is then carried out. As machinery has to be used to cut and remove the commercial logs, roads widened to transport the logs out and snig tracks and landings put in, so soil disturbance and compaction occur. Any gaps produced also cause fragmentation of the forest habitat. Implementation of after logging rehabilitation practices minimize any of the soil compaction and disturbances where they occur. Even so the over all impact on the forest of the commercial logging tends to be greater than that for the non commercial thinning.

Method

The types of capture mechanisms employed during the program are

- Box Traps baited with a universal bait (and for the case of the use of cage traps for reptile monitoring, tomatoes). These include the medium and large Elliots and cage traps.
- Medium pit traps with drift netting out to each side
- Small arthropod pit-like traps with preservative.
- Bird observation along a transect.

The intensity of the monitoring program per trapping period per trap/observation type is outlined in Table 1 for the different techniques used.

Table 2. Data collection Intensity

Trap/Observation Type	Number per Plot (2 transects)	Trapping/Observation days per Trapping Period per Plot	Total Trap/Observation Days per Trapping Period per Plot
Medium Elliot	16	4	64
Large Elliot	4	4	16
Cage Trap	4	4	16
Pit Trap with 6 m fly wire drift net (Mammal)	5	4	20
Pit Trap with 6 m fly wire drift net (Reptiles)	5	5	25
Arthropod pit trap with preservative	20	7	70
Bird Observation	1	3	3

The time of the monitoring was twice per sampling year – summer and winter

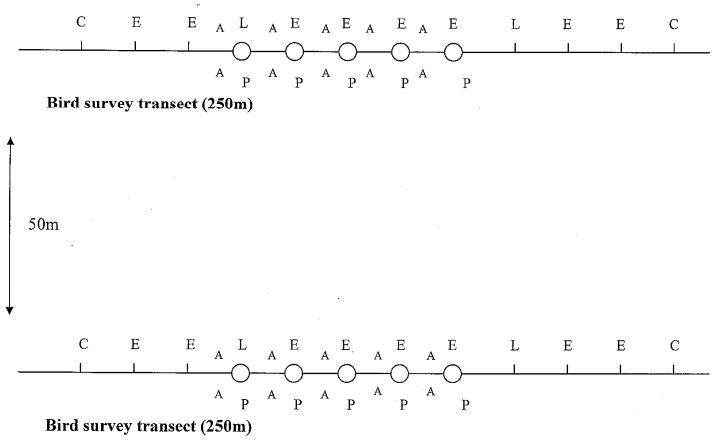

Figure 1: **Design of permanent fauna monitoring plots. C = Cage (Chuditch type) trap, E = Elliot trap, L = Large Elliott trap, A = ant trap, P = 150mm dia PVC Pit trap. Traps are placed 20m apart. At some sites it was necessary to bend transects eg to follow watercourses in stream zones.**

Table 2. Monitoring periods for the Wungong Pre Treatment Fauna Monitoring Program

Monitoring program	Dates sampling undertaken	Consecutive Day Monitoring (inclusive)	
		Date of Start	Date of End
Mammal Early Autumn		10 April 2006	13 April 2006
Mammal Late Winter		7 August 2006	10 August 2006
Ants Early Autumn		7/8th March 2006	14/15 March 2006
Birds Late Winter	17th Aug, 24th Aug and 28th Aug 2006		
Birds Early Summer	29th Dec 2006, 5th Jan, 8th Jan and 9th Jan 2007		
Reptiles Early Summer		12 December 2006	16 December 2006

Table 3. Location of Plots within Catchment Treatment Type Areas

Plot No	Easting	Northing	Remarks
1a	418107	6427780	TA1, coupe 3 (upper bit)
1b	417957	6427957	TA1, coupe 3 (upper bit)
2a	418778	6428389	TA1, coupe 3 (upper bit)
2b	418772	6428337	TA1, coupe 3 (upper bit)
3a	424352	6424410	TA2, coupe 2
3b	424212	6424615	TA2, coupe 2
4a	424621	6423902	TA2, coupe 2
4b	424580	6424127	TA2, coupe 2
5a	427320	6421972	Control in Serpentine catchment
5b	427137	6422089	Control in Serpentine catchment
6a	428775	6420332	Control in Serpentine catchment
6b	428545	6420330	Control in Serpentine catchment

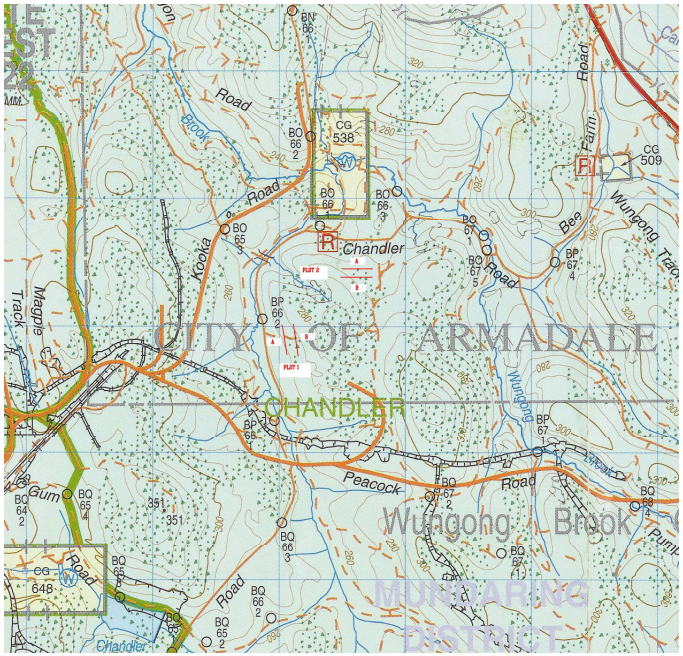

Figure 7. Catchment Thinning Treatment Plots 1 and 2

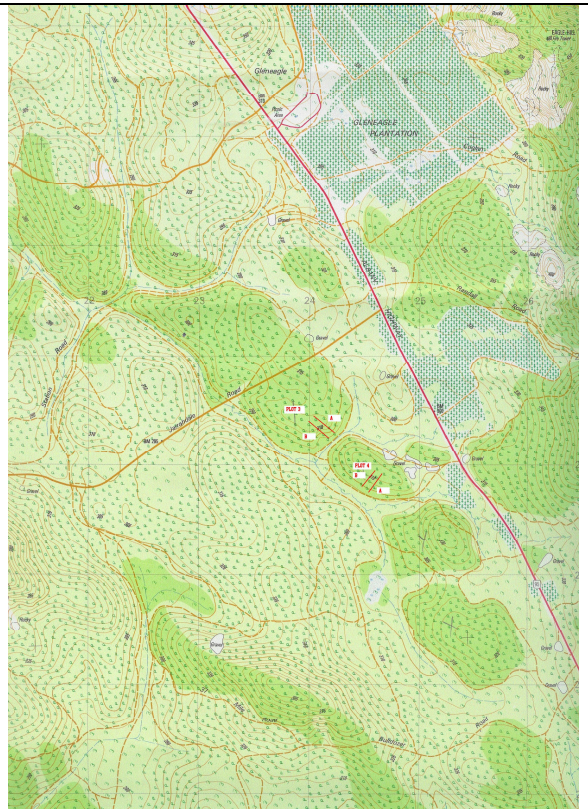

Figure 3. Catchment Logging and Thinning Treatment Plots 3 and 4

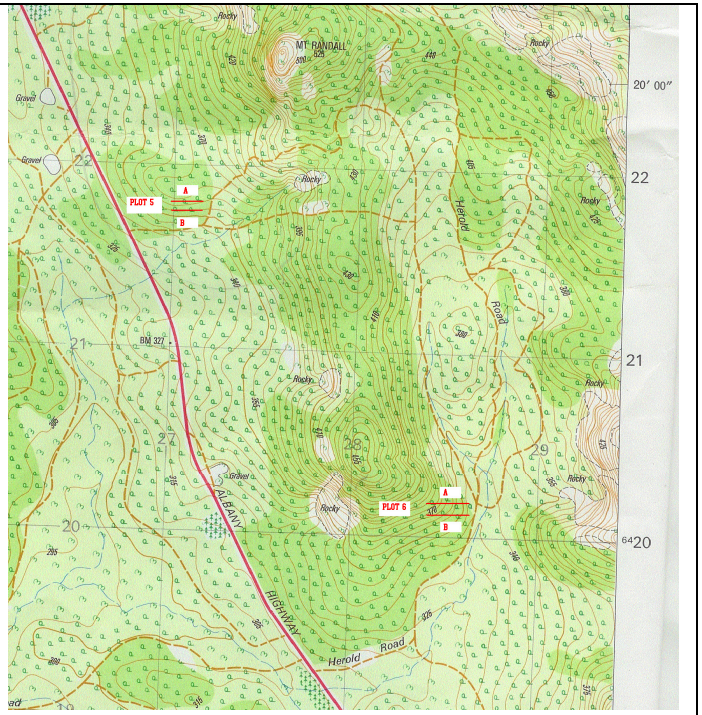

Figure 4. Control Plots 5 and 6

Results and Discussion

Vegetation description of plots

Table 4. Summary of Plot Characteristics (derived from Sections 4.4 and 4.5)

Plot Number	1	2	3	4	5	6
Proposed Catchment Treatment	Thinning	Thinning	Logging and Thinning	Logging and Thinning	Control	Control
Vegetation Type	P/S or P	S	P or P/S	P or P/S	P or P/S	P
Burning History (Years since last burn)	19	18	4.5	4.5	5.5	5.5
Dieback Status	Dieback Free	Dieback Free	Dieback Free	Dieback Free	Dieback Free	Dieback Free
% Canopy Cover (FB)	32.5	30	46.5	49	31.5	49.5
Basal Area over Bark (m^2/ha (FB)	27.5	29	37.5	31	41.5	25.5
0-50cm % Cover(M)	6.1	9.2	20.3	22.0	39.5	31.6
>100cm % Cover (M)	36.4	44.9	43.7	55.6	67.2	87.8
Litter and logs<10cm % Cover (M)	39.3	49.1	31.6	75.9	32.2	30.7
Logs >10cm % Cover (M)	1	6.9	6.1	11.4	11.4	12.8

FB=Frank Batini M= Mattiske and Associates

Table 5. Correlation between the various vegetation Characteristics of the Plots (R>0.805 is significant at the 5% level with 1 tail test and 5 D of F)

	Basal Area m^2/ha	***Burning History (Years since last burn)***	***0-50cm % Cover***	***>100cm % Cover***	***Litter and logs<10cm % Cover***	***Logs >10cm % Cover***
Basal Area m^2/ha	1.00					
Burning History (Years since last burn)	-0.66	1.00				
0-50cm % Cover	0.46	-0.81	1.00			
>100cm % Cover	0.00	-0.59	0.81	1.00		
Litter and logs<10cm % Cover	0.24	0.00	-0.27	-0.23	1.00	
Logs >10cm % Cover	0.23	-0.74	0.82	0.86	0.15	1.00

Differences between plots within treatments

Table 6. Differences between plots within catchment treatment areas in the various fauna groups and parameters.

Plot Group	Fauna Group and parameter				
	Reptile No	Bird No	Ant Diversity	Ant Species No	Arthropoda
Thinning (Plots 1 and 2)	(2)	(2)	(2)		Spider No(1) and Mite No (1)
Logging/thinning (Plots 3 and 4)		(3)	(3)		
Control (Plots 5 and 6)				(5)	Springtails (5) beetles (5) Flies (6)

Figure in () indicate the plot with the highest figure

There are no differences between plots within treatments for Mardos.

Differences between pre treatment areas

Table 7 summarizes these data. These data indicate the treatment areas do not have the same fauna characteristics. For example the groupings and those that have high numbers in the respective parameter.

- Mardos numbers : Proposed logging/thinning (Plots 3 / 4) with Control (Plots 5 / 6)
- Birds numbers and species: Proposed thinning (Plots 1 / 2 with Proposed logging/Thinning (Plots 3 / 4)
- Reptiles numbers and species : Proposed thinning (Plots 1 / 2) with Control (Plots 5 / 6)
- Arthropods (Ants, springtails and beetles - numbers and species): Proposed thinning (Plots 1 / 2) are separate from the other proposed treatment areas (3, 4, 5 and 6).

Table 7. Summary of Fauna Parameters for the Different Catchment Treatment Areas of the Wungong Catchment

Fauna Group	Thinning Catchment Treatment Areas (Plots 1 & 2)	Logging and Thinning Treatment Areas (Plots 3 & 4)	Control (Plots 5 & 6)
Total Mardos Apl 06	**2**	**19**	**20**
Total Aug 06	**0**	**16**	**17**
Total Mardos Dec 06	**0**	**9**	**12**
Total Birds Winter	**17**	**32**	**6**
No. Bird Species Winter	**8**	**10**	**3**
Total Birds Summer	**57**	**27**	**9**

Fauna Group	Thinning Catchment Treatment Areas (Plots 1 & 2)	Logging and Thinning Treatment Areas (Plots 3 & 4)	Control (Plots 5 & 6)
No. Bird Species Sumer	21	10	4
Total Reptiles (Mar 06) total TA and TB	13	0	8
Number of Reptile Species (Mar 06) total TA and TB	3	0	3
Total Reptiles (Dec 06)	23	2	12
Number of Reptile Species (Dec 06) total TA and TB	6	2	7
Ant Numbers	1202	351	685
Ant Species	46	40	36
Ant Species Diversity (Means)	0.96*	0.79*	0.72*
Ant Species Evenness (Means)	0.69*	0.74*	0.62*
Number of Araneae	38	54	60
Number of Acarina	159	123	170
Number of Collembola	243	84	132
Number of Coleoptera	1159	158	352
Number of Diptera	49	44	53
Number of Hymenoptera	38	48	27

Table 8. Summary of the fauna data

Fauna Group	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
Total Mardos Apl 06	1	1	7	12	11	9
Total Mardos Aug 06	0	0	11	5	10	7
Total Mardos Dec 06	0	0	7	2	7	5
Total Birds Winter	3	14	26	6	2	4
No Bird Species Winter	2	6	9	4	2	1
Total Birds Summer	19	38	20	7	7	2
No Bird Species Sumer	11	15	10	3	3	1
Total Reptiles (Mar 06)	4	9	0	0	7	1
Number of Reptile Species (Mar 06)	2	3	0	0	3	1
Total Reptiles (Dec 06)	11	12	0	2	9	3
Number of Reptile Species (Dec 06)	4	6	0	2	5	3
Ant Numbers	675	527	105	246	390	295
Ant Species	44	54	27	24	41	17
Ant Species Diversity	0..85	1.07	0.9	0.69	0.93	0.5
Ant Species Evenness	0.64	0.75	0.8	0.68	0.71	0.54
Number of Aranae	30	8	22	32	32	28
Number of Acarina	109	50	47	76	83	87
Number of Collembola	140	93	44	40	103	29
Number of Coleoptera	453	706	104	54	281	73
Number of Diptera	27	22	15	29	10	43
Number of Hymenoptera	16	22	22	26	10	17
Number of Opilionida	0	0	1	0	0	0
Number of Pseudoscorpionida	3	6	1	10	3	3
Number of Scorpionida scorpions	0	0	1	0	0	0
Number of centipedes	2	1	0	0	1	0

Fauna Group	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
Number of Isopoda	5	5	2	6	1	5
Number of Thysanura	3	0	6	1	3	4
Number of Blattodea	3	2	28	11	3	18
Number of Isoptera	3	4	0	0	4	2
Number of Mantodea	0	0	1	0	0	0
Number of Dermaptera	2	2	0	1	2	0
Number of Orthoptera	5	6	1	0	2	0
Number of Psocoptera	8	13	2	4	5	5
Number of Hemiptera	5	4	10	9	6	7
Number of Thysanoptera	0	5	6	27	6	8
Number of Lepidoptera	2	1	1	1	1	2
Number of Endopterygote larvae	5	7	30	27	3	21

Correlations between Vegetation Characteristics and Faunal Assemblages

Table 9. Relationship of faunal group to vegetation characteristics

Fauna Group	General Relationship with Vegetation Characteristics	Possible Reason
Mardos	+ve	Source of cover, nesting and feeding?
Reptiles and Ants	-ve	More active with less cover allowing increase energy from the sun to reach the ground?
Birds	- ve	Unknown but these vegetation characteristics could be – ve related to food sources eg flowering plants such as Banksia spp?
Arthropod groups	-ve and +ve depending upon group	Due to cover and food sources?

Table 10. Correlation between Vegetation and Fauna Characteristics of Plots
(two tailed 5%significance with 5 d of f is 0.88)

	Total Mardos Apl 06	*Total Mardos Aug 06*	*Total Mardos Dec 06*	*Total Birds Winter*	*No Bird Species Winter*	*Total Birds Summer*	*No Bird Species Sumer*	*Total Reptiles (Mar 06)*	*Number of Reptile Species (Mar 06)*	*Total Reptiles (Dec 06)*	*Number of Reptile Species (Dec 06)*	*Ant Numbers*	*Ant Species*	*Ant Species Diversity*	*Ant Species Evenness*
Basal Area m^2/ha	0.72	0.61	0.50	-0.06	0.04	-0.58	-0.51	-0.46	-0.44	-0.49	-0.51	-0.48	-0.39	-0.13	0.22
Burning History (Years since last burn)	-0.93	-0.89	-0.81	-0.11	-0.07	0.72	0.77	0.62	0.59	0.83	0.62	0.89	0.79	0.50	0.02
0-50cm % Cover	0.84	0.79	0.81	-0.28	-0.34	-0.75	-0.83	-0.14	-0.04	-0.37	-0.09	-0.52	-0.49	-0.39	-0.22
>100cm % Cover	0.63	0.44	0.49	-0.43	-0.56	-0.72	-0.83	-0.18	-0.05	-0.31	0.03	-0.34	-0.59	-0.70	-0.65
Litter and logs<10cm % Cover	0.19	-0.38	-0.54	-0.13	0.08	0.04	-0.03	-0.15	-0.29	-0.09	-0.03	-0.03	-0.03	-0.06	0.08
Logs >10cm % Cover	0.83	0.52	0.49	-0.26	-0.28	-0.61	-0.79	-0.17	-0.15	-0.42	-0.04	-0.55	-0.55	-0.50	-0.30

	Number of Aranae	*Number of Acarina*	*Number of Collembola*	*Number of Coleoptera*	*Number of Diptera*	*Number of Hymenoptera*	*Number of Opilionida*	*Number of Pseudoscorpionida*	*Number of Scorpionida scorpions*	*Number of centipedes*	*Number of Isopoda*
Basal Area m^2/ha	0.73	0.12	-0.16	-0.65	-0.41	-0.04	0.25	0.12	0.25	-0.25	-0.40
Burning History (Years since last burn)	-0.48	0.20	0.76	0.89	0.03	-0.05	-0.35	0.00	-0.35	0.82	0.37
0-50cm % Cover	0.50	0.06	-0.41	-0.60	-0.09	-0.48	-0.04	-0.15	-0.04	-0.48	-0.53
>100cm % Cover	0.34	0.19	-0.54	-0.51	0.47	-0.33	-0.32	-0.04	-0.32	-0.50	-0.05
Litter and logs<10cm % Cover	0.04	-0.08	-0.17	-0.04	0.16	0.70	-0.32	0.96	-0.32	-0.18	0.63
Logs >10cm % Cover	0.25	-0.13	-0.67	-0.54	0.23	-0.03	-0.24	0.31	-0.24	-0.70	-0.06

	Number of Thysanura	*Number of Blattodea*	*Number of Isoptera*	*Number of Mantodea*	*Number of Dermaptera*	*Number of Orthoptera*	*Number of Psocoptera*	*Number of Hemiptera*	*Number of Thysanoptera*	*Number of Lepidoptera*	*Number of Endopterygote larvae*
Basal Area m^2/ha	0.29	0.22	-0.50	0.25	-0.12	-0.60	-0.78	0.66	0.50	-0.38	0.33
Burning History (Years since last burn)	-0.46	-0.64	0.60	-0.35	0.67	0.95	0.86	-0.81	-0.54	0.30	-0.66
0-50cm % Cover	0.31	0.21	-0.02	-0.04	-0.30	-0.70	-0.57	0.32	0.23	-0.16	0.11
>100cm % Cover	0.14	0.18	0.03	-0.32	-0.42	-0.63	-0.30	0.11	0.21	0.25	0.13
Litter and logs<10cm % Cover	-0.70	-0.24	-0.35	-0.32	0.18	-0.07	0.11	0.16	0.83	-0.36	0.26
Logs >10cm % Cover	-0.09	0.17	-0.14	-0.24	-0.36	-0.70	-0.34	0.30	0.57	-0.24	0.29

Comments on the Different Fauna Groups

Detailed analysis were made on the various faunal assembles and the following comments are made

Invertebrates

Ants

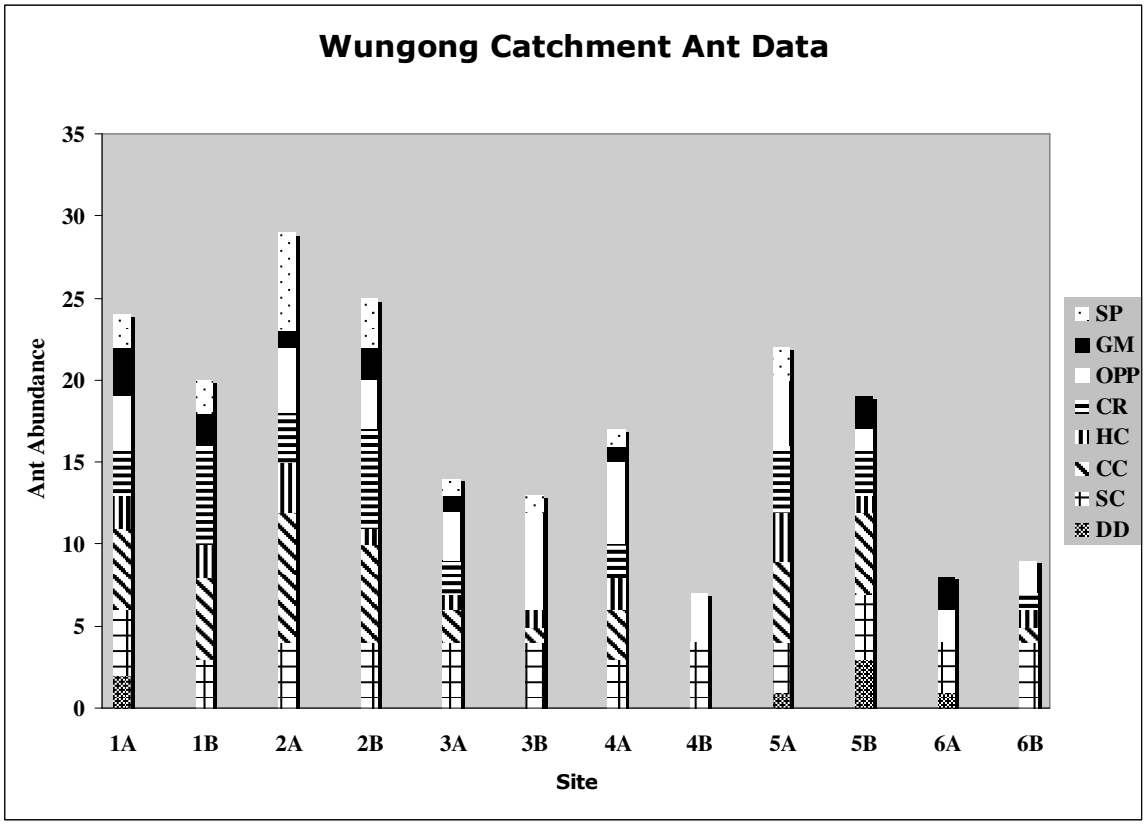

Figure 8 . Legend for Ant Functional Groups:

SP	Solitary predators
GM	Generalized Myrmicinae
OPP	Opportunists
CR	Cryptic species
HC	Hot Climate Specialists
CC	Cold Climate Specialists
SC	Subordinate Camponotini
DD	Dominant Dolichoderinae

Other Invertebrates

The data show

1. Ants, beetles and mites were the three main arthropod groups caught in all the plots.
2. The arthropod groups consist of three main feeding guilds - defoliators, scavengers and predators. All plots had representatives from the three main feeding guilds though the particular arthropod group represented in the particular feeding guild differed between plots.
3. Total numbers of individuals of a particular arthropod group and the actual arthropod groups caught differed between plots.
4. The vegetation characteristics collected for each plot does not seem to explain this variation between plots.

Amphibians
The two *Crinia georgiana* that were caught in April were caught have a rain event and would illustrate the general dispersal of frogs begins at the start of the autumn rains and the area of dispersal includes upland areas (where all plots were located) of the Jarrah forest away from streams. No frogs were caught in the August period while three dehydrated individuals of *C georgiana* (2) and *Heleioporus inornatus* were caught during December indicating some movement of frogs in the upland area of the Jarrah forest during this period.

Reptiles
The skinks are the most abundant reptile group caught in terms of number of species and number of individuals. Within this group there are common and widely dispersed species (e.g. *Lerista distingunda*) and uncommon species (e.g. *Egernia pulchra*) and species that seem to be restricted to a single site (e.g. *Ctenotus delli*). Overall 10 skink species and 58 individuals were caught.

The other families are restricted to one species and the same number of individuals.

Of those species that large numbers were caught, there were no differences in snout/vent length between Plots in reptiles of the same species. Though there was an increase in SV length for *L distinguenda* over the period March to December this was not significant. Thus statistically there was no difference in SV length between plots or time of sampling. This would indicate either reptile SV length had reached its peak in March and didn't increase or that no growth occurred during the winter period when temperatures and activity would have been low for reptiles.

Birds
Bird species fluctuated between seasons and between catchment treatment area types. Some bird species were not seen during the either of the monitoring period especially summer. These species which had sufficient number of observations included:

- Pardalotes: Increased numbers in summer. Alcoa data have more in winter which is similar to Johnsone and Storr (2004). The current summer survey may have been too early to detect the summer migration out of the forest
- Nectivorous species: Increased numbers in summer. Similar to Alcoa data. Most likely related to the flowing period of Jarrah forest plants
- Red caped parrot: Increased number in summer. Similar to what is seen in the Alcoa data
- Western Rosella: Increased numbers in winter. Alcoa has higher number in summer. Johnstone and Storr (2004) do not have this or the previous species as one that undergoes migratory movements.

The control plot was depauperate in terms of species and number of birds. To study this further the bird species were classified according to food eaten (from Johnstone and Storr 2004). This indicates that the Control sites had less nectivorous, insectivorous and nut eating species that the other two. There were less banksia trees at the control plot but the insect population and forest trees were similar between Plots 3 and 4 and the Control plots so the reason for the lower number of these guild types is not known.

Mammals
Adult male Mardos weighed more than adult females.

The adult males of plots 3 and 4 were significantly heavier than those from 5 and 6 (Table 23). The reason for this is not known as:

1. Food availability, in terms of the number of arthropods and reptiles caught, are similar for the two areas (3/4 and 5/6).
2. Animal competition (through Mardo densities) in terms of numbers caught, are similar for the two areas (3/4 and 5/6).
3. Availability of sites for protection and stress from predators in terms of vegetation characteristics (logs and ground cover see Table 6 to 11), are similar for the two areas (3/4 and 5/6).

Numbers of Mardos at each of the combined sites are similar (see Table 14). As well the number of invertebrates and reptiles is lower (see Table 15, Figure 5) in Plots 3 and 4 so it is unlikely to be food. However this lower numbers of these two food sources **might be due** to the greater degree of predation of Plot 3 and 4 Mardos on these two food sources causing the greater weight of these Mardos and the lower food sources in Plot 3 and 4 compared to Plots 5 and 6.

There may also be slightly different breeding seasons between the two site with Mardos from Plots 3 and 4 being born before those from Plots 5 and 6. The weight of juvenile Mardos (especially males) from these two sites suggests that this could be so. Juveniles from plots 3 and 4 are a little heavier than those from plots 4 and 5 (see Table 23). Thus these animals would reach a heavier weight.

The characteristics of the captures of the Mardos over the year conforms with the recorded life histories of the species (Strain 1995) with males (56g average) being heavier than female (34g average), both male and females being present in autumn and late winter (April/August trappings) mating and males dying after mating (no males caught in December) and females living longer (some females caught in December) and the young weaning 4 months after mating (juveniles caught in December).

Conclusion

The fauna monitoring plots for the Wungong Catchment Forest Thinning Project have been successfully set up and the first pre treatments monitoring has been carried out. Predicable differences have been found between the areas that will undergo different thinning treatments and the fauna/flora characteristics of the different areas have been determined. The structure of the fauna monitoring program should be adequate to detect changes in the fauna that is due to the forest thinning treatments.

Recommendations

Timely monitoring is programmed to be undertaken over the next 15 years to confirm any changes in the fauna of the catchment that is due to the treatments and the reduction in forest canopy in the catchment.

Acknowledgements

Appreciation is given to Frank Batini for his advice during the program.

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FORESTCHECK monitoring

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Summary

A proposal to establish six FORESTCHECK monitoring grids within the Wungong catchment has been discussed between Water Corporation and the Department of Environment and Conservation (DEC).

Introduction

FORESTCHECK is an integrated, site-based monitoring program designed to sample a broad spectrum of the biota with the aim of identifying changes and trends in biodiversity and ecosystem condition.

To date, 48 monitoring grids have been established throughout the jarrah forest to provide information about responses to commercial timber harvesting. Establishment of these grids has been jointly funded by DEC and the Forest Products Commission. Data from the first five years of sampling are currently being analysed and prepared for publication. Sites established in Donnelly District during the first year of the project in 2001/02 were re-assessed in 2007/08.

Representatives of Water Corporation and DEC conducted several field inspections in the Wungong Catchment during 2007 and developed a proposal to establish six monitoring grids within Treatment Area 3. Subsequently, implementation of thinning within Treatment Area 3 was deferred due to issues associated with ongoing management of rehabilitated bauxite pits. This has resulted in a delay in establishment of monitoring grids pending resolution of this issue, or a decision to specifically thin the forest around the sites proposed for FORESTCHECK grids.

Method

The proposal is for six grids as follows:

Dwellingup complex – 2 thinned grids (sparse understorey/ dense understorey
– 1 untreated grid as a control

Murray complex – 2 thinned grids (sparse understorey/ dense understorey
– 1 untreated grid as a control

Monitoring would follow the standard protocol and include:

- forest structure
- cryptogams
- macrofungi
- vascular plants
- invertebrate fauna
- vertebrate fauna
- soil disturbance

The sampling methodology is described in the Operating Plan on the Science homepage of DEC's Naturebase website. Measurements are made within a core grid of 1 ha with supplementary measurements in a 2 ha area. Grids would be monitored prior to treatment and again 12-18 months following treatment.

Results

Sites have not yet been established and no data has been collected.

Discussion

DEC is awaiting advice from Water Corporation regarding whether or not to proceed with establishment of monitoring sites. This will be influenced by whether results are available in time to contribute to the 5-year review of the Wungong trial.

There will be a lead time of at least 6 months required to undertake grid establishment, should this be decided upon.

Conclusion

None at this stage

Recommendations

At the discretion of Water Corporation pending review of other environmental monitoring and assessment projects in the Wungong Catchment and the availability of sufficient ongoing funding.

Aquatic fauna biodiversity assessment

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Summary

As part of the Wungong Catchment Trial Project (WCTP), the Aquatic Research Laboratory (ARL) of The University of Western Australia is assessing the effects of the project on the biodiversity of aquatic macro invertebrates and fish. Sampling is conducted in spring each year, using standard protocols developed in 1984 for sampling jarrah forest streams, and used by the ARL since that time. Sampling will provide data on the abundance of macro invertebrate species in riffle zones and fish and crayfish in the stream reach. Sampling is conducted in areas being manipulated (Impact) and in adjacent 'Control' catchments, following a Before-After:Control-Impact Pairwise (BACIP) approach.

Historical data collected at some of the selected sites in the 1980s are also being used to assess longer term effects of reduced rainfall and 'climate change' on jarrah forest stream macro invertebrates. These data showed that seasonal and perennial streams have distinctly different faunas. As a result of reduced rainfall, perennial streams in the jarrah forest are becoming seasonal, with an associated change in fauna.

The WCTP is expected to increase stream flows, and will increase flow period, and may even return seasonal streams to perennial. The effects of changes in flow regime on aquatic fauna will be monitored.

To date, sampling has been conducted at six sites in 2005 and 2006, and at eight sites in spring 2007, with the aim of collecting pre-thinning data for all treatment sub-catchments. Additional sites were added in 2007 to assess effects of a CSIRO-initiated thinning project on the smaller 31 Mile Brook sub-catchment, and DEC-initiated fine-scale mosaic burning on 39 Mile Brook.

Water quality sampling conducted as part of the project showed all surveyed parameters to be within acceptable levels for jarrah forest streams. Fauna sampling recorded 74 taxa of aquatic macro invertebrates from the six sites in 2005, with 102 taxa recorded in 2006, and 87 in 2007. The fauna was dominated by Insecta (≥80%) with at least 67 species representing 24 families. Chironomidae (non-biting midges) constituted a large proportion of the insect fauna (60%). Crustacea (including freshwater crayfish) constituted only 6% of the total fauna.

No significant changes that may be attributable to the WCTP have been detected; however, significant changes in streams have occurred since 1984, likely reflecting a transition from perennial to seasonal flows. Also, data in 2007 showed a significant decline in species richness and abundance across all sites from 2006. This is attributed to the extremely dry winter in the

preceding year, when some streams did not flow, and others did not commence until late July or August. It is thought that this truncated hydro-period prevented many species completing their life cycles before streams dried; resulting is population reductions across jarrah forest streams. The dry winter also resulted in one normally perennial 'impact' site, Vardi Road ceasing to flow, and this resulted in detectable changes in fauna composition at this site.

It is intended that stream fauna monitoring will continue for the duration of the project, with sampling starting in each treatment area at least three years prior to treatment commencing, to characterise 'baseline' conditions, and then continuing for at least three years after treatment to detect any effects. The results of stream fauna monitoring is presented annually in detailed progress reports.

Introduction

The Water Corporation has commissioned the Aquatic Research Laboratory (ARL) of The University of Western Australia to assess the effects of the Wungong Catchment Trial Project (WCTP) on the biodiversity of aquatic fauna in the Wungong catchment. In 2005, ARL, in consultation with the Water Corporation, established an annual monitoring programme for aquatic fauna (ARL 2006, 2007).

The anticipated effect of the WCTP on the Wungong streams is a change in stream hydrology. Overall, forest thinning is anticipated to increase total annual discharge.

The WCTP may actually assist in returning stream hydrology towards that of a mature forest catchment and help ameliorate the effects of a drying climate.

Thinning operations may result in up to a 25% increase in total annual discharge from the Wungong catchment (ARL 2007).

Streams which once flowed all year, but which now flow seasonally due to reduced rainfall and catchment vegetation characteristics, may once again become perennial. Naturally seasonal streams may also have more secure flows, with increased flow duration in winter. Seasonal streams tend to be less bio-diverse and support taxa with life-history strategies evolved to avoid desiccation, as opposed to perennial streams, which support a distinctly different fauna, with species requiring permanent flows, and taking longer to complete life cycles.

Periods of drying over the last twenty-five years have reduced the number of perennial streams whilst increasing the proportion of seasonally flowing streams, and this will have likely resulted in a reduction in species richness and a change in species composition of some creeks.

Potentially, perennial stream fauna could be threatened if the majority of streams were to dry. Therefore, maintaining stream flows in the Wungong may play an important role in conserving perennial stream fauna, and increased flows due to the project could enhance the fauna.

Method

The aquatic fauna monitoring programme involves:

i). Quantitative, replicate sampling for riffle-zone macro invertebrates (Surber sampling),

ii). *in-situ* replicate measurement of a range of physico-chemical parameters, and

iii). standardised CPUE electrofishing for fish and crayfish.

The programme follows a classic BACI design with both univariate and multivariate (PRIMER) analyses used to test for differences between exposed (potential impact) and reference (control) sites and to test for changes through time.

To date the programme has focused on three exposed sites within and downstream of WCTP Treatment Areas #1 and #2 and three reference sites outside the influence of the Project. Sites are listed in Table 1.

These sites will be sampled annually in spring, before, during and after thinning and any changes in biodiversity assessed. Sampling will continue for the life of the Project, with monitoring sites progressively moving to include new treatment areas as they come on-line.

Table1. Aquatic fauna monitoring sites

Site Name & Code	Catchment	WCTP Treatment Area	Exposed / Reference	Stream Order	Sampling Location	UTM (zone 50) WGS84	
Waterfall Gully (WF)	Wungong	---	Reference	1	Upstream from road culvert 400m above gauging station.	413201E	6436061N
Treatment Area 1 (TA1)	Wungong	1	Exposed	1	Along Chandler Rd, immediately down-stream of Coronation Rd intersection.	417987E	6428604N
Treatment Area 2 (TA2)	Wungong	2/3	Exposed	1	This site was originally located 100m upstream from Orchard Rd bridge. In 2006, site was relocated to Pumping Station Rd 300 m upstream of the Coronation Rd bridge.	419389E	6428254N
Vardi Road (VR)	Wungong	1/2/3	Exposed	2	Immediately downstream from gauging station and near 'flying fox'.	416382E	6431737N
31 Mile Brook (31MB = CD6)	Canning	---	Reference/ Exposed	1	Off 31 Mile Road; immediately upstream from gauging station.	420806E	6434022N

					Originally a reference site but will now be impacted by CSIRO thinning trials.		
Jack Rocks 39 Mile Brook (JR)	Serpentine	---	Reference/ Exposed	1	Jack Rocks. Off Kennedia Rd (*via* Balmoral Rd), immediately upstream from gauging station. Not strictly part of WCEWMP monitoring - first sampled in 2007 to assess impact of DEC fine-scale mosaic burns.	420689E	6417649N
Foster Brook (FB = ND1)	Nth Dandalup	---	Reference	1	Immediately upstream of Sharp Rd culvert, above Nth Dandalup reservoir.	410324E	6403239N
Wilson Brook (WB ~ ND4)	Nth Dandalup	---	Reference	1	Off North Road, above Nth Dandalup reservoir. First sampled in 2007 as replacement for 31MB which will be impacted by CSIRO thinning trials.	410084E	6399053N

In 2007, two new sites were added to the programme: Wilson Brook in the North Dandalup catchment near Foster Brook, and Jack Rocks on 39 Mile Brook in the Serpentine catchment. Wilson Brook as a replacement for the reference site on 31 Mile Brook, as it is intended to manipulate this subcatchment under a concurrent trial thinning project proposed by CSIRO; the 31 Mile Brook site will continue to be monitored in order to assess the effects of CSIRO trials on the sub-catchment.

Sampling at Jack Rocks is not strictly part of WCTP monitoring, but is to provide data on the effects of fine-scale mosaic burns being trialled by DEC in this sub-catchment. DEC will perform these prescribed burns with a 4–6 year return frequency.

In order to separate short-term stochastic fluctuations from any effects of the WCTP, it is critical that collection of pre-treatment baseline data and post-treatment monitoring data each be continued for a period of years.

The intention of the current programme is to sample reference and exposed sites for at least three years prior to commencement of treatments in each sub-catchment. Sampling will then continue during and after thinning to track changes in biodiversity and assemblage composition. As new treatment areas come on-line, additional exposed sites will be incorporated, and sampling

frequency at existing exposed sites will be reduced post-treatment, particularly if no significant effects are detected.

The collection of enough baseline data to adequately quantify natural interannual variation is of particular importance in light of the apparent decline in summer flows at Vardi Road, associated with declines in rainfall and runoff. In summer 2006/07, flow at Vardi Road ceased for the first time on record.

Results and Discussion

Summary of 2005–07 Baseline Sampling

Stream Zone Condition and Water Quality

Despite historic land-use practises (logging and mining), the riverine condition of most sites was good, with a dense, healthy cover of native vegetation (regrowth stands) and high diversity of in-steam habitats. In 2005, prescribed burns had removed most of the overstorey and understorey vegetation along stream banks at the control site on Foster Brook (Nth Dandalup) and the exposed site TA1. By spring 2007 however, vegetation at both sites showed good recovery and strong regrowth.

Spot measurements of water quality indicated values were within ranges expected (ANZECC/ARMCANZ 2000) for 'slightly to moderately disturbed' aquatic ecosystems of the northern jarrah forest. All waters were fresh (189 - 462 µS cm^{-1}) with very low turbidity levels (typically 0 NTU), a pH range from slightly acidic to alkaline (6.4 - 8.4) and high day-time dissolved oxygen levels (>80%). Long-term monthly data from nearby Water Corporation surface water monitoring sites showed a similar range; *i.e.* salinity 180 - 420 µS cm^{-1}, turbidity levels typically <1 NTU and pH 5.6 - 6.7 for sites SP15 (below ARL Vardi Road site), SP46A (below ARL 31 Mile Brook site) and SPND4 (below ARL Foster Brook site).

Macro invertebrate Fauna

For the original six WCTP sites, a total of 87 taxa were recorded from 36 replicate Surber samples taken in October 2007. This compared to 102 taxa recorded in 2006 and 74 in 2005. An additional two taxa were collected from the two new sites sampled at Wilson Brook and Jack Rocks.

The majority of taxa recorded were considered tolerant of a wide range of environmental conditions, common and frequently encountered in both seasonal and perennial river systems in south-western Australia.

The fauna was dominated by Insecta (≥80%) with at least 67 species representing 24 families. Chironomidae (non-biting midges) constituted a large proportion of the insect fauna (60%). Crustacea (including freshwater crayfish) constituted only 6% of the total fauna.

Monitoring detected a significant decline in species richness and abundance at exposed and reference sites in spring 2007. Abundances were particularly low in 2007 and the relative change was most obvious at exposed site Vardi Road. Measures of 'statistical distance' (pairwise similarity) between reference

and exposed sites showed increased similarity in community structure within exposed sites in 2007 (Figure 1).

This was principally related to the relatively large decline in abundances at Vardi Road. The fact that the river channel at Vardi Road dried for the first time on record in summer 2007 was seen as the most likely explanation for the large decline in abundances at this site.

At least two species believed to require permanently flowing water were conspicuously absent from Vardi Road - the dragonfly *Austrosynthemis cyanitincta* and the caddis-fly *Taschorema pallescens.*

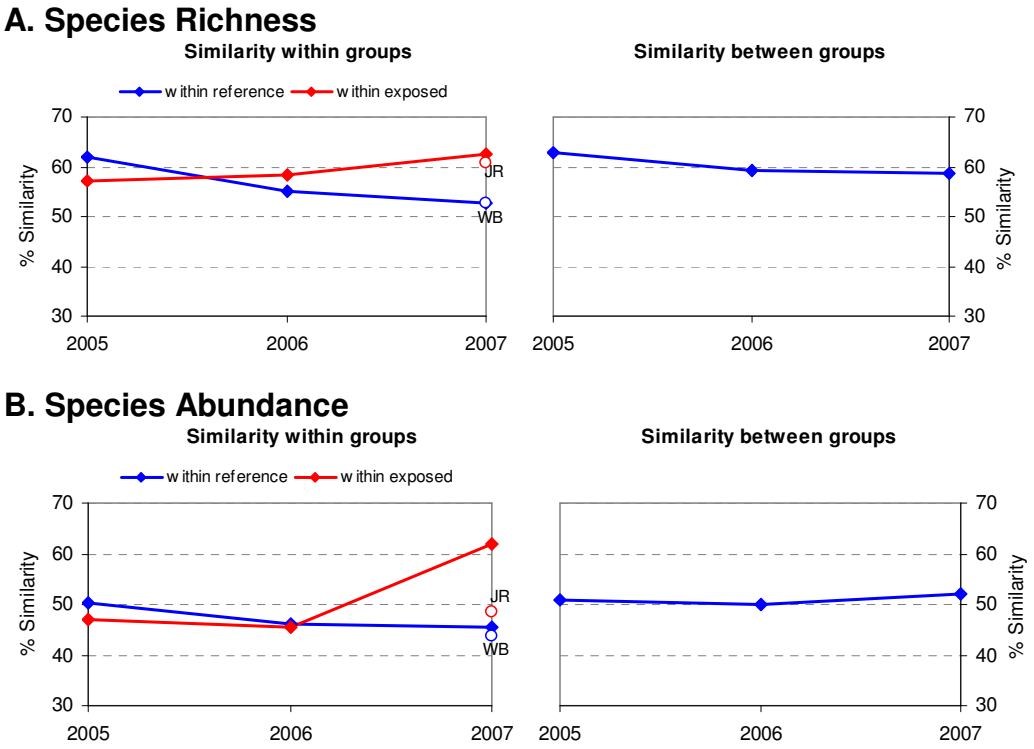

Figure 1 A-B. Change in similarity of macro invertebrate species richness and abundance both within and between reference and exposed groups over time. Similarity determined from pairwise percentage similarity matrix (PRIMER). Similarity of new site Wilson Bk (WB O) to other reference sites, and of Jack Rocks (JR O) to exposed sites, is also indicated.

Historic baseline data collected by ARL during between 1984 and 1990 (ARL 1986a-c, ARL 1987, ARL 1988a-e) were also used to assess temporal changes at control sites 31 Mile Brook, in the Canning catchment, and Foster Brook in the North Dandalup catchment (see example Figure 2).

Both abundance and richness data suggest that macro invertebrate communities at these control sites are already shifting away from that characteristic of the historic more perennial condition, toward a fauna more typical of temporary streams.

Flows in both 31 Mile Brook and in Foster Brook are believed to have become increasingly seasonal since the early 1990s and this difference in community structure may well reflect a change in flow permanence at these sites.

Taxa that appear to be in decline include some more typically associated with higher water velocities and fast-flowing reaches; *e.g.* hydrobiosid and hydroptilid caddis-flies, baetid mayflies and a number of midge species. Species that appear to be on the increase include paramelitid amphipods, leptophlebiid mayflies, seed shrimps (ostracods), water mites (acarina) and midges *Pentaneura* sp., *Cricotopus annuliventris* and *Botryocladius bibulmun*.

Historic data for the Wungong catchment are not available so it is not possible to directly assess any long-term changes prior to 2005. Therefore baseline data collected as part of the current monitoring will be used as reference against which to assess possible future changes in fauna at these sites.

Rare and/or Restricted Macro invertebrate Taxa

Approximately 20-30% of taxa were considered to be either local or regional endemics. Two listed species (IUCN category, vulnerable D2) were recorded in 2005 and 2006, the tiny freshwater snail *Glacidorbis occidentalis* from Vardi Road and 31 Mile Brook, and the freshwater mussel *Westralunio carteri* from Vardi Road. Neither species was recorded in 2007. As both are known to occur naturally in intermittent streams, their absence may be an artefact of the quadrat-style sampling technique which may under-estimate low occurrence species and which is also habitat-specific (*i.e.* riffles). While *G. occidentalis* is known to inhabit riffle zones it is typically only present in low numbers (Bunn *et al.* 1989). *W. carteri* however, is more typically found in stable sandy or muddy sediments.

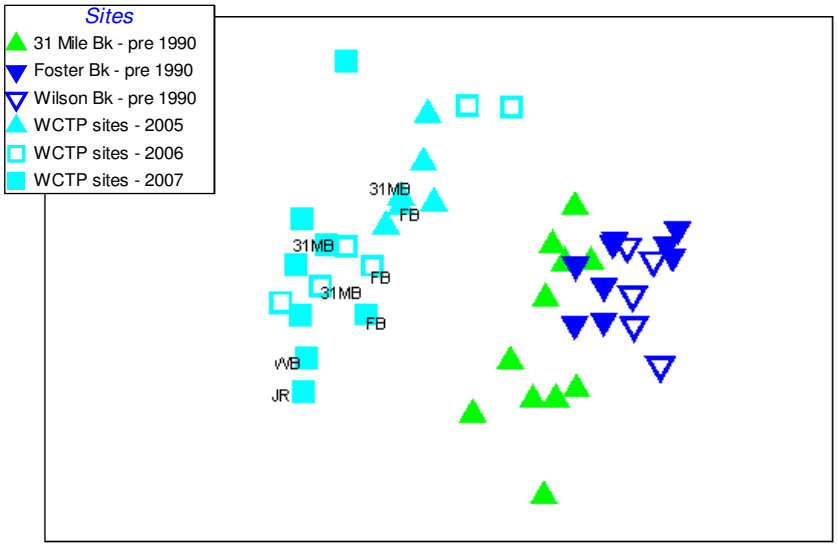

Figure 2. MDS ordination on macro invertebrate species richness (presence-absence) recorded at all WCTP sites during 2005-2007, together with historic 1984-1990 spring and summer data for 31 Mile Brook, Foster Brook and Wilson Brook. New sites Wilson Brook (WB-07) and Jack Rocks (JR-07) are also indicated. Optimum solution for the ordination was three dimensions (stress of 0.17), but for visualisation, only dimensions 1 and 2 (stress 0.25) are shown.

Stygofauna

Also of note was the presence of paramelitid amphipods at most sites except Foster Brook. These amphipods are obligate groundwater (stygofauna) species. Their presence suggests ground and surface waters intersect at these sites.

The conservation significance of these taxa is difficult to determine owing to limited information on their biology and distribution (Dr Brenton Knott, UWA, pers. com.). There were no obvious changes in distribution of these amphipods between 2005 and 2007. In fact, abundances appeared to have increased relative to historical records (1984-1990).

Fish and crayfish

Four freshwater fishes and two freshwater crayfish species were recorded from the study sites (Table 2). As sampling is not quantitative, results have been tabulated as relative abundance categories rather than total counts per site.

Native species included western minnow (*Galaxias occidentalis*), western pygmy perch (*Edelia vittata*), nightfish (*Bostockia porosa*) and gilgies (*Cherax quinquecarinatus*). All native species are south-west endemics and are common and widespread throughout the region. Two introduced species were also recorded: rainbow trout (*Onychorhynchus mykiss*) at Foster Brook and upstream of the Vardi Road weir, and yabbies (*Cherax destructor*) at Jack Rocks. The yabby is a native to eastern Australia and has proved to be a highly successful invasive species, spreading throughout much of the southwest of the state. The presence of yabbies in natural aquatic systems is of concern owing to its highly aggressive nature and superior competitive ability in comparison with native freshwater crayfish such as the gilgie (Lynas *et al.* 2004, WRM 2006). Also, yabbies are adept burrowers, adapted to long-term population survival in the fluctuating environments of impermanent wetlands (WRM 2006).

Fish and crayfish historically recorded from individual study sites, but not observed during the 2005-2007 sampling include western pygmy perch and nightfish at 31 Mile Brook (ARL 1988c) and marron *Cherax cainii* at Foster Brook (ARL database).

Table 2. Fish and crayfish recorded.

Codes: - not recorded; ★ present; ★★common, ★★★abundant.

Site	Date	Fish				Crayfish	
		Western minnow	Western pygmy perch	Nightfish	Rainbow trout*	Gilgies	Yabbies*
TA1	20/12/2005	-	-	-	-	★★	-
TA1	17/10/2006	-	-	-	-	★★	-
TA1	16/10/2007	-	★★	★★	-	★★★	-
TA2	19/12/2005	-	-	-	-	★★★	-
TA2	17/10/2006	-	-	★	-	★★	-
TA2	16/10/2007	★★	★★	★	-	★★★	-
Vardi Road	20/12/2005	-	-	-	-	-	-
Vardi Road	18/10/2006	-	★★	★★	-	★★★	-
Vardi Road	16/10/200	-	★★	-	★	★★★	-

	7						
Waterfall Gully	16/12/2007	-	-	-	-	-	-
Waterfall Gully	18/10/2006	★	-	-	-	★★★	-
Waterfall Gully	11/10/2007	-	-	-	-	★★★	-
31 Mile Bk	16/12/2005	★★	-	-	-	★★	-
31 Mile Bk	17/10/2006	★★★	-	-	-	★★	-
31 Mile Bk	12/10/2007	★★★	-	-	-	★★	-
Foster Bk	19/12/2005	-	-	-	★★	--	-
Foster Bk	5/10/2006	-	-	-	★★	★★	-
Foster Bk	11/10/2007	★★	-	-	★	★★★	-
Wilson Bk	11/10/2007	★★	-	-	-	★★★	-
Jack Rocks	12/10/2007	★★★	-	-	-	★★	★★

Conclusions

The 2005-2007 annual baseline monitoring and reporting is now complete. Field sampling for 2008 was conducted in September and the milestone report is due mid 2009.

Communities in the once permanent reaches of the Wungong at Vardi Road may already be showing signs of impact due to a drying climate and reduced summer-autumn flows, as evidenced by the 2005-2007 data. As well as the Wungong catchment, the authors have observed a general decline in macro invertebrate species richness and abundance in other parts of northern jarrah forest during 2007. Data collected from the Canning and North Dandalup catchments as part of the current project would appear to support this observation, with fauna assemblages showing a shift away from those characteristic of the historic (pre-1990) more perennial condition, toward a fauna more typical of temporary streams.

A changing climate with reduced winter and increased summer rainfall may mean a shift in the timing of life-cycles. Species may compensate by emerging either later in the year or much earlier. For other species, too short a rainfall season may altogether prevent completion of life-cycles. It appears that the exceptionally dry winter of 2006, when some streams did not flow and others did not start until late July or August may have resulted in such a short hydro-period as to result in many species having insufficient time to complete their life cycles. This may explain the reduced abundance observed across all streams in the following winter, reflecting depletion of many populations. On-going monitoring should reveal any changes at WCTP sites.

Continued monitoring of reference sites is critical in order to separate the effects of climate change from that of thinning trials at exposed sites.

Recommendations

Sampling of reference and exposed sites should continue for at least three years prior to commencement of treatments in each sub-catchment to adequately quantify within and between site variability in species diversity and assemblage structure. Sampling should then continue during and after thinning to track changes in biodiversity and assemblage composition, using paired similarity between reference and exposed sites to assess if the thinning process has detectable effects on stream biodiversity.

Recommendations based on the 2005-2007 monitoring are:

1. Monitoring in future years should be conducted during September/October to provide spring data comparable with existing baseline data to allow optimum comparisons. For comparative purposes, future sampling should continue to use existing standardised methods consistent with those used in the 2005-2007 and historic baseline studies.
2. Surface water quality monitoring should include regular (at least monthly) sampling of salinity and turbidity levels downstream from each treatment area. Monitoring should also include discharge for each site/treatment area.
3. If glyphosate (or any other herbicide) is to be used in thinning operations then levels in downstream receiving environments must be monitored to determine possible effects on stream biota. Analyses of water quality conducted by external laboratories must provide detection limits that meet ANZECC/ARMCANZ (2000) trigger values for the protection of slightly to moderately disturbed aquatic ecosystems; *i.e.* trigger level of 0.37 mg glyphosate L^{-1}.
4. Baseline monitoring should continue for at least three years prior to commencement of any treatment in order to establish natural variability, and therefore allow differentiation of treatment effects, should they occur.
5. Long-term monitoring of the aquatic ecosystem should continue during the application of thinning treatment and for at least three years post-treatment to ensure any lag-effects in species response and biodiversity are adequately evaluated. Should effects continue post three years, then monitoring to continue, but at a progressively reducing frequency.

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Establishment of demonstration sites in the northern jarrah forest

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Summary

The Wungong Catchment Trial began in 2004 with a Ministerial launch and is subject to on-going rigorous research and community debate (Water Corporation 2005).

The aim of the 12-year trial is to improve stream run-off while monitoring ecosystem function for retention of its existing biodiversity.

The trial's operations include dieback interpretation, commercial logging, non-commercial thinning of cull trees, control of coppice and excessive regrowth and regular prescribed burning.

An extensive research program to improve existing knowledge and support on-going adaptive management is being funded by the Water Corporation.

The Wungong Catchment is about 60 km south-east of Perth and covers almost 13 000 ha of which 60% is available for logging and thinning with the remainder in various types of reserves.

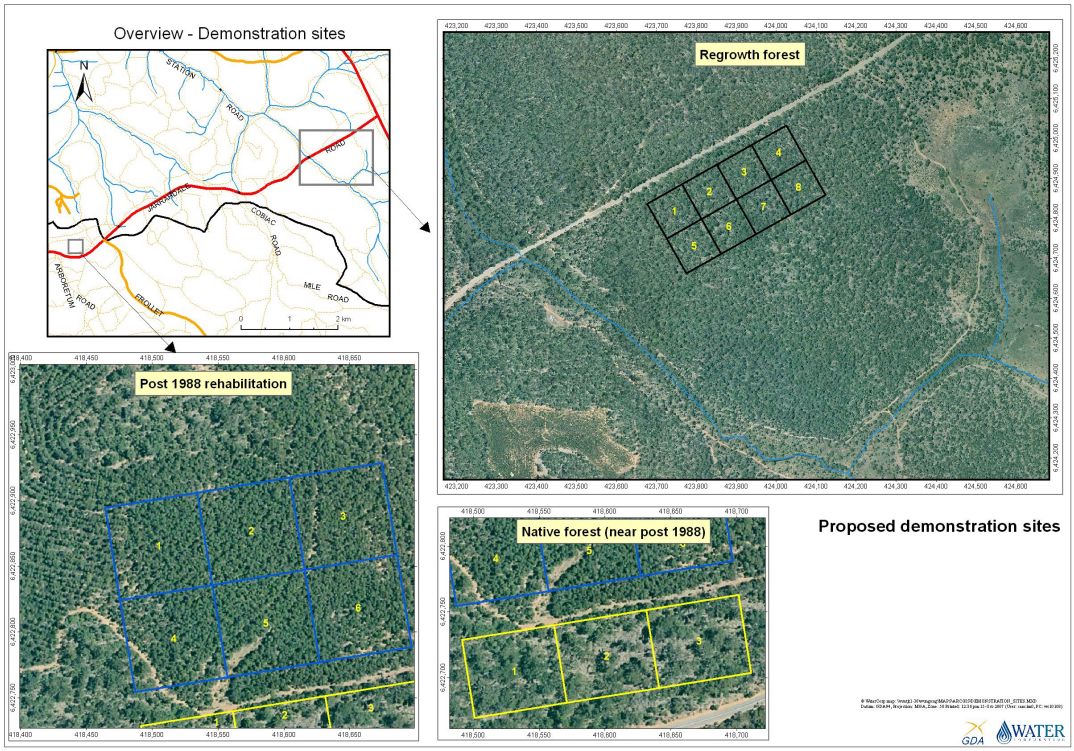
Since the Trial's inception the knowledge and impact of a drying climate have increased and it is now even more relevant to provide opportunities for informed discussions on how best to manage drinking water catchments.

The three demonstration areas that have been developed provide an example of a range of operational thinning in the northern jarrah forest. They are relatively conveniently situated and made accessible to interested visitors.

The success of the demonstration sites is provided by feedback obtained from tour visitors. There is a high demand for site visits which are best conducted during mild weather conditions mainly during spring and autumn.

Introduction

The Water Corporation funded the establishment of three demonstration areas alongside Jarrahdale road (see Map below).



The aim of constructing the demonstration sites is to show stakeholders representative areas that have been treated to various silviculture prescriptions including those applying to the Wungong Catchment trial.

The ability to view and experience various forest structures and discuss the benefits and implications of catchment management on-site will assist people to form opinions and shape attitudes regarding sourcing sustainable future water supplies.

The sites have also been useful for monitoring and research projects.

Method

During 2006-07 construction of the sites was managed by the Water Corporation and implemented with the assistance from the Department of Environment and Conservation (DEC) and the Forest Products Commission (FPC).

The criteria for selection of these areas included good access, visitor safety and reservoir protection. Two of the sites are in native jarrah regrowth and the other in a post 1988 rehabilitated bauxite mine pit.

Each plot is square, at least 0.5 hectares and is large enough for monitoring studies. At each site the various treatments and their advantages and disadvantages are observed and discussed with visitors. Discussions include how thinned areas can yield useful benefits for water, biodiversity, forest health and timber production. In addition, the demonstration sites will be useful for training Water Corporation, DEC and FPC staff.

A separate detailed report on the establishment and ongoing management of the following three Demonstration Areas has been prepared (Batini & Bradshaw 2007).

Site 1 : Native regrowth forest with commercial logging by FPC

Eight plots, each of one hectare have been established to demonstrate 7 silvicultural techniques in a high-quality jarrah forest site, 1100mm rainfall, that is dieback-free, of co-dominant height 22-24 metres, high-rainfall Dwellingup (Mattiske/Havel) and Havel "s" type, that was last cut-over in the 1940-50 decade.

The different silvicultural treatments compare the following:

- Basal areas ranging from 9 to 57 square metres per hectare
- Stems per hectare from 60 to 560
- Culling of non-commercial trees by either falling or notching
- Retention of non-commercial materials on-site or removal for possible sale
- Preferential retention of larger trees compared to retention of growing-stock.

All tree-marking and field operations were supervised by DEC, FPC and Corporation staff. The plots were prescribed burnt in December, 2007.

Site 2 : Native regrowth jarrah forest, no commercial logging

These areas are adjacent to some clear-felled and mined bauxite pits and were commercially logged in conjunction with the clear felling of the pits in the late 1980s. Commercial products are not present in sufficient quantity to warrant a logging operation by FPC. However these areas are overstocked with culls and non-commercial species.

Each plot is about 0.4 ha in size. This area has a rainfall of 1250mm, was interpreted as understorey affected by dieback and was prescribed burnt by DEC in spring 2006, in advance of treatment.

Three treatments were used that will achieve a similar prescription to some of the plots logged commercially, but without any snig tracks or other logging disturbances.

- Control - no treatment
- Retention of crop and habitat trees to about 12–13 m^2 basal area, by hand falling culls.
- Retention of crop and habitat trees to about 12–13 m^2 basal area, by notching culls.

Site 3 : Rehabilitation in bauxite pits with native species.

The area was mined for bauxite and then seeded by Alcoa World Alumina in 1991 with a mixture of native understorey and tree species. It is dominated by healthy jarrah regrowth to a height of 11–14 metres, basal areas over bark of 16–18 m^2 and diameters of 15–20 cm in co-dominants. This area was prescribed burnt by DEC in spring 2006, in advance of treatment. There are six plots, each 0.5 hectares in size.

The following silvicultural treatments are compared.

- Thinning to 150 sph, 350 sph and 600 sph with an unthinned control (~ 1500 sph)
- Thinning by falling or by notching
- Removal off-site or retention of thinning 'waste' on-site
- BAOB range 8–18 m^2

The plots cover a wide range of age classes (16 to 70+ years old), of stem numbers (60–1500/ha), of basal areas (~8–57 m^2/ha) and of leaf cover (18–75 per cent) that will be useful for comparative studies. Data such as basal areas, leaf cover, number of stems and diameters have been collected on each plot.

Results / Discussion

Already hundreds of visitors, including industry and community groups, university students and several journalists have toured the sites. Positive feedback has been obtained following the tours via Feedback Forms and personal communication. Visitors are genuinely grateful for the opportunity to view various silviculture treatments and discuss biodiversity concerns. Many visitors report that they gain a better understanding of the project and a high level of interest in the Trial's outcome is demonstrated.

Recommendation

It is important that stakeholders, in particular regulators and community leaders, are encouraged to visit the demonstration sites and discuss the Trial's progress. Timely and up-to-date information through the supply of relevant handouts, use of examples and provision of appropriate interpretation material should be done during site visits. Avenues for on-going communications with visitors should be actively pursued.

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Michael Loh, Water Corporation manages the project and organises many of the site visits.

Louisa Kinnear, Water Corporation provided communication advice on the Trial during 2006.

Jack Rocks prescribed burning trial

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in partnership with Water Corporation

Summary

The outcome of the project will be to determine, at an operational level, the degree to which frequent burning of a catchment can maintain or enhance streamflow within the current dryer climate, while not having a detrimental effect on biodiversity or streamflow quality.

If this is demonstrated it is hoped that maintaining streamflow and catchment protection from wildfire will be recognised as a priority for the fire management of forested catchments, along with biodiversity and community protection.

Introduction

DEC and the Water Corporation will partner in an investigation into the effects of regular prescribed burning at 4-6 yearly intervals on the quantity of streamflow from a gauged surface water catchment in the Darling range.

A suitable catchment of 5536 ha, being 39 Mile Brook gauged at Jack Rocks (614031), and located south-east of Jarrahdale within the Serpentine catchment has been selected as appropriate for this study.

The Jack Rocks catchment has 19 years of sound streamflow, and catchment rainfall record (1981–1998 and 2006) with an average catchment runoff of 101 mm (1983-1998). At the instigation of the Water Corporation the gauging station and two pluviographs were re-established prior to the 2006 winter. If manual water quality sampling indicates rising salinities a continuous stream conductivity monitor will be added at this station in support of this trial. The Water Corporation will fund the ongoing hydrographic operation for this catchment.

To assess the results of this trial, a comparison will be made with other gauged catchments that will be burnt under DEC's "normal" prescribed burning program together with rainfall runoff modelling of this catchment. It is expected that several burning cycles will need to be implemented and the trial could run for up to 20 years.

Method

An agreed monitoring and research program is to be prepared in consultation with both agencies within 6 months of commencement. There is a significant research bank of knowledge regarding the effect of fire on vegetation and this should be referenced to maximise outcomes in relation to this project.

Water Corporation will arrange and fund the catchment rainfall and streamflow monitoring.

The drying of streams is having an adverse impact on aquatic fauna. As this project is aiming to maintain or enhance streamflow the Aquatic fauna monitoring, lead by Dr Storey, Aquatic Research Laboratory University of WA, of representative sites in this region will provide the understanding on aquatic fauna necessary for this project.

Quokka population within Frollet Swamp will require monitoring to document any effects on the population. A key part of the pre-burn planning and during and post-burn monitoring, will be the recognized Quokka habitat around Frollet Swamp.

This work would be undertaken consistent with the existing Perth Hills District prescribed burning and fauna monitoring programs. This would include more intensive trials of habitat management (mosaic and unburnt) and radio tracking of fauna during the burn and return and feeding patterns post-burn. Some support from Water Corporation to complete this work would be applicable.

DEC will monitor and report against the prescription including fuel loadings (pre- and post-burn), area burnt, scorch (area and percentage), flame height (against target), as well as qualitative criteria as outlined within the prescribed purpose (primary and secondary).

Results

No results have been recorded to date.

Discussion

None to date.

Conclusion

None to date.

Recommendations

Suitable areas within the Jack Rocks sub-catchment will be identified for burning within the proposed schedules and in accordance with existing and proposed fire management priorities.

Jack Rocks Sub-catchment